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An EMG Analysis of Five Abdominal Exercises

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AN EMG ANALYSIS OF FIVE ABDOMINAL EXERCISES

by

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AN EMG ANALYSIS OF FIVE ABDOMINAL EXERCISES

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The problem of this study was to compare the basic crunch, Ab Roller Plus, EZ-Krunch, and Resist-A-Ball abdominal exercises. For the Resist-A-Ball, a beginner and advanced abdominal exercise were measured. Subjects performed 5 repetitions of each of the 5 exercises and the 4th repetition of each exercise was analyzed. The dependent variables were peak EMG and time to peak EMG of the rectus abdominis; time spent in the concentric, coupling, and eccentric phases; range of motion for the low back, hip, and trunk; and EMG activity of the vastus lateralis, rectus femoris, vastus medialis, and biceps brachii. The results indicated that the basic crunch, Ab Roller Plus, and Resist-A-Ball advanced exercises were not significantly different in recruiting the rectus abdominis muscle, however, all three recruited the abdominals to a greater magnitude than the EZ-Krunch. The Resist-A-Ball advanced exercise was also significantly greater than the beginner exercise in the recruitment of the rectus abdominis, although the beginner exercise was not different than the basic crunch or Ab Roller Plus. All the exercises with the exception of the EZ-Krunch could be used to effectively recruit the rectus abdominis muscle.

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CHAPTER I

INTRODUCTION

Individual exercise is an important component of physical fitness. As time and convenience factors continue to inhibit the average person's exercise regime, more and more companies are manufacturing home fitness equipment. For many companies, the focus has recently been placed upon abdominal exercise equipment. Many people are searching for an answer for their potbelly problem area. Late night infomercials saturate television with various abdominal home exercise machines. The Ab Roller Plus, EZ- Krunch, Abdominizer, and Ab Sculptor are a few examples of such machines.

As the market becomes more saturated with home fitness equipment, it becomes increasingly difficult for the consumer to decipher which manufacturer is presenting accurate claims. A problem also exists in determining whether these abdominal machines are of more benefit than abdominal exercises done without a machine, therefore warranting a consumer to purchase abdominal exercise devices. Presently, little research was found to determine the effectiveness of various abdominal machines.

Statement of the Problem

The problem was to compare exercises using the Ab Roller Plus (Concord-Chase), EZ-Krunch (Tele Brands, Roanoke, VA), and Resist-A-Ball (Ground Control, Indianapolis, IN) abdominal exercise devices. In addition, all three abdominal exercise devices were compared to the basic crunch. For the Resist-A-Ball, a beginner and an advanced abdominal exercise were measured. Specifically, kinematic and electromyography (EMG) data were compared for the concentric, coupling, and eccentric phases of each exercise device. The primary muscles investigated were the rectus abdominis, rectus femoris, vastus lateralis, vastus medialis, and biceps brachii. The muscles associated with the quadriceps group and the biceps brachii were included to determine the extent to which the hip flexors and the upper arm were recruited to perform the exercise.

Purpose of the Study

The purpose of the study was to provide more product information about the effectiveness of the Ab Roller Plus, EZ-Krunch, and Resist-A-Ball to consumers and the manufacturers. Currently no research has been found that compared these three specific pieces of equipment. This study will help determine the effectiveness of each, so the consumer may make a better decision when purchasing an abdominal machine for home use.

Delimitations

The following delimitations were established for this study:

1. The 10 volunteer subjects were Western Michigan University students and staff between the ages of 22 and 30 years.

2. The subjects had a horizontal abdominal skinfold of no more than 16mm.

3. The subjects had no known history of low back or abdominal problems within the 12 months prior to the study.

4. The subjects performed five different abdominal exercises: (1) the basic abdominal crunch, (2) Ab Roller Plus, (3) EZ-Krunch, (4) Resist-A-Ball beginner, and (5) Resist-A-Ball advanced.

5. Five muscles were analyzed by surface electrode EMG: (1) rectus abdominis, (2) rectus femoris, (3) vastus lateralis, (4) vastus medialis, and (5) biceps brachii.

6. Subjects who scored above the 50th percentile on the timed abdominal curl-up test were selected to participate in this study.

7. The study was performed in a laboratory setting.

Limitations

The study was limited by the following facts:

1. All subjects were volunteers and were not randomly selected, therefore, this investigation may not represent the general population.

2. The subjects had varying levels of experience with each abdominal exercise.

Assumptions

The basic assumptions of the research were as follows:

1. The subjects performed each repetition to the best of their ability.

2. The EMG electrode measurement sites were isolated correctly by the researcher.

3. The electromyograph, camera, computer, and software were all working properly.

4. Subjects were properly warmed up at the time the trials were performed.

Research Hypotheses

The study was conducted to test the following hypotheses:

1. The range of motion of the low back will be different for the five abdominal exercises.

2. The peak EMG of the rectus abdominis will be stronger in the Resist-A-Ball advanced exercise than in the other four abdominal exercises..

3. The percentage of time spent in the concentric, coupling, and eccentric phases will be different for each abdominal exercise.

4. The percentage of time spent in the eccentric phase will be the greatest during the Resist-A-Ball advanced abdominal exercise.

5. The EMG activity of the quadriceps muscle group will be different for each abdominal exercise.

6. The EMG activity of the biceps brachii will be different for each abdominal exercise.

Definition of Terms

The following definitions and terms are important to the understanding of this study:

1. Ab Roller Plus: an abdominal exercise machine that has a head rest and arm bar overhead. As an individual engages in the exercise, the spine flexes and extends (see Appendix C for picture).

2. Concentric phase: the time phase when the muscle shortens or decreases the angle of pull (Howley & Franks, 1992).

3. Coupling phase: the period of time from the end of the concentric phase to the beginning of the eccentric phase (Howley & Franks, 1992).

4. Eccentric phase: the time phase when the muscle lengthens or increases the angle of pull (McArdle, Katch, & Katch, 1994).

5. Electromyography (surface): a technique to measure muscle activity. The amplitude of the signal ranges from 0 to 6 mV (peak to peak), and the usable energy frequency range is 0 to 500 Hz (DeLuca, 1996).

6. EZ-Krunch: an abdominal exercise machine that resembles a short pogo-type stick with a bar for the hands. This device fits between an individual's thighs and

extends under the rib cage. The exercise is performed from a seated position (see Appendix C for picture).

7. Recruitment: stimulation of motor units to cause the strength of a muscle contraction (Howley & Franks, 1992).

8. Resist-A-Ball: a large air-filled ball, 55 cm in circumference, used as a piece of exercise equipment (see Appendix C for picture).

CHAPTER II

REVIEW OF LITERATURE

Introduction

Many people have become obsessed with the desire to obtain perfect abdominals. Newspaper ads, television, and magazines are portraying sculpted abdominals, thus abdominal products and exercises have become popular topics of discussion in the fitness field. According to an article in USA Today, the nation now has a 145 million dollar a year market in abdominal equipment. In 1996 it was estimated that over 100 million dollars will be spent by companies buying overall television time selling abdominal products (Urschel, 1996).

Due to this abdominal obsession, there is a great need for consumers to be properly informed about the physiology and mechanics behind abdominal exercises. In addition, consumers also need to be made aware of the manufacturers claims and whether they are accurate. In this chapter a review of literature on abdominal exercises and related information is presented to allow consumers to make more informed decisions regarding their abdominal regime.

Muscle Physiology and Mechanics

Muscle Contraction

The force of a muscle contraction depends on the number of muscle fibers stimulated, length of the muscle at the time of stimulation, the strength of the nervous stimulation, and the type of muscle fibers recruited. Greater muscular contraction is created when more muscle fibers are stimulated along with a stronger nervous stimulation (Gelder, 1987). Muscles are composed of three basic types of fibers: (1) slow twitch, type I; (2) fast twitch, type IIa; and (3) fast twitch, type IIb. Slow twitch (type I) are endurance fibers. They are relatively small and have less strength that fast twitch fibers. These fibers also have dense capillary networks, thus they are resistant to fatigue. Fast twitch (type IIa) are larger and stronger than slow twitch muscle fibers, and they contract quickly with moderate force. These fibers have good blood supply and are fatigue resistant. Fast twitch (type IIb) are larger and stronger than type IIa and type I and they produce the greatest force. However, type IIb have a small capillary supply and fatigue quickly (McArdle et al., 1994). Neither fast twitch nor slow twitch muscle fibers can be changed into muscle fibers of another type. However, training can increase the efficiency of both types of muscle fibers (Seeley, Stevens, & Tate, 1992).

Individual skeletal muscle fibers are arranged into motor units inside each skeletal muscle. The "all or none" principle implies that there is no such thing as a strong or weak contraction from a motor unit. If a stimulus is strong enough to elicit an action potential in the motoneuron, then all of the accompanying muscle fibers in the motor unit are stimulated to contract (McArdle et al., 1994).

Muscle Recruitment

The force of muscular contractions varies from light to maximal by either increasing the number of motor units recruited or by increasing the frequency at which they discharge. Low-force contractions require activation of fewer motor units, and higher-force contractions require more motor units. When exercises of increasing force are required, the slow twitch fibers with the lowest threshold are recruited first followed by fast twitch fibers, which provide more power for peak force. (McArdle et al., 1994).

Muscular Actions

Muscular actions are primarily classified as concentric, eccentric, or isometric. The concentric phase of a muscular action is characterized by the shortening of the muscle or by the decrease in the angle of pull. In the concentric phase the muscles must develop sufficient force to overcome the gravitational force (Howley & Franks, 1992). The eccentric phase is characterized by the lengthening of the muscle or the increase in the angle of pull (McArdle et al., 1994). Eccentric movements are sometimes termed "negative work," and typically occur by moving with gravity or lowering a resistance to the starting position, thus controlling the velocity of the motion (Gelder, 1987). When the eccentric movement is in the same direction as gravity, then gravity rather than muscle contraction is responsible for the movement. (Howley & Franks, 1992). Isometric actions are those in which the muscle is not shortening or lengthening, rather the muscle is static while contracted (McArdle et al., 1994). According to Howley and Franks (1992), "More muscle tension can be exerted through eccentric contraction than through either concentric or isometric contraction" (p. 181).

Stretch-Reflex Mechanism

All muscles contain sensory receptors, called muscle spindles, that sense the length and rate of muscle changes. These spindles are interwoven in the muscle fibers and are covered by connective tissue. The spindles respond to stretching or shortening of the muscle and in turn stretch or shorten accordingly. Whenever the muscle length changes, the spindles report the changed condition back to the brain and spinal cord to make the appropriate adjustments in muscle contraction (Lamb, 1978). The spindles are important in regulating the movement and maintenance of posture. Neural input is continuously being sent to postural muscles to maintain their readiness to respond to voluntary movement or to counteract the downward pull of gravity (McArdle et al., 1994).

For exercise analysis the stretch-reflex mechanism is of great importance. When resistance is increased during an exercise, the muscle is stretched and the muscle spindles react by sending impulses to the spinal cord to activate alpha motoneurons. This causes the returning motor impulses to contract more forcefully, thereby relieving the stretch (Lamb, 1978).

Range of Motion

Flexibility is defined as the ability to move a joint throughout its range of motion (ROM). Maintaining a reasonable degree of flexibility is necessary for efficient body movements as well as for preventing muscle injury and soreness. One area of great importance for flexibility is the pelvic region. The pelvis is the foundation of the spine, and any muscle that crosses the iliofemoral joint can ultimately upset the abdominal musculature's ability to control the proper pelvic positioning. This may cause one's center of gravity to be unbalanced, thus resulting in spinal and low back problems (Howley & Franks, 1992).

Flexibility or ROM is improved by stretching the muscles that become tense (Gelder, 1987). Exercises that move the joints through their full ROM have been known to increase flexibility by 20% to 50% in men and women (McArdle et al., 1994). According to Howley and Franks (1992), to improve flexibility active ROM should be used. Active ROM consists of movements in which the muscle contraction is controlled by the exerciser. Passive ROM consists of movement resulting from an outside force such as an exercise partner or gravity. If the difference between active and passive ROM is large, the joint surrounding the muscle may be susceptible to injury. Active ROM exercises are the safest for increasing flexibility.

Abdominal Musculature

The anterior trunk musculature is composed of the rectus abdominis, transverse abdominis, internal obliques, and external obliques. The rectus abdominis is a flat, narrow muscle that originates on the pubic crest and symphysis and inserts on the xiphoid process and inferior ribs. The rectus abdominis lies most superficially and is responsible for flexing the vertebral column. This muscle also plays a role in proper postural alignment. The transverse abdominis lies directly posterior to the rectus abdominis. This muscle originates on the 7th to 12th costal cartilages, lumbar fascia, iliac crest, and inguinal ligament with its insertion on the xiphoid process, linea alba, and pubic turbercle. The function of the transverse abdominis is to compress the abdomen. The internal obliques originate on the iliac crest, inguinal ligament, and lumbar fascia with its insertion on the 10th to 12th ribs and rectus sheath. The functions of this muscle are to flex and rotate the vertebral column, compress the abdomen, and depress the thorax. The external obliques originate on the 5th to 12th ribs with its insertion on the iliac crest, inguinal ligament, and rectus sheath. The functions of this muscle are to flex and rotate the vertebral column, compress the abdomen, and depress the thorax. The transverse abdominis, internal oblique, and external oblique muscles contain white tendon-like matter on the ends called aponeuroneses. The aponeuroneses of these muscles form medially to create the linea alba. The linea alba is connective tissue that divides the rectus abdominis into right and left halves. This crossing pattern of the abdominal muscles holds and protects the abdominal visera (Seeley et al., 1992).

According to Chek (1997), the abdominals are composed of slightly more fast twitch than slow twitch muscle fibers. Fast-twitch-dominant muscles respond better to training with fewer reps and higher levels of resistance. He stated that training the abdominals with high reps and low resistance will not create a great deal of muscle hypertrophy.

Measurement of Muscle Activity

Electromyography

Electromyography (EMG) is used to identify the recruitment of motor units in skeletal muscle by measuring the frequency and amplitude of the electrical activity. EMG data can be collected by placing electrodes over the skin or by inserting fine wire electrodes into the skeletal muscle. The frequency and amplitude of the EMG signal provide insight into the type and number of motor units, recruitment patterns, and muscular force. As a general rule there is usually a positive relationship between EMG and muscle force, however, many conditions, including fatigue, age, and velocity of movement, can alter this relationship (Brooks, Fahey, & White, 1996).

To obtain accurate EMG signals, accurate placement of electrodes and careful site preparation are necessary. A reference electrode or ground electrode should always be used to provide a common reference to the differential input of the preamplifier in the electrode. The reference electrode should be placed as far way as possible, and over a electrically neutral tissue like a bony prominence. It is recommended that electrodes be large, such as 2 cm x 2 cm. Smaller electrodes must be highly conductive and should contain strong adhesive properties. Prior to electrode placement the skin should be abraded with an alcohol pad. If hair is present, the area should be shaved to insure proper conduction between the skin and the electrode. The electrodes should be placed parallel to the longitudinal axis of the muscle fibers. Both detection surfaces should intersect most of the same muscle fibers. The electrode location is between the motor point, or innervation zone, and the tendinous insertion (DeLuca, 1996).

Many conclusions have been drawn about analysis of EMG signals. According to Basmajian and DeLuca (1985), large muscles have many more motor units than small muscles. Generally, large muscles do not require a finer force graduation to accompany a task, therefore firing rates do not require continual regulation. Large muscles primarily rely on recruitment of more motor units to modulate their force rather than firing rate. Overall, higher-force-threshold motor units consistently have lower firing rates than lower-force-threshold motor units.

Validity of Electromyography

Over the years many experiments have been conducted with surface EMG. Leisman, Zenhausern, Ferentz, Tefera, and Zemcov (1995) concluded that all measurements of integrated EMG were a valid index of motor unit recruitment, thus EMG reflected the extent to which a muscle is active. However, fatigue was concluded to result in a less efficient muscle process. The authors recommended that the fatigue factor should be controlled in situations in which EMG is used as a functional training measure of force output. To control this, they suggested short trials interspersed with sufficient rest periods.

Infomercials

Infomercials are paid advertisements that look and sound like a television show, often imitating the format of genuine talk shows or investigative consumer news programs. The products being sold may be discussed by paid experts or reporters. The advertisements usually last 30 min or longer and are sometimes interrupted by realistic looking advertisements displaying the product information. According to advertising promoters, the 30 min commercial is the most effective medium for advertising, and infomercials are becoming more educational with a softer sell (Koeppel, 1992). The Federal Trade Commission (FTC, 1996) is responsible for investigating infomercials that do not disclose their true advertising nature or ones that make deceptive claims about their products. The Federal

Communications Commission requires television stations to disclose who is paying for an infomercial at the beginning or end of the advertisement. The FTC brochure included a warning concerning celebrity and expert testimonials, noting that they are often being paid by the advertiser. The consumers in the studio audience are also often pre-selected by the advertiser, and some are paid. The FTC warned that these are just a few techniques used as part of the overall sales pitch.

To avoid legal ramifications, infomercials must adhere to the basic principles of advertising. The first principle of advertising states that the substantiation for an implied claim must be as strong as an expressed claim. The second principle states that substantion must have a high level of documentation. In other words if the infomercial states the "studies show" or "tests demonstrate," then they must actually have the documentation that the claim suggests. The third principle is that claims made by individuals must be true for them personally, or must refer solely to the product and not to other factors that may have contributed to the study. If the advertiser's experience is true but abnormal, then the advertiser must use a disclaimer. The FTC requires infomercials to have documentation for at 2 years when long term claims such as weight loss are made ("Legal pitfalls," 1996).

The Abdominal Obsession

The abdominals are continually classified as one of the top three areas that most people would like to tone or reduce. Due to the demand for a quick-fix solution, the market has become immersed with a variety of products that claim to help one carve out a chiseled midsection (Wolkodoff, 1995). In addition to desiring a great midsection, 60% to 80% of adults have encountered low back pain (Lahad, Malter, Berg, & Deyo, 1994). To help alleviate low back pain, strengthening the abdominal muscles is generally prescribed.

In general, most people do not fully understand the process of reducing the abdominal area nor the treatments for reducing low back pain. Reduction of the abdominal area takes a combination of aerobic exercise, strength training, and a low-fat diet (Avery, 1991; Salem, 1996; Serapere, 1994; Thomas & Ridder, 1989; "You can flatten" 1995; Wolkodoff, 1995). According to Steve Fleck, exercise physiologist: "The value of these devices are [sic] their novelty. If they can get you to exercise areas that you wouldn't normally exercise, they might pay for themselves" (Wolkodoff, 1995, p. 2). Low back pain is also often associated with weak abdominals. Lahad et al. (1994) reviewed 64 articles for treatments of low back pain. The effect of exercise programs were shown to be modest, and durations were unknown. Overall, people with low back pain are better off exercising than not, however specific exercises have not yet been determined.

Abdominal Exercise Tests

The curl-up test has been suggested as an alternative to the sit-up test. Robertson, Darville and Magnusdottir (1986, cited in Robertson & Magnusdottir, 1987) demonstrated by surface EMG that the modified curl-up test showed greater demand on the abdominal muscles with no demand on hip flexor muscles. Robertson and Magnusdottir (1987) conducted studies to complement their earlier work by further evaluating the curl-up test against the standardized modified sit-up test. In this study, the modified curl-up test consisted of subjects moving their fingertips 7.62 cm as they curled their trunk and head forward. Starting from the down position, the upper back but not the head comes down to the mat. In the modified sit-up test the subjects curled up to touch forearms to their thighs as the ankles were stabilized by a partner. In the down position the middle back touched the mat, and feet were between 30.48 and 45.72 cm away from the buttocks. The results supported the use for the curl-up as an alternative to the sit-up in abdominal fitness testing. Howley and Franks (1992) and Reebok (1991) also recommended the curl-up test to measure muscular strength and endurance of the abdominals. Howley and Franks protocol required the subject to curl up as the fingertips slide 8 cm to a second tape mark. This is followed by the return of the trunk until the head touches the tester's hands. For women 35 years of age or younger, 50 curl-ups in 1 min is considered excellent. For men 35 years of age or younger, 60 curl-ups in 1 min is considered excellent.

Analysis of Abdominal Exercises

Basic Crunch

In analysis of abdominal exercises, researchers generally investigate the movement between the lumbar and iliofemoral joints. When a full sit-up is performed on the ground, lumbar flexion ceases at about 30°, and then the hip flexors act to further elevate the trunk while the abdominals contract isometrically. To alleviate this problem, partial curls or a basic crunch (see Appendix C for picture) should be substituted for the full sit-up. Basic crunches have been found to utilize the abdominal muscles to a greater extent than full sit-ups while decreasing the involvement of the hip flexors. The correct positioning consists of a posterior tilt followed by the raising of the head and shoulders in the sagittal or oblique planes (Howley & Franks, 1992). Crunches are also recommended for replacing the straight-leg sit ups and leg lifts. A basic crunch with bent knees ensures that the pelvis will not tilt forward, thus hyperextension of the vertebral column is minimized. Overall, the best exercise for strengthening the abdominals depends on the condition of the participants. People with very weak abdominals should only flex the cervical and upper thoracic areas. As strength increases they can curl up farther to include the lower lumbar area (Gelder,1987).

Humphrey (1988), Iknoian (1996), and Reebok (1991) recommended the trunk curl. This exercise is performed from a supine position with bent knees. The abdominal muscles should contract so the shoulders and upper back lift 30° to 45° from the floor. Humphrey recommend three sets of 10-12 repetitions. To further increase the resistance, curls may be performed by holding a weight at the chest. To improve muscular strength and endurance, these curls should be performed two to three times per week. Routines can be performed three to five times a week, however, more than five times per week was not recommended. Reebok (1991) recommended training the abdominals every other day, but no less than two times per week.

Ab Roller Plus

The Ab Roller Plus is an abdominal device that has a head rest and arm bar overhead. A basic crunch movement is performed while the device rolls up and down with the flexion and extension of the spine (see Appendix C for picture). The Ab Roller Plus is sold on television infomercials, on home shopping networks, and in some retail stores. The price varies from $69 to $89. Brenda Dykgraaf, U.S. Aerobic Champion and certified personal trainer, is pictured on the packaging and is the host of the infomercials. The Ab Roller Plus comes with a 15 min instructional video and owner's manual. The video offers a beginner and an advanced workout. It is recommended that everyone start out with the beginner workout using the device every day for 5 to 10 min. A warm-up, consisting of walking, bike riding, or marching in place, is also recommended before using the Ab Roller Plus. In the basic curl-up using this device the elbows rest on the elbow pads and the hands gently grasp the side bars located on each side of the head. The instructions state to keep the elbows slightly bent at all times and to keep the head positioned on the headrest to eliminate the upper body from assisting the abdominal muscles (Venture Aerobic Productions, 1995).

In a recent report on ABC's 20/20 television program, various abdominal machines were examined with the help of New York City's Crunch Gym Experts (Neufeld, 1996). The experts evaluated and tested many roller type devices similar to the Ab Roller Plus. The experts concluded that it was a good machine for beginners who did not have a good strength base or had cervical problems. However, overall they recommended that if people would take just a few minutes and learn the proper curl-up technique, then such a device was not needed. For people with neck problems, they suggested a towel would work just as well.

NBC's Dateline television program also broadcast a recent report on abdominal devices (Shapiro, 1996). The devices were examined by Lynn Kravitz, Ph.D.(an exercise physiologist). Kravitz evaluated various roller devices with and without pivot points. He stated that the rollers with one pivot point did not simulate the natural movement of the spine and were therefore less effective. He suggested that the roller devices without the pivot point, such as the original Ab Roller Plus, were better and he believed roller type devices are the best abdominal devices he has seen. Overall, Kravitz stated that the same results can be achieved by the old fashioned crunch. He recommended a crunch in which the calves are supported by a chair. The ribs then move toward the pelvis while the shoulders slightly clear the floor.

Gibson and Johansson (1996) conducted a study in which the Ab Roller was compared to the Ab Isolator, Ab Flex, EZ-Krunch, unassisted crunch, and the unassisted reverse crunch. The exercises were measured by EMG of the rectus abdominis. The researchers concluded that the Ab Roller was not significantly different than the unassisted crunch, although it was slightly greater in recruiting the rectus abdominis. They did, however, report that the Ab Roller does give support for the neck.

The Ab Roller Plus was tested out by the editors of Men's Health ("Does it work," 1996) magazine. They found that the device was awkward and uncomfortable. According to John Jakicic, Ph.D, exercise physiologist and assistant professor at the University of Pittsburgh School of Medicine:

> They offer no physiological advantage over doing crunches with good form. And 20 crunches would take about one minute, so its doubtful whether much fat is being burned at all. By pulling with your arms, you can use muscles other than your abdominals to curl yourself up (p. 57).

The editors of Men's Health also consulted with William Kraemer, Ph.D; professor of applied physiology and director of research at the Center for Sport Medicine at Pennsylvania State University. Kraemer stated that there have not been any scientific studies on these abdominal devices. Some studies have been mentioned in infomercials, however they are not published in scientific research. In conclusion, Kraemer recommended that great abdominals may be obtained by reducing caloric intake and getting regular exercise. The muscles themselves were the best machine recommended for abdominal exercises.

EZ-Krunch

The EZ-Krunch is an abdominal exercise device that resembles a short pogo stick with an attachment around the upper thighs (see Appendix C for picture). Power bands may be attached to the device for resistance and each band is said to equal 20 lb of resistance. The EZ-Krunch is priced between $39 and $59. This device is sold on television infomercials and in some retail stores. It comes with five resistance bands, an owner's manual, and a nutritional guide. Statements in the manual claim that the special pivoting cylinder moves in the natural arc of the body, providing a full range of motion. Results are promised quickly, safely, and all in the comfort of a chair or sofa. The EZ-Krunch also claims less stress placed on the lower back than traditional curl-ups performed on the floor (Media Group, 1996).

The EZ-Krunch beginner abdominal exercise is performed from a seated position with both feet placed on the floor. Hands are placed along either side of the t-bar. The t-bar is then placed directly under the chest. In the crunch movement the torso curls forward toward the thighs and then releases. Using recommendations printed in the manual, the following order of execution should be used for the crunch: (a) curl down for 2 counts (b) hold for 1 s then (c) uncurl for 2 counts (Media Group, 1996).

In a recent report on ABC's 20/20 (Neufeld, 1996) television program, the EZ-Krunch was examined by Dr. James Skinner (exercise physiologist). The EZ-Krunch infomercial claimed that 5 min a day, 5 times a week would result in a 4-in. and 10-lb weight loss in just 1 month, guaranteed. Skinner laughed at this claim and stated that it was virtually impossible to lose 10 lb in a month unless a strict diet was also part of the program. The EZ-Krunch infomercial never mentioned the additional hours of aerobic workouts and muscle toning needed to reduce one's weight. This information is only given in the EZ-Krunch manual. The EZ-Krunch nutritional guide also stated a very restrictive low-calorie diet is required, which is mentioned in fine print in the infomercial. The EZ-Krunch infomercial also contains the appearance of

Steve Mahollick, a former Mr. Universe. In the infomercial, Mahollick stated that the EZ-Krunch put him back into shape after a crippling car crash. In ABC's 20/20 television report, Arnold Diaz stated that Mahollick was injured in 1976 and was back in shape by the mid 1980s for his movie appearance in "Pumping Iron II." This was 8 years before EZ-Krunch was even patented. This revealed Mahollick's false testimonial.

In NBC's Dateline television report (Shapiro, 1996), New York City's Crunch Gym Experts examined the EZ-Krunch and gave it a thumbs down evaluation. They believed that the upper body was forcing the bar down and that there was not much muscle contraction by the abdominals. In NBC's Dateline report, Lynn Kravitz, Ph.D., exercise physiologist, also examined the EZ-Krunch. Kravitz stated the abdominals were not working in this exercise but instead the action actually worked the muscles of the hips. When Dateline asked the company for information or studies to back up their claims, the company did not respond.

In a study conducted by Gibson and Johansson (1996), the EZ-Krunch was compared to the Ab Isolator, Ab Roller, Ab Flex, unassisted crunch, and unassisted reverse crunch. The exercises were measured by EMG of the rectus abdominis. The researchers concluded that the EZ-Krunch was significantly lower than the unassisted crunch with regard to eliciting the rectus abdominis.

Resist-A-Ball

The Resist-A-Ball (see Appendix C for picture) is one product that has recently been introduced in many fitness classes and infomercials across the nation. In the last year, over 25,000 various exercise ball have been sold. Professional teams, athletes, dancers, and fitness instructors are big fans of stability balls. They claim that the ball provides a total-body workout without stress to joints ("Let's play ball," 1995). In the past decade, there has been an increase in the number of physical therapists who use the Resist-A-Ball primarily when rehabilitating their patients (Resist-A-Ball, 1995).

According to the Resist-A-Ball: Programming Guide for Fitness Professionals (1995), ball exercises are beneficial because they incorporate functional movement, balance, and open and closed chain movements. Functional movement is defined as the ability of the body to move and respond without restriction. According to Gin Miller, creative director of Resist-A-Ball, ball exercises provide body weight resistance, which improves functional strength. Functional exercise is another application of the "specificity principle of training," which states that muscles will adapt specifically to the specific demand placed on them.

Balance is another key factor of ball exercises. Since the ball is spherical in nature, one must maintain balance at all times during various exercises. In abdominal exercises on the ball, balance and stabilization are required from the leg muscles. Ball workouts have also been said to be very effective due the incorporation of both open and closed chain exercise. Open chain exercise occurs when the distal segment of the chain, arms or legs, is not fixed and does not support the weight of the body. Closed chain exercise involves the distal segment supporting the body's weight. Closed chain exercises require a dynamic response from the whole body to perform the movement correctly. According to the article Let's Play Ball: Stability Balls Take To The Field (1995), exercises performed on the ball help reduce low back pain by increasing the strength of the trunk and low back muscles. The trunk exercises on the ball are helpful in maintaining neutral alignment or posture of the lumbar spine. The authors stated that when the spine is in neutral alignment the forces on the discs between the vertebrae are greatly reduced.

According to Chek (1997), Swiss ball exercises are recommended for abdominal training. Chek stated that the spherical shape of the ball gives the abdominals a wide range of motion, practically double the ROM that crunches performed on the floor require. To obtain washboard abs Chek stated that one must use loads that result in muscle failure before one reaches 12 reps. The most effective range is 8 to 12 reps.

In an infomercial for exercise balls, Miller and Brooks (exercise physiologist) were interviewed. They stated that the ball is good for any fitness level because there are beginner, intermediate, and advanced exercises. They believed the ball is also especially beneficial for training the abdominals and back muscles. Trunk exercises on the ball minimize spinal stress by strengthening and stretching both anterior and posterior muscle groups. One key element of the ball is that it engages more muscles when needed and also isolates various muscle groups. Brooks stated that ball exercise can cut workout time in half, because the exercises are more efficient. He stated that when the muscles are fully stretched before being flexed, a greater contraction will occur. In abdominal exercises, the ball allows for a great ROM because the back is being supported while the body has the ability to extend past the horizontal plane (Flexaball informercial, 1996).

CHAPTER III

METHODS AND PROCEDURES

Firm, lean, and strong abdominals seem to be of great importance to many people. Many new home abdominal machines have saturated the market, promising such results as loss in inches, weight loss, and rock-hard abdominals. In this study, selected EMG and kinematic parameters were compared for five abdominal exercises: (1) the basic crunch, (2) Ab Roller Plus, (3) EZ-Krunch, (4) Resist-A-Ball beginner abdominal exercise, and (5) Resist-A-Ball advanced abdominal exercise. The investigator used surface EMG synchronized with video to analyze the EMG in relation to the phases of motion associated with the five exercises. The following topics are covered in this chapter: (a) subjects, (b) equipment, (c) research design, (d) data collection procedures, and (e) statistical analysis.

Subjects

The subjects for this study were 10 male and female volunteer students and staff from Western Michigan University, Kalamazoo, MI. The ages of the subjects were 22 to 30 years. Each subject signed an informed consent form (see Appendix A). Approval to conduct this study was given by Western Michigan University's Human Subjects Institutional Review Board (see Appendix B). All subjects had no history of low back or abdominal problems 12 months prior to participating in the study. Only subjects who were able to score above the 50th percentile in a timed abdominal curl-up test were selected to participate. Western Michigan University's fitness testing data was used to determine the scores. To score at the 50th percentile males had to perform 64 curl-ups and females had to perform 59 curl-ups in 1-min test. According to Howley and Franks (1992), both of these scores are considered to be in the excellent category for abdominal muscular strength and endurance

Equipment

Bipolar surface electrodes, Medi trace, 1 cm, silver-silver chloride (ECE 1801 Graphic Controls, Buffalo, NY) were placed on each subject's rectus abdominis, rectus femoris, vastus lateralis, and vastus medialis. The EMG electrodes were linked to a Myosystem 2000 EMG data collection system (Noraxon, Phoenix, AZ). This was then linked with the analog-to-digital board used by Peak Motion Analysis hardware-software package (Peak Performance Technologies, Inc., Englewood, CO).

Data manipulation, collection, and analysis were attained on an IBM-compatible Tenex computer, Model 486 DX-2 with Peak 5V 1.2 software. A Butterworth data-smoothing procedure (6 Hz) filtered the integrated EMG signal. The filtered EMG data were then transferred to the Myosoft 2000 EMG analysis on the Tenex 486 DX-2.

Kinematics of the low back were assessed through the use of a Panasonic WV-D5100HS video camera (Panasonic Broadcast & Television Systems Company, Secaucus, NJ) set at a frequency of 60 Hz. Fuji S-VHS ST 120 N videotape was used. The video data were synchronized to the EMG data through an event synchronization unit (ESU, Peak Technologies, Inc., Englewood, CO).

Research Design

This study was comprised of five different abdominal exercises: (1) the basic crunch, (2) Ab Roller, (3) EZ-Krunch, (4) Resist-A-Ball beginner abdominal exercise, and (5) Resist-A-Ball advanced abdominal exercise. Each abdominal exercise was divided into three phases: (1) concentric, (2) coupling, and (3) eccentric. The EMG responses of the rectus abdominis, rectus femoris, vastus lateralis, vastus medialis, and biceps brachii were measured during the execution of all five exercises. Each subject completed one set of five repetitions of each exercise. The dependent variables for this study were (a) percentage of time spent in the concentric, coupling, and eccentric phases; (b) range of motion of the low back, hip, and trunk; (c) peak EMG signals; (d) time to peak EMG, and (e) mean EMG. The research design was repeated measures. Subjects repeated the abdominal exercises, and the five muscles were analyzed for all five exercises. The exercises were presented to each subject in a random order.

Data Collection Procedures

Data collection took place in the Exercise Physiology and Biomechanics Laboratories in the Student Recreation Center at Western Michigan University, Kalamazoo, MI between November 18 and 25, 1996. The male subjects removed their shirts to facilitate the placement of electrodes, and female subjects wore a sports bra. Each subject was capable of performing five repetitions of each of the five different abdominal exercises. The fourth repetition of each exercise was analyzed. The subjects were allowed a 2-min rest between exercises. Procedures for the testing were as follows:

1. Subjects were given a warm-up prior to executing the abdominal exercises. The warm-up consisted of the following: (a) a 5-min ride on a stationary cycle and (b) specific static stretches for the abdominals and low back.

2. Subjects performed the five repetitions of the five exercises in a random order.

3. The rest period between consecutive exercises was 2 min.

4. For each exercise, the researcher signaled when to begin the movement.

Electromyography Procedures

Bipolar surface electrodes (Medi trace, 1 cm, silver-silver chloride) were placed at a point half the distance between the center of the innervation zone (motor point) and the distal tendon of the muscle, parallel with the muscle fibers. The electrode detection surfaces were placed approximately 1 cm apart near the midline of the muscle. Prior to electrode placement, all placement sites were carefully isolated, prepped, and shaved (if necessary).

The EMG electrodes were linked to the Peak Motion Analysis analog-to-digital module. The system provided integrated EMG signals that were time matched and coordinated with the video recorder.

The integrated EMG signal was filtered using a Butterworth data smoothing procedure (6 Hz). The video-matched EMG data files were analyzed by Peak 5 software. The EMG response for the rectus abdominis was analyzed to determine (a) time to peak EMG, and (b) peak EMG. The EMG response of the rectus femoris, vastus lateralis, vastus medialis, and biceps brachii were analyzed to determine the extent to which the hip flexors and elbow flexor were recruited to perform abdominal exercises.

Filming Procedures

Kinematics for the low back, hip and trunk ROM were assessed through the use of a Panasonic WV-D5100HS camera set at a frequency of 60 Hz. An ESU (Peak Technologies, Inc.) matched the video data to the EMG data. A light-emitting diode (LED) was electrically triggered through the ESU unit. The EMG data were time matched with the video because the electrical signal was simultaneously recorded on the video and EMG outputs.

EMG data collection was controlled by the ESU. A hand-held switch triggered the LED. The LED signal allowed EMG data to be collected 1.0 s prior to the signal and ended 4.0 s following the signal. The EMG data were collected at a rate of 480 Hz resulting in eight EMG data points per video frame.

A two-dimensional video analysis of each exercise was performed. The camera was set at a distance of 40 ft from the subject. The focal length of the lens of the video camera was perpendicular to the sagittal plane of the subject. The camera's lens was 3 ft above ground. Subjects performed in front of a black background to aid in identifying the landmarks to be digitized.

To scale digitized data to the video analysis a meter stick was used. The motion of the fourth repetition in each abdominal exercise was analyzed. Each subject's data were collected in one 30-min session.

Video Digitizing Analysis

After the data collection took place, the digitizing process began. First, the videotape was projected onto the video screen to digitize. Second, anatomical landmarks were digitized for every frame of the fourth repetition of each exercise. The anatomical points used to calculate the kinematics of the low back, hip, and trunk ROM were the shoulder joint, iliac crest, greater trochanter of femur, and the knee joint. One complete abdominal exercise was digitized for each of the five conditions. Each abdominal exercise was composed of three phases: (1) concentric, (2) coupling, and (3) eccentric. The concentric phase began with the first signs of flexion of the truck and ended when forward flexion ceased. The eccentric phase began with the first signs of downward extension of the trunk and ended when downward extension ceased. The coupling phase was noted as the time difference between the concentric and eccentric phases when no movement about the trunk was occurring in either direction.

Statistical Analysis

Data were analyzed by inferential and descriptive statistics. A randomized block ANOVA was calculated for EMG data, time spent in each phase (concentric, coupling, and eccentric), and for ROM of the low back, hip, and trunk. The Tukey HSD multiple comparison test was calculated to determine which exercises were significant. Descriptive statistics including means, standard deviations, and percentages, were used to compare the stabilizing muscles and exercises.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem of this study was to compare the Ab Roller Plus, EZ-Krunch, and Resist-A-Ball abdominal exercise devices. In addition, all three abdominal exercise devices were compared to the basic crunch. For the Resist-a-Ball, a beginner and an advanced abdominal exercise were measured. Specifically, kinematic and electromyography (EMG) data were compared for the concentric, coupling, and eccentric phases of each exercise device. The primary muscles investigated were the rectus abdominis, rectus femoris, vastus lateralis, vastus medialis, and biceps brachii. The muscles associated with the quadriceps group and the biceps brachii were included to determine the extent which the hip flexors and arm were recruited to perform the exercise. This chapter will address (a) peak EMG and time to peak EMG for the rectus abdominis; (b) time spent in the concentric, coupling, and eccentric phases of all exercises; (c) joint ROM for the low back, hip, and trunk; and (d) EMG activity of the vastus lateralis, rectus femoris, vastus medialis, and biceps brachii. The level of significance used to explain the results of this study was .05.

Results

ANOVA

ANOVAs were calculated for the EMG data, time spent in each phase (concentric, coupling, and eccentric), and for the ROM of selected joints. The EMG data were represented by the peak EMG of the rectus abdominis and the time to peak EMG. The phase times of each exercise were measured in seconds. The ROM was measured in degrees for the low back, trunk, and hip angles. Each ANOVA was a repeated measures design with one research variable, exercises. The design consisted of five exercises: (1) the basic crunch abdominal exercise, (2) the Ab Roller Plus abdominal exercise, (3) the EZ-Krunch abdominal exercise, (4) the Resist-A-Ball beginner abdominal exercise, and (5) the Resist-A-Ball advanced abdominal exercise. Descriptive statistics were calculated for the following stabilizing muscles: (a) vastus lateralis, (b) rectus femoris, (c) vastus medialis, and (d) biceps brachii. Descriptive data for these muscles included the means and standard deviations across the time of stabilization.

Rectus Abdominis

Peak EMG. The summary for the peak EMG for the rectus abdominis is presented in Table 1. The ANOVA for peak EMG indicated the following:

1. A significant difference for peak EMG was found among the subjects, $F(9, 36) = 17.89$, $p < .05$.

2. A significant difference was found for the mean peak EMG values for the exercises, $F(4, 36) = 16.14$, $p < .05$. The means for the exercises were 423.35 mV, 441.12 mV, 214.53 mV, 326.37 mV, and 535.58 mV for the basic crunch, AB Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 1

ANOVA Summary for Peak EMG for the Rectus Abdominis

Source	SS	df	MS	F
Subjects	1489769.698	9	165529.972	17.89*
Device	597407.746	4	149351.945	16.14*
Residual	333059.042	36	9251.641	

*Significant at .05 level.

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for peak EMG is presented in Table 2. The Tukey test indicated the following significant differences between paired means of the rectus abdominis: (a) the EZ Krunch was lower than the basic crunch, (b) the EZ-Krunch was lower than the Ab Roller Plus, (c) the EZ-Krunch was lower than the Resist-A-Ball advanced, and (d) the Resist-A-Ball beginner was lower than the Resist-A-Ball advanced.

Table 2

Differences Between Ordered Means for Peak EMG for Exercises

		Exercise Means			
		RBB	B	R	RBA
Exercise	M	326.370	423.347	441.123	535.583
EZ	214.533	111.837	208.814*	226.590*	321.050*
RBB	326.370		96.977	114.753	209.213*
B	423.347			17.776	112.236
R	441.123				94.460
RBA	535.583				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

Time to Peak EMG. The ANOVA summary table for the time to peak EMG for the rectus abdominis is presented in Table 3. The ANOVA for the time to peak EMG indicated the following:

1. There were no significant differences for time to peak EMG among the subjects, $F(9, 36) = 2.03$, $p > .05$.

2. A significant difference for time to peak EMG was found among the exercises, $F(4, 36) = 2.71$, $p < .05$. The means for the time to peak EMG of the

exercises were 0.453 s, 0.467 s, 0.656 s, 0.329 s, and 0.420 s, for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 3

ANOVA Summary for Time to Peak EMG

Source	SS	df	MS	F
Subjects	0.964	9	0.107	2.03
Device	0.572	4	0.143	2.71*
Residual	1.899	36	0.053	

*Significant at .05 level.

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for time to peak EMG is presented in Table 4. The Tukey test indicated that the Resist-A-Ball advanced was significantly lower in time to peak recruitment of the rectus abdominis than the EZ-Krunch.

Table 4

Differences Between Ordered Means for Time to Peak EMG for Exercises

		Exercise Means			
		RBB	B	R	EZ
Exercise M		0.420	0.453	0.467	0.656
RBA	0.329	0.091	0.124	0.138	0.327*
RBB	0.420		0.033	0.047	0.236
B	0.453			0.014	0.203
R	0.467				0.189
EZ	0.656				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

Phase Time

Concentric Time. The ANOVA summary table for concentric phase time of each exercise is presented in Table 5. The ANOVA for the concentric time indicated the following:

1. A significant difference for concentric phase time was found among the subjects, $F(9, 36) = 9.61$, $p < .05$.

2. No significant differences were found for the concentric phase time among exercises, $\underline{F}(4, 36) = 1.77$, $\underline{p} > .05$. The means for concentric phase time were 0.913 s 0.988 s, 1.080 s, 0.932 s, and 0.920 s for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 5

ANOVA Summary for Concentric Phase Time

Source	SS	df	MS	F
Subjects	2.420	9	0.269	9.61*
Device	0.195	4	0.049	1.77
Residual	0.992	36	0.028	

*Significant at .05 level.

Coupling Time. The ANOVA for coupling phase time is presented in Table 6. The ANOVA summary indicated the following significant differences in coupling time for the exercises:

1. No significant differences were found for coupling time among the subjects, $\underline{F}(9, 36) = 0.96$, $\underline{p} > .05$.

2. A significant difference for coupling phase time was found among the exercises, $\underline{F}(4, 36) = 3.08$, $\underline{p} < .05$. The means for the coupling time of the exercises

were0 0.041 s, 0.046 s, 0.037 s, 0.068 s, and 0.044 s, for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 6

ANOVA Summary for Coupling Phase Time

Source	SS	df	MS	F
Subjects	0.00400	9	0.00044	0.96
Device	0.00580	4	0.00145	3.08*
Residual	0.01697	36	0.00047	

*Significant at .05 level.

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for coupling phase time is presented in Table 7. The Tukey test indicated a significant difference between the EZ-Krunch and the Resist-A-Ball beginner exercise. The EZ-Krunch had a lower coupling time than the Resist-A-Ball beginner exercise.

Eccentric Phase Time. The ANOVA summary table for the time to peak EMG for the rectus abdominis is presented in Table 8. The ANOVA for the eccentric phase time indicated the following:

1. A significant difference for eccentric phase time was found among the subjects, $F(9, 36) = 20.33$, $p < .05$.

2. A significant difference for eccentric phase time was found among the exercises, $F(4, 36) = 3.97$, $p < .05$. The means for the eccentric phase time of the exercises were 1.030 s, 1.365 s, 1.304 s, 1.197 s, and 1.210 s, for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 7

Differences Between Ordered Means for Coupling Phase Time for Exercises

		Exercise Means			
		B	RBA	R	RBB
Exercise	M	0.041	0.044	0.046	0.068
EZ	0.037	0.004	0.007	0.009	0.031*
B	0.041		0.003	0.005	0.027
RBA	0.044			0.002	0.024
R	0.046				0.022
RBB	0.068				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for eccentric phase time is presented in Table 9. The Tukey test indicated the following significant differences: (a) the eccentric phase time for the basic crunch was significantly lower than the EZ-Krunch, and (b) the basic crunch eccentric phase time was significantly lower than the Ab Roller Plus.

Table 8

ANOVA Summary for Eccentric Phase Time

Source	SS	df	MS	F
Subjects	7.325	9	0.813	20.33*
Device	0.647	4	0.161	3.97*
Residual	1.468	36	0.040	

*Significant at .05 level.

Range of Motion

Low Back Range of Motion. The ANOVA summary table for the low back ROM is presented in Table 10. The ANOVA for the low back ROM indicated the following:

1. No significant differences were found for low back ROM among subjects, $F(9, 36) = 2.28$, $p > .05$.

2. A significant difference for the low back ROM was found among the exercises, $F(4, 36) = 7.84$, $p < .05$. The means for the low back ROM of the exercises were 25.852°, 26.473°, 39.223°, 29.718°, and 37.875° for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 9

Differences Between Ordered Means for Eccentric Phase Time for Exercises

		Exercise Means			
		RBB	RBA	EZ	R
Exercise	M	1.197	1.210	1.304	1.365
B	1.030	0.167	0.180	0.274*	0.335*
RBB	1.197		0.013	0.107	0.168
RBA	1.210			0.094	0.155
EZ	1.304				0.061
R	1.365				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for the low back ROM is presented in Table 11. The Tukey test indicated the following significant differences among the exercise means: (a) the basic crunch had a smaller ROM than the Resist-A-Ball advanced, (b) the basic crunch had a smaller ROM than the EZ-Krunch, (c) the Ab Roller Plus had a smaller ROM than the Resist-A-Ball advanced, and (d) the Ab Roller Plus had a smaller ROM than the EZ-Krunch.

Table 10

ANOVA Summary for Low Back Range of Motion

Source	SS	df	MS	F
Subjects	1050.218	9	116.669	2.28
Device	1600.929	4	400.232	7.84*
Residual	1838.143	36	51.060	

*Significant at .05 level.

Hip Flexion Range of Motion. The ANOVA summary table for hip ROM for the exercises is presented in Table 12. The ANOVA for hip ROM indicated no significant differences among subjects or exercises, $F(9, 36) = 1.77$, $p > .05$ and $F(4, 36) = 2.21$, $p > .05$, respectively. The means for the exercises were 2.622°, 3.749°, 6.814°, 1.914°, and 4.518°, for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 11

Differences Between Ordered Means Summary for Low Back Range of Motion

		Exercise Means			
		R	RBB	RBA	EZ
Exercise M		26.473	29.718	37.875	39.223
B	25.852	0.621	3.866	12.023*	13.371*
R	26.473		3.245	11.402*	12.750*
RBB	29.718			8.157	9.505
RBA	37.875				1.348
EZ	39.223				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

Trunk Range of Motion. The ANOVA summary table for the trunk ROM for the exercises is presented in Table 13. The ANOVA for the trunk ROM indicated the following:

1. No significant differences for trunk ROM were found among subjects, $F(9, 36) = 2.16$, $p > .05$.

2. A significant difference for the trunk ROM was found among the exercises, $F(4, 36) = 11.37$, $p < .05$. The means for the trunk ROM for the exercises

were 23.872°, 25.415°, 42.400°, 30.127°, and 36.278° for the basic crunch, Ab Roller Plus, EZ-Krunch, Resist-A-Ball beginner, and Resist-A-Ball advanced, respectively.

Table 12

ANOVA Summary for Hip Range of Motion

Source	SS	df	MS	F
Subjects	260.099	9	28.900	1.77
Device	144.709	4	36.177	2.21
Residual	588.937	36	16.359	

A Tukey HSD multiple comparison test was calculated to determine which pairwise comparisons were significant. A table of differences between ordered means for the trunk angle is presented in Table 14. The Tukey test indicated the following significant differences for the trunk ROM: (a) the basic crunch ROM was smaller than the Resist-A-Ball advanced, (b) the basic crunch ROM was smaller than the EZ-Krunch, (c) the Ab Roller Plus ROM was smaller than the Resist-A-Ball advanced, (d) the Ab Roller Plus ROM was smaller than the EZ-Krunch, and (e) the Resist-A-Ball beginner ROM was smaller than the EZ-Krunch.

Table 13

ANOVA Summary for Trunk Range of Motion

Source	SS	df	MS	F
Subjects	1022.178	9	113.575	2.16
Device	2386.679	4	596.670	11.37*
Residual	1888.833	36	52.469	

*Significant at .05 level.

Descriptive Statistics

Descriptive statistics were calculated for the following stabilizing muscles: (a) vastus lateralis, (b) rectus femoris, (c) vastus medialis, and (d) biceps brachii. Data for these muscles were the means and standard deviations across the time of stabilization. A summary of the activity of these muscles is seen in Table 15. The means and standard deviations indicated the following findings:

1. The vastus lateralis mean EMG recordings and corresponding standard deviations were relatively the same for all exercises.

2. The rectus femoris mean EMG recordings and corresponding standard deviations were relatively the same for the basic crunch, Ab Roller Plus, and the EZ-Krunch. The activity in the Resist-A-Ball beginner and advanced rectus femoris was relatively higher than the other exercises measured, however, the Resist-A-Ball

advanced showed the greatest amount of variability in mean EMG activity and standard deviation.

Table 14

Differences Between Ordered Means for Trunk Range of Motion

		Exercise Means			
		R	RBB	RBA	EZ
Exercise	M	25.415	30.127	36.278	42.400
B	23.872	1.543	6.255	12.406*	18.328*
R	25.415		4.712	10.863*	16.985*
RBB	30.127			6.151	12.273*
RBA	36.278				6.122
EZ	42.400				

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

*Significant at .05 level.

3. The vastus medialis showed a pattern similar to that of the rectus femoris. The mean EMG activity and standard deviations were relatively the same for the basic crunch, Ab Roller Plus, and EZ-Krunch. The Resist-A-Ball beginner and advanced exercises were greater than the other exercises, however the Resist-A-Ball

advanced showed the greatest amount of variability in both mean EMG activity and standard deviation for the vastus medialis.

Table 15

Descriptive Statistics for Stabilizing Muscles

Muscle	Exercise	M_M	M_{SD}
Vastus Lateralis	Basic crunch	66.009	4.724
	Ab Roller Plus	67.719	4.922
	EZ-Krunch	64.689	6.324
	Resist-a-Ball beginner	64.765	5.260
	Resist-a-Ball advanced	68.666	7.630
Rectus Femoris	Basic crunch	31.288	2.162
	Ab Roller Plus	30.296	0.655
	EZ-Krunch	30.791	1.409
	Resist-a-Ball beginner	36.258	3.093
	Resist-a-Ball advanced	40.157	6.830
Vastus Medialis	Basic crunch	33.249	1.450
	Ab Roller Plus	33.803	1.460
	EZ-Krunch	34.195	3.652
	Resist-a-Ball beginner	51.168	10.850
	Resist-a-Ball advanced	47.303	13.435
Biceps Brachii	Basic crunch	48.998	7.994
	Ab Roller Plus	30.902	0.733
	EZ-Krunch	55.967	14.351
	Resist-a-Ball beginner	62.294	7.266
	Resist-a-Ball advanced	55.009	10.576

Note. All measures are in mV.

4. The biceps brachii EMG means and standard deviations were very different among the exercises. The Ab Roller Plus had the lowest mean and standard deviation, thus the biceps were being used as a stabilizer during this exercise. The basic crunch showed more EMG activity than the Ab Roller Plus. However, the basic crunch's standard deviation showed more variability, thus the biceps may have been initiating some of the curl-up movement. The Resist-A-Ball beginner had the highest mean EMG activity for the biceps brachii with an average variability of the standard deviation similar to that of the basic crunch. This could have been the result of the biceps initiating the movement, peaking, or because of the crossed position of the arms. The EZ-Krunch and the Resist-A-Ball advanced showed similar mean EMG activity and the mean standard deviations were both high compared to the other exercises. Their standard deviations were also higher than the standard deviations of the other exercises. For these exercises, the biceps brachii were more involved in the movements.

Discussion

Basic Crunch

The literature review of the basic crunch suggested that lumbar flexion should not exceed 30° because additional movement would be the result of the hip flexors and not the abdominal muscles (Howley & Franks, 1992). In this study the average mean ROM for the trunk in the basic crunch exercise was 23.872°, well below the suggested maximum. This finding was consistent with the minimal activity of the rectus femoris (M = 31.288 mV and SD = 2.162 mV), which measured the involvement of the hip flexors as stabilizers. In interviews and reports from NBC's Dateline (Shapiro, 1996) and ABC's 20/20 (Neufeld, 1996), many experts agreed that the basic crunch was just as beneficial as using many of the devices on the market. In this study, the basic crunch was significantly better than the EZ-Krunch with regard to peak EMG, however, the basic crunch was no different than the other exercises. This may mean that the basic crunch, Ab Roller Plus, and both Resist-A-Ball exercises are recruiting similar motor units and muscle fibers for peak EMG of the rectus abdominis. The biceps brachii for the basic crunch was more involved because of the high variability in the mean standard deviation. Logically, this would seem reasonable because the arms were supporting the subject's head.

Ab Roller Plus

The literature stated that the Ab Roller Plus was a good device for beginners who do not have good abdominal strength or have had cervical problems (Neufeld, 1996). In observations of this exercise it has been suggested that the arms are initiating some of the movement. In NBC's Dateline interview (Shapiro, 1996), Dr. Lynn Kravitz suggested that the Ab Roller Plus was one of the better roller devices, however, he believed the same results could be achieved with the basic crunch. In this study, it was concluded that the Ab Roller Plus (M = 441.123 mV) was significantly better than the EZ-Krunch (M = 214.533 mV) with regard to peak EMG of the rectus abdominis, however, it was no different than any of the other exercises. In regard to ROM of the trunk, the Ab Roller Plus (M = 25.415°) was very similar to the basic crunch (M = 23.872°) and the Resist-A-Ball beginner (M = 30.127°). This researcher also concluded that the biceps brachii were not involved in this exercise. In fact of all the other exercises, the Ab Roller Plus had the least mean EMG activity (M = 30.296 mV) and the lowest mean standard deviation (M = 0.655 mV) for the biceps.

EZ-Krunch

In interviews and reports from NBC's Dateline (Shapiro, 1996) and ABC's 20/20 (Neufeld, 1996) it was stated that the EZ-Krunch was not an acceptable device to work the abdominal muscles. According to Gibson and Johansson (1996), the EZ-Krunch was significantly lower than an unassisted crunch (basic crunch) with regard to eliciting rectus abdominis muscle activity. In an evaluation of the EZ-Krunch sponsored by New York's Crunch Gym Experts (Shapiro, 1996), the authors stated that the upper body was forcing the bar down, and they did not believe the abdominal muscles were major contributors. Dr. Lynn Kravitz stated that this exercise was working the muscles of the hip instead of the abdominals (Shapiro, 1996). In this study, it was concluded that the response elicited from the rectus abdominis of the EZ-Krunch exercise (M = 214.533 mV) was significantly lower than in the basic crunch (M = 423.347 mV), Ab Roller Plus (M = 441.123 mV), and the Resist-A-Ball advanced (M = 535.583 mV) with respect to peak EMG of the rectus abdominis. The low EMG activity of the rectus abdominis may have been the result of fewer motor units or slow twitch muscle fibers being recruited. In this study the biceps brachii for the EZ-Krunch (M = 55.967 mV) were more involved than in the other exercises, thus, the subjects were utilizing the arms to push the bar forward and downward. Upon observation of the EZ-Krunch exercise, it seems as if there would be an isometric contraction near the end of the concentric phase. In this study, this was not the case because the coupling time was not significantly lower than the other exercises; in fact the EZ-Krunch had the lowest coupling time (M = 0.037 s). The EZ-Krunch did have a significantly greater ROM for the trunk (M = 42.400°) than the basic crunch (M = 23.872°), Ab Roller Plus (M = 25.415°), and the Resist-A-Ball beginner (M = 30.127°). This ROM could have been due to the resistance of the device. One band of resistance (equal to 20 lb) was used for each subject; this may have been too easy for the subjects, who were all physically fit. An interesting finding in this study was the mean EMG activity of the rectus femoris (M = 30.791 mV) in the EZ-Krunch exercise. It was concluded that the hip flexors (measured by the rectus femoris mean EMG activity) were used as a stabilizer. In fact the hip flexor activity was very similar to the basic crunch (M = 31.288 mV) and Ab Roller Plus (M = 30.296 mV). This fact is not in accordance with Dr. Kravitz, who stated that the hip flexors were utilized in executing the EZ-Krunch exercise.

Resist-A-Ball Beginner and Advanced

The literature stated that the one primary purpose for using the Resist-A-Ball was to improve functional strength. Functional strength is said to prepare one for practical life stresses by providing body weight resistance. The ball is also noted for providing both open and closed exercises to obtain a dynamic response from the whole body (Resist-A-Ball, 1995).

Biomechanically, the advanced abdominal curl-up creates an increased resistance because gravity is always acting on the body. There is also an opportunity for the subject to have a greater range of motion because the horizontal plane is not the floor. Greater range of motion can cause the stretch-reflex mechanism to activate, thus eliciting more force. In this study the Resist-A-Ball beginner (M = 326.370 mV) was significantly lower than the advanced (M = 535.583 mV) exercise with respect to peak EMG of the rectus abdominis. However, the Resist-A-Ball beginner's mean peak EMG of the rectus abdominis was no different than the mean peak EMG for the other exercises. The advanced exercise (M = 535.583 mV) was significantly better in peak EMG recruitment of the rectus abdominis than the EZ-Krunch (M = 214.533 mV), yet it was no different from the other exercises.

The beginner exercise was significantly smaller in trunk ROM (M = 30.127°) than the EZ-Krunch (M = 42.400°), but the advanced exercise (M = 36.278°) was significantly greater than the basic crunch (M = 23.872°) and the Ab Roller Plus (M = 25.415°). This was to be expected by the nature of the movements involved with the exercises. However, the researcher did observe that the advanced exercise displayed much variability with ROM depending on the subject's orientation with the ball. Some subjects were comfortable with the ball, but others seemed to hurry the movement and ROM in order to finish the five repetitions. This may have also been due to the passive ROM that occurred with the advanced ball exercise. Research suggested that passive ROM can cause the joint surrounding the muscle to be susceptible to injury (Howley & Franks, 1992).

With respect to the stabilizing muscles, the two ball exercises showed similar activities. The rectus femoris EMG activity was relatively higher in both exercises, with the advanced exercise showing the greatest variability of all exercises. This indicated that the hip flexors were more involved in this movement. According to research on abdominal crunches, this would be detrimental when strengthening abdominals. However, according the Resist-A-Ball: Programming Guide for Fitness Professionals (1995), one of the main purposes of ball exercises is to incorporate other muscles to improve functional strength. The vastus medialis was also initiating a lot of EMG activity during both ball exercises. This finding was expected due to the nature of the exercises and the balance factor. The biceps also showed a great amount of activity in both exercises, but with more involvement in the advanced exercise. With the beginner exercise this may have been due to the nature of the arms crossed over the chest. With the advanced exercise the biceps involvement was more likely due to the increased resistance of the head when the body was suspended against gravity on the eccentric phase.

Summary

In Table 16, the means for time to peak, percentage of concentric phase time to peak, and total time for each exercise were compared. With regard to time to peak EMG, there was a significant difference between the Resist-A-Ball advanced (M = 0.329 s) and the EZ-Krunch (M = 0.656 s). This also corresponds to the percentage of the concentric phase's time to peak EMG for the Resist-A-Ball advanced (M = 36%) and the EZ-Krunch (M = 61%). In addition these exercises were significantly different in peak EMG with the Resist-A-Ball advanced (M = 535.583 mV) and EZ-Krunch (M = 214.533 mV). Overall, these two exercises were found to be different. Total mean times for each exercise were all relatively similar, thus on the average most subjects were moving at a consistent pace in all of the exercises. The basic crunch, Ab Roller Plus, and Resist-A-Ball beginner were all the same with respect to peak EMG, time to peak EMG, concentric time, coupling time, low back ROM, hip ROM, and trunk ROM. The EZ-Krunch and Resist-A-Ball advanced exercises indicated differences in one or more of these variables.

Table 16

Summary of Mean Times for the Exercises

Exercise	Time to Peak EMG	Percentage of Concentric Phase Time to Peak	Total Time of Exercise
B	0.453	50%	1.984
R	0.467	47%	2.399
EZ	0.656	61%	2.421
RBB	0.420	45%	2.197
RBA	0.329	36%	2.174

Note. B = Basic crunch, R = Ab Roller Plus, EZ = EZ-Krunch, RBB = Resist-A-Ball beginner, RBA = Resist-A-Ball advanced.

Note. Time is in seconds.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted to compare the basic crunch, Ab Roller Plus, EZ-Krunch, and Resist-A-Ball beginner, and Resist-A-Ball advanced abdominal exercises. The design consisted of one research variable, exercises. The dependent variables were (a) peak EMG for the rectus abdominis; (b) time to peak EMG for the rectus abdominis; (c) phase time for the concentric, coupling, and eccentric; (d) ROM for the low back, hip, and trunk; and (e) mean muscle activity for the vastus lateralis, rectus femoris, vastus medialis, and biceps brachii. Inferential and descriptive statistics were used to analyze the data

The subjects for this study were 10 female and male volunteers between 22 and 30 years of age who were Western Michigan University (WMU) graduate students or staff. The subjects performed five repetitions of each abdominal exercise; the fourth repetition was analyzed. All exercises were presented in a random order. Each subject had an abdominal skinfold of 16mm or less, and were able to pass (50th percentile or above on WMU Phytstyles standards) a timed abdominal curl-up test.

EMG recordings of the rectus abdominis, vastus lateralis, rectus femoris, vastus medialis, and biceps brachii were measured by bipolar surface electrodes. The EMG was synchronized with the video to provide time-matched data.

Kinematics of the low back, hip, and trunk were measured through computerized video images. Single frames of motion were digitized to acquire the anatomical landmarks necessary for range of motion analysis. The low back range of motion was measured by the anatomical points of the shoulder, iliac crest, and greater trochanter of the femur. The hip range of motion was measured by the anatomical points of the iliac crest, greater trochanter of the femur, and the knee. The trunk range of motion was measured by the line formed between shoulder and iliac crest with a horizontal line through the iliac crest. The analysis began with the initiation of the concentric phase and ended with the completion of the eccentric phase for the fourth repetition.

Findings

For all the exercises the following findings were relevant:

1. A significant difference was found among the exercises for peak EMG activity of the rectus abdominis, $F(4, 36) = 16.14$, $p < .05$. The Tukey test indicated the following significant differences between paired means: (a) the EZ-Krunch was lower than the basic crunch, (b) the EZ-Krunch was lower than the Ab Roller Plus, (c) the EZ-Krunch was lower than the Resist-A-Ball advanced, and (d) the Resist-A-Ball beginner was lower than the Resist-A-Ball advanced.

2. A significant difference for time to peak EMG was found among exercises, $F(4, 36) = 2.71$, $p < .05$. The Tukey test indicated that the Resist-A-Ball advanced was lower in time to peak recruitment of the rectus abdominis than the EZ-Krunch.

3. No significant differences were found for the concentric phase time among exercises, $F(4, 36) = 1.77$, $p > .05$.

4. A significant difference was found for the coupling time among the exercises, $F(4, 36) = 3.08$, $p < .05$. The Tukey test indicated that the EZ-Krunch had a lower coupling time than the Resist-A-Ball beginner.

5. A significant difference for eccentric phase time was found among the exercises, $F(4, 36) = 3.97$, $p < .05$. The Tukey test indicated the following differences: (a) the eccentric phase time for the basic crunch was lower than the EZ-Krunch, and (b) the basic crunch eccentric phase time was lower than the Ab Roller Plus.

6. A significant difference for the low back ROM was found among the exercises, $F(4, 36) = 7.84$, $p < .05$. The Tukey test indicated the following differences: (a) the basic crunch had a smaller ROM than the Resist-A-Ball advanced, (b) the basic crunch had a smaller ROM than the EZ-Krunch, (c) the Ab Roller Plus had a smaller ROM than the Resist-A-Ball advanced, and (d) the Ab Roller Plus had a smaller ROM than the EZ-Krunch.

7. No significant differences among subjects or exercises were found for hip flexion ROM, $F(9,36) = 1.77$, $p > .05$ and $F(4, 36) = 2.21$, $p > .05$, respectively.

8. A significant difference for the trunk ROM was found among the exercises, $F(4, 36) = 11.37$, $p < .05$. The Tukey test indicated the following differences: (a) the basic crunch ROM was smaller than the Resist-A-Ball advanced, (b) the basic crunch ROM was smaller than the EZ-Krunch, (c) the Ab Roller Plus ROM was smaller than the Resist-A-Ball advanced, (d) the Ab Roller Plus ROM was smaller than the EZ-Krunch, and (e) the Resist-A-Ball beginner ROM was smaller than the EZ-Krunch.

Conclusions

Based on the results of this study, the following conclusions were drawn:

1. All the exercises, with the exception of the EZ-Krunch, could be used to effectively recruit the rectus abdominis.

2. The Resist-A-Ball advanced recruits the rectus abdominis to a greater degree than the Resist-A-Ball beginner exercise.

3. The Ab Roller Plus exercise involved the biceps brachii to a smaller degree than the other exercises.

4. The Resist-A-Ball beginner and advanced elicited greater EMG responses from most of the stabilizing muscles studied than the other exercises. The nature of the Resist-A-Ball exercises required these muscles to maintain balance.

Recommendations

The following are recommendations for further research:

1. A similar study should be conducted with more subjects to increase reliability and external validity.

2. A study should be conducted with subjects of poor fitness levels to increase the population sample.

3. A study should be conducted that separates the subjects by gender to investigate any differences.

4. A study should be conducted with specific training programs for the abdominal exercises with different frequencies, intensities, and durations.

5. A study should be conducted with wire electrodes in the rectus abdominis, transverse abdominis, and obliques to determine specific recruitment orders and peak EMG activity among the exercises.

Appendix A

Informed Consent Form

Western Michigan University
Department of Health, Physical Education, and Recreation

Principal Investigator: Dr. Mary Dawson

Research Associate: Teresa E. Brady

I have been invited to participate in a research project entitled: "An EMG Analysis of Three Abdominal Exercise Devices." I understand that this research is intended to study the effectiveness of various abdominal exercises as it relates to EMG stimulation of the rectus abdominis and the range of motion of the low back I further understand that this project is Teresa Brady's masters thesis for the department of Health, Physical Education & Recreation at Western Michigan University.

My consent to participate in this project indicates that I will be asked to attend one 30 minute session with Teresa Brady. This session will take place in the Exercise Physiology Laboratory in the Student Recreation Center. The subject will perform the following abdominal exercises: (1) Ab Roller Plus, (2) EZ-Krunch, (3) Resist-a-Ball beginner curl-up (4) Resist-a-Ball advanced curl-up and (5) the basic crunch. The session will involve the following: (a) answering verbally if I have had any low back or abdominal problems within the past 12 months, (b) having an abdominal body composition measured by skinfold calipers, (c) performing a timed abdominal curl up test, (d) an introduction to the techniques used for each abdominal condition, (e) a warm-up on a stationary cycle for 5 min, stretches for the low back and abdominals, (f) performance of five repetitions for the five different abdominal exercises in random order, with a 2-min rest between conditions; and (g) stretches for the low back and abdominals.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or treatment will be made available to me except as otherwise specified in this consent form. I understand that one potential risk of my participation in this project is muscle soreness or muscle strain. I understand that I may terminate my involvement with this research for any reason at anytime.

I may benefit from this activity by gaining insight as to how the abdominal devices are used. I also understand that fitness professionals may gain knowledge about the effectiveness of these abdominal devices.

I understand that all the information collected from me is confidential. That means that my name will not appear on any papers on which this information is recorded. The forms will all be coded, and Teresa Brady will keep a separate master list with the names of participants and corresponding code numbers. Once the data are collected and analyzed, the master list will be destroyed. All other forms will be retained for three years in a locked file in the principal investigator's laboratory.

I understand that I may refuse to participate or quit at any time during the study without prejudice or penalty. If I have any questions or concerns about this study, I may contact either Teresa Brady at 387-3543 or Mary Dawson at 387-2720. I may also contact the Chair of Human Subjects Institutional Review Board at 387-8293 or the Vice President for Research at 387-8298 with any concerns that I have. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

________________________________ _____________

Signature Date

Appendix B

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899

WESTERN MICHIGAN UNIVERSITY

Date: 12 November 1996

To: Mary Dawson

From: Richard Wright, Chair

Re: HSIRB Project Number 96-11-06

This letter will serve as confirmation that your research project entitled "An EMG Analysis of Three Abdominal Exercise Devices" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

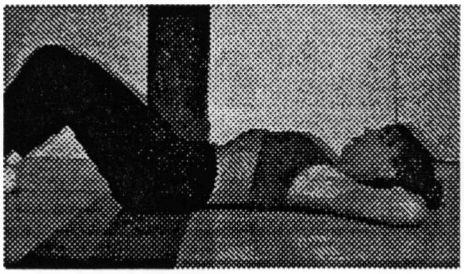
The Board wishes you success in the pursuit of your research goals.

Approval Termination: 9 November 1997

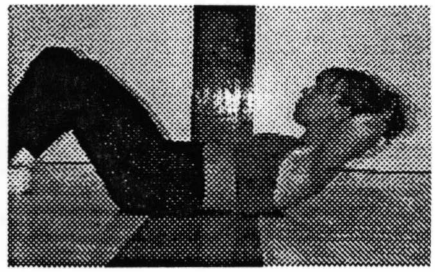
xc: Teresa Brady

Appendix C

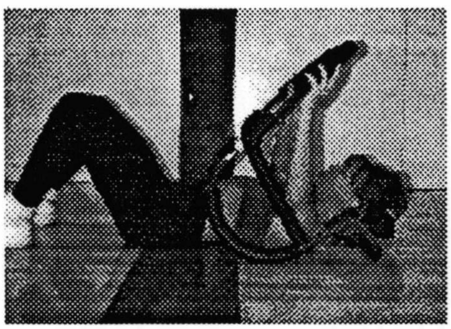
Pictures of Abdominal Exercises



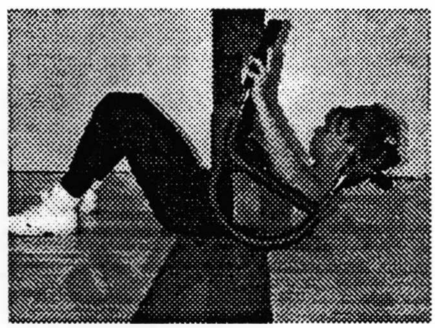
Basic Crunch Start



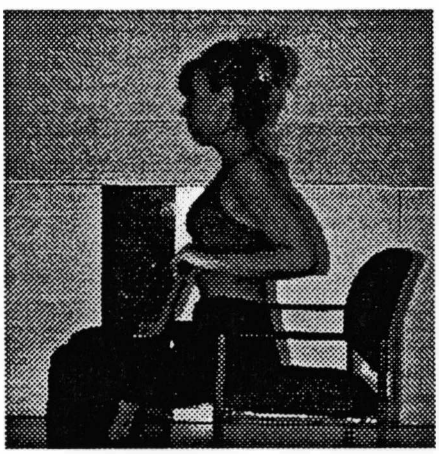
Basic Crunch Concentric



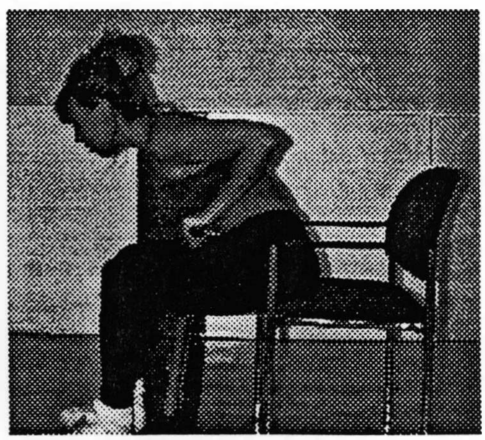
Ab Roller Plus Start



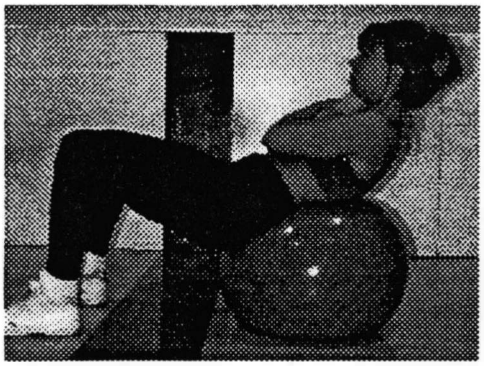
Ab Roller Plus Concentric



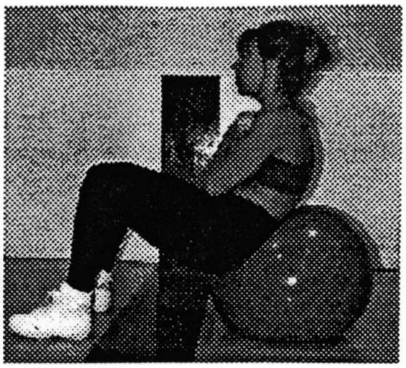
EZ-Krunch Start



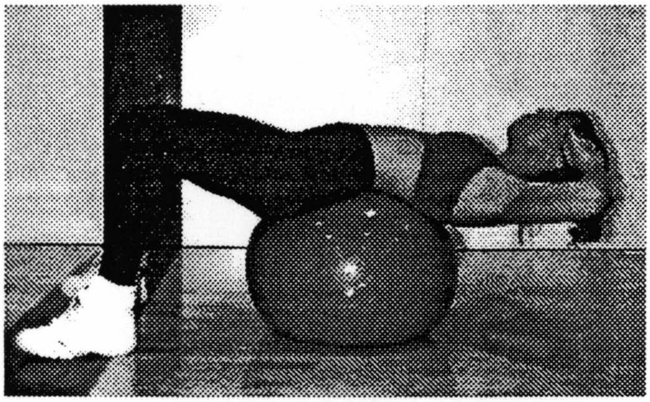
EZ-Krunch Concentric



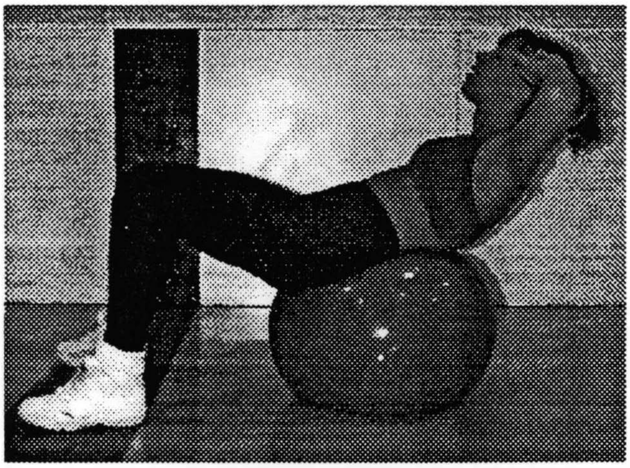
Resist-A-Ball Beginner Start



Resist-A-Ball Beginner Concentric



Resist-A-Ball Advanced Start



Resist-A-Ball Advanced Concentric

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