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A Comparison of Abdominal Muscle Activity during the Crunch, Crunch on Ball, and Abslide Exercises

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This Scholarly Project, submitted by Jessica Norton, Lesley Sponskowski, Hayley Strauss and Sabrina Wagner in partial fulfillment of the requirements of the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)

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Title	A Comparison of Abdominal Muscle Activity During the Crunch, Crunch on Ball, and AbSlide® Exercises
Department	Physical Therapy
Degree	Master of Physical Therapy

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Abstract

People have developed an obsession with flattening their stomachs and slimming down their waistlines. The so called "ab machines" have become the most popularly purchased home exercise tools. Although numerous electromyographic (EMG) analysis studies have been done on various forms of equipment-free abdominal exercise, little research has been done to evaluate the effectiveness of equipment-aided exercise. The purpose of this study was to analyze and evaluate any differences in EMG activity between three abdominal exercises: the traditional crunch, the crunch on a ball, and utilization of a prone rolling machine (AbSlide®).

Thirty, healthy subjects between the ages of 19 and 29 performed a maximal voluntary contraction (MVC) and two trials of each abdominal exercise. Abdominal EMG activity was recorded through surface electrodes and then normalized to percent MVC (%MVC) by comparing the muscle activity in the trial with the muscle activity during the reference MVC.

Results of this study showed no significant difference in %MVC between the upper rectus abdominis, lower rectus abdominis, and external oblique during the crunch, crunch on a ball, and the AbSlide®. However, equipment-aided abdominal strengthening could be utilized to add variety or

motivation to a current strengthening routine provided they are not contraindicated by a person's health status.

Chapter I

Introduction

People have developed an obsession with flattening their stomachs and slimming down their waistlines. In fact, in 1996 Americans alone spent approximately three billion dollars on home fitness equipment. Not surprisingly, the so called "ab machines" have been the most popular purchased home exercise tools.[1] However, having a great figure is not the most important reason for strengthening abdominal musculature. Several studies have noted the importance of strong abdominal muscles (the external obliques, internal obliques, rectus abdominus, and transversus abdominis), in preventing both low back pain and aiding postural control.[2] Evidence suggests that 25 percent of young, healthy subjects have weak abdominal muscles and that more than 80 percent of all cases of low back pain are directly related to weak abdominal muscles.[2,3]

Problem Statement:

Although numerous electromyographic (EMG) studies have been done on various forms of equipment-free abdominal exercise, little research has been done to evaluate the effectiveness of equipment-aided exercise. Previous research has shown that the first abdominal strengthening craze – the ab-rocker, a supportive abdominal curling device – was no more effective in firing the abdominal muscles than the traditional crunch.[2,4] Claims of supremacy of the latest equipment-aided abdominal strengthening techniques, such as crunches on a dynamic surface or utilization of prone rolling machines like the AbSlide®, must be evaluated to assess any significant differences in muscle activity.

Purpose of Study:

The purpose of this study is to analyze and evaluate any differences in EMG activity between three abdominal exercises: the traditional hook-lying crunch, the crunch on a ball, and utilization of a prone rolling machine, specifically the AbSlide®.

Significance:

With little research on these three types of abdominal exercises, it is difficult for physical therapists to appropriately answer their client's questions about these methods of abdominal training. This research will help both therapists and the general public make more informed decisions regarding the prescription and use of abdominal exercise equipment.

Research Questions:

1) Is there a significant difference in muscle activity (%MVC) between the three abdominal exercises?

2) Which abdominal exercise produces the most activity for each of the three studied muscle groups?

Null Hypothesis:

There will be no significant difference in abdominal muscle activity (%MVC), between the three abdominal exercises.

Chapter II

Literature Review

Traditional Hook-lying Crunch:

According to Warden et al.[5], in terms of performance and lumbar stabilization, it is muscular endurance of the secondary stabilizers, (rectus abdominis (RA) and external obliques (EO) not strength that is considered to be most important. Although some research has shown that the obliques and transverses abdominis are major participants in laughing[6] and coughing[7], investigators have shown that the rectus abdominis is not recruited in normal daily activities and therefore, this muscle receives little conditioning/training with activities of daily living.[7,8] Floyd and Silver[7], found that the only daily activities which did cause meaningful rectus abdominis involvement were breathing in the presence of trunk flexion and lifting the head from a supine position.

EMG research has shown that muscle action patterns are similar for all types of sit-ups. For example, the initial and final 45 degrees of the sit-up cycle are primarily the responsibility of the abdominal muscles.[2,9,10] While performing antigravity trunk flexion, the external obliques contribute more to force development than the rectus abdominis.[11] An additional finding was that greater muscle activity was achieved with concentric contractions than with eccentric contractions; even though most muscle groups elicit more force eccentrically.[2,10]

Numerous studies have shown the shoulder lift hook-lying crunch (i.e. a crunch just to the point where the inferior angle of the scapula clears the mat and the knees are bent at a 90 degree angle), is best for maximizing abdominal muscle activity while at the same time minimizing the degree of lumbar flexion and hip flexor (i.e. iliopsoas and rectus femoris) involvement.[2, 9-12] LaPier et al.[11] found that the hooklying position allowed the pelvis to remain in the posterior tilt position, thereby preventing hyperextension of the lumbar spine and decreasing stress on the low back.

During the traditional crunch, Halpern and Bleck[12] found that the rectus abdominis was active during 93 percent of the sit-up cycle, while both obliques were active an average of 90 percent of the cycle. Fixing the feet on the floor caused greater recruitment of the lower rectus abdominus muscles,[10] but unfortunately it also recruits more hip flexor muscle action. To reduce the recruitment of hip flexors, a group of researchers added gastrocnemius and soleus muscles contractions, but no appreciable difference was attained.[8] Researchers found no force production advantage found in beginning a sit-up with the abdominal muscles on stretch (i.e. the upper body below horizontal).[8]

Crunch on Ball Exercise:

Those who promote dynamic surface crunches claim that the instability provided by the ball forces the abdominal muscles to work in a way they are not used to, yielding "major" increases in muscle activity.[13] Vera-Garcia, Grenier, and McGill[14] found differences in muscle activity when the abdominal exercises were performed on a labile surface. Exercises performed on dynamic surfaces nearly doubled abdominal muscle activity. Lying on a therapeutic ball with feet on the floor was found to be the most demanding in terms of whole-body stability, increases in external oblique activity were greater than increases in the other abdominal muscles. This study's results showed that performing curl-ups on labile surfaces change the co-activation of muscles to provide stabilization and changed the level of muscle activity.

Prone Rolling Machines (AbSlide®):

Despite manufacturer claims, there is no scientific research to support the effectiveness of the various prone rolling machines that back up their claims of abdominal strengthening supremacy. Makers of the Ab-Slide Complete Abdominal System® make the claim on their website that their machine works "in just 3 minutes per day" because "each muscle is isolated for a portion of the slide."[13] In fact, a recent study sponsored by the American Council on Exercise (ACE) revealed the AbRoller® (a device comparable to the AbSlide® used in this study) was no more effective than the traditional crunch.[15] The lack of reliable information provided by the manufacturers of such devices necessitates further study.

Chapter III

Methods

Subjects

Thirty healthy subjects (10 males and 20 females) volunteered to participate in this study. All subjects were between the ages of 19 and 29 (Table 1). The subjects reported no history of back pathology that would interfere with the study or put the subject at risk for injury. Participants were informed of the testing procedures and their rights as a subject in accordance with the Institutional Review Board Procedures at the University of North Dakota. Each subject signed an informed consent form prior to participation in the study (Appendix). This study was performed on campus at the University of North Dakota in the Physical Therapy Department within the School of Medicine and Health Sciences.

Table 1. Descriptive Statistics of Subjects

	Mean	Range	Standard Deviation
Age (years)	22.5	19-29	2.4
Height (inches)	66.7	60-75	3.7
Weight (pounds)	152.1	119-243	29.7

Instrumentation

The AbSlide®, (Tristar Products, Laureldale, PA 19605), a 65 cm Fit Ball, (DynaFlex International, 1401 Cramer Blvd. Suite B, Anaheim, CA 92806, 714-630-0909), and a 55 cm Physio Gymnic Therapy Ball, (Abilitations, One Sportime Way, Atlanta, GA 30340, 1-800-850-8602), were used for the trials.

The electromyographic data was collected using a Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale Arizona, 85254).

Electrode Placement

The abdominal area was prepared prior to electrode placement. An electric razor was used for hair removal if necessary, the skin was then wiped with an alcohol swab to decrease impedance of the skin.

A total of 12 electrodes were placed over the selected musculature along with one ground electrode. The muscles tested included both the right and left upper rectus abdominis (URA), lower rectus abdominis(LRA), and external obliques (EO) (Table 2)[16]. The placement of the electrodes is described in Figure 1 and Figure 2 shows the actual electrode placement on the subject.

Exercises

Maximal Voluntary Contraction (MVC)- The subject was positioned in supine on a plinth with knees flexed to 90° (measured with a goniometer) and feet flat on the plinth (Figure 3). The hands were positioned behind the head, with unlocked fingers and the elbows out. A towel was placed across the subject's chest and then a gait belt was fastened over the towel and around the plinth to restrict flexion motion and provide a stable restriction to help develop the force of the contraction. The subject was asked to perform a crunch and push as hard as possible against the gait belt for six seconds.

Crunch Exercise- The subject was positioned in supine on a plinth with their knees flexed to 90° (measured with a goniometer) and feet flat on the plinth (Figure 4). The hands were positioned behind the head, with unlocked fingers and the elbows out. The subject was instructed to perform a crunch without flexing the neck and holding it for six seconds. A tennis ball hanging from the ceiling was adjusted to touch the subject's forehead when the inferior angles of the scapulae cleared the mat, thus establishing a reproducible stopping point.

Crunch on Ball Exercise - Two different sized therapeutic balls (55 cm and 65 cm) were used to ensure proper body alignment. The subject was positioned in supine with the low back in contact with the therapeutic ball (Figure 5). The hips were at 0° of hip flexion, the knees were flexed to 90° (measured with a goniometer) and feet flat on the floor. The hands were positioned behind the head, with unlocked fingers and the elbows out. The subject was instructed to perform a crunch without flexing the neck and holding it for six seconds. A tennis ball hanging from the ceiling was adjusted to touch the subject's forehead when the inferior angles of the scapulae cleared the plinth, thus establishing a reproducible stopping point.

AbSlide® Exercise- The subject began in a four-point position (on hands and knees) on the floor with the hands on the AbSlide® handles (Figure 6). With the knees at 90° (measured with a goniometer), tape was placed on the floor to identify the starting point of the AbSlide®. The subject was instructed to keep the arms and back straight, to tuck the abdominal muscles in, and roll forward on the AbSlide®. The subject was asked to stop when 50° of knee flexion was obtained (measured with a goniometer). A piece of tape was then placed on the floor marking the stopping point. The exercise consisted of beginning at the established starting point, rolling forward until the stopping point was reached, and maintaining an isometric hold for six seconds before going back to the starting position.

Procedure

After electrode placement, the first exercise performed by every subject was the MVC. This was done one time for a six second hold timed with a stop watch. The subject was then allowed to rest for two minutes. The crunch, crunch on ball, and AbSlide® exercises were then performed in a randomized order, which was predetermined prior to testing by drawing numbers out of a hat. Every subject was allowed five practice trials before recording the EMG data for each individual exercise. Two trials of each exercise were performed with a two minute rest between each one. Each trial consisted of a six second hold at the stopping point.

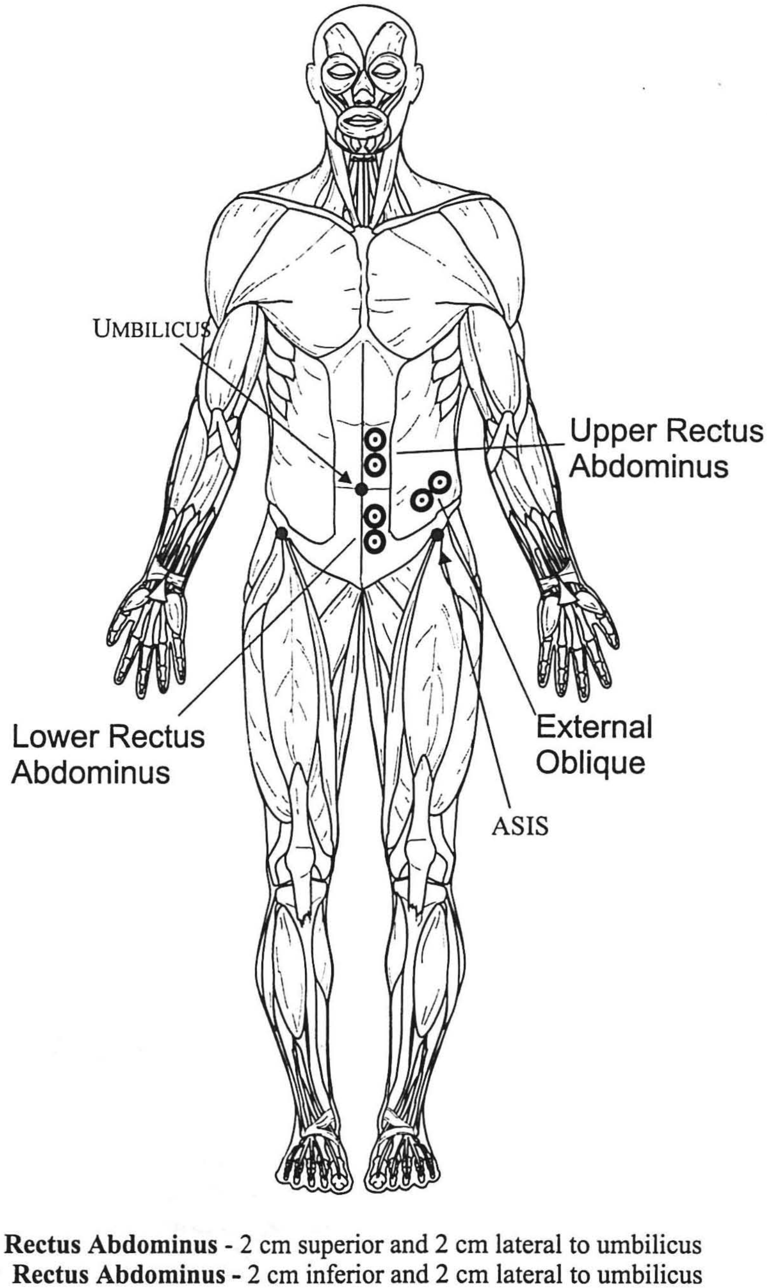
Data Analysis

The EMG data was analyzed using the MyoResearch version 2.02 software package to make comparisons between the muscle activity during the three modes of exercise. The EMG data was quantified by the software which selected the highest three second period of contiguous data values that occurred during the trial period. This same method of analysis was used for both the MVC trials and the experimental trials. First, the MVC for a particular muscle was quantified and that data was saved in a temporary stack (file) on the computer hard drive. Then each of the trials for that same muscle was analyzed using the same three second window of activity. The software then automatically calculated a percent of MVC by comparing the muscle activity in the trial with the muscle activity during the MVC. In order to normalize the data, this procedure was used for each muscle and each trial.

Following the quantification of the EMG data, the %MVC values were entered into the SPSS 10.0 software package for statistical analysis. To determine if there was a significant difference in EMG activity, a repeated measures analysis of variance (ANOVA) was performed using a two-way analysis of variance design with $\alpha = .05$. Subjects were used as one independent variable to enable the repeated measures design. Sit-up type was the other independent variable used and the independent variable of interest. The % MVC, the dependent variable, used in the calculations for each of the muscle groups (URA, LRA, and EO) was an average of the % MVC readings for the right and left sides. The mean %MVC and standard deviation for each muscle group and sit-up type was also calculated.

Table 2. Origin, insertion, and action of selected muscles

Muscle	Origin	Insertion	Action	Innervation
Rectus Abdominis	Pubic Symphysis, Pubic Crest	Xiphoid, Costal Cartilages of Ribs 5-7	Trunk Flexion	Intercostals T_7-T_{12} & L_1, Iliohypogastric, Ilioinguinal
External Oblique	Ribs 5-12	Linea Alba, Pubic Tubercle, Anterior 1/2 of Iliac Crest	Rotates Trunk to the Opposite Side, Lateral Trunk Flexion, Trunk Flexion (Bilaterally)	Intercostals T_7-T_{12} & L_1, Iliohypogastric, Ilioinguinal
Internal Oblique	Lumbar Fascia, Anterior 2/3 of Crest of Ilium, Inguinal Ligament	Lower Anterior Ribs 10-12, Linea Alba	Rotates Trunk to the Same Side, Lateral Trunk Flexion, Trunk Flexion (Bilaterally)	Intercostals T_7-T_{12} & L_1, Iliohypogastric, Ilioinguinal
Transversus Abdominis	Ribs 7-12, Lumbar Fascia, Crest of Ilium, Inguinal Ligament	Linea Alba, Pubic Crest	Compresses Abdominal Contents	Intercostals T_7-T_{12} & L_1, Iliohypogastric, Ilioinguinal



Upper Rectus Abdominus - 2 cm superior and 2 cm lateral to umbilicus
Lower Rectus Abdominus - 2 cm inferior and 2 cm lateral to umbilicus
External Obliques - 5 cm superior to the ASIS

Figure 1. Electrode placements for the abdominal muscles.

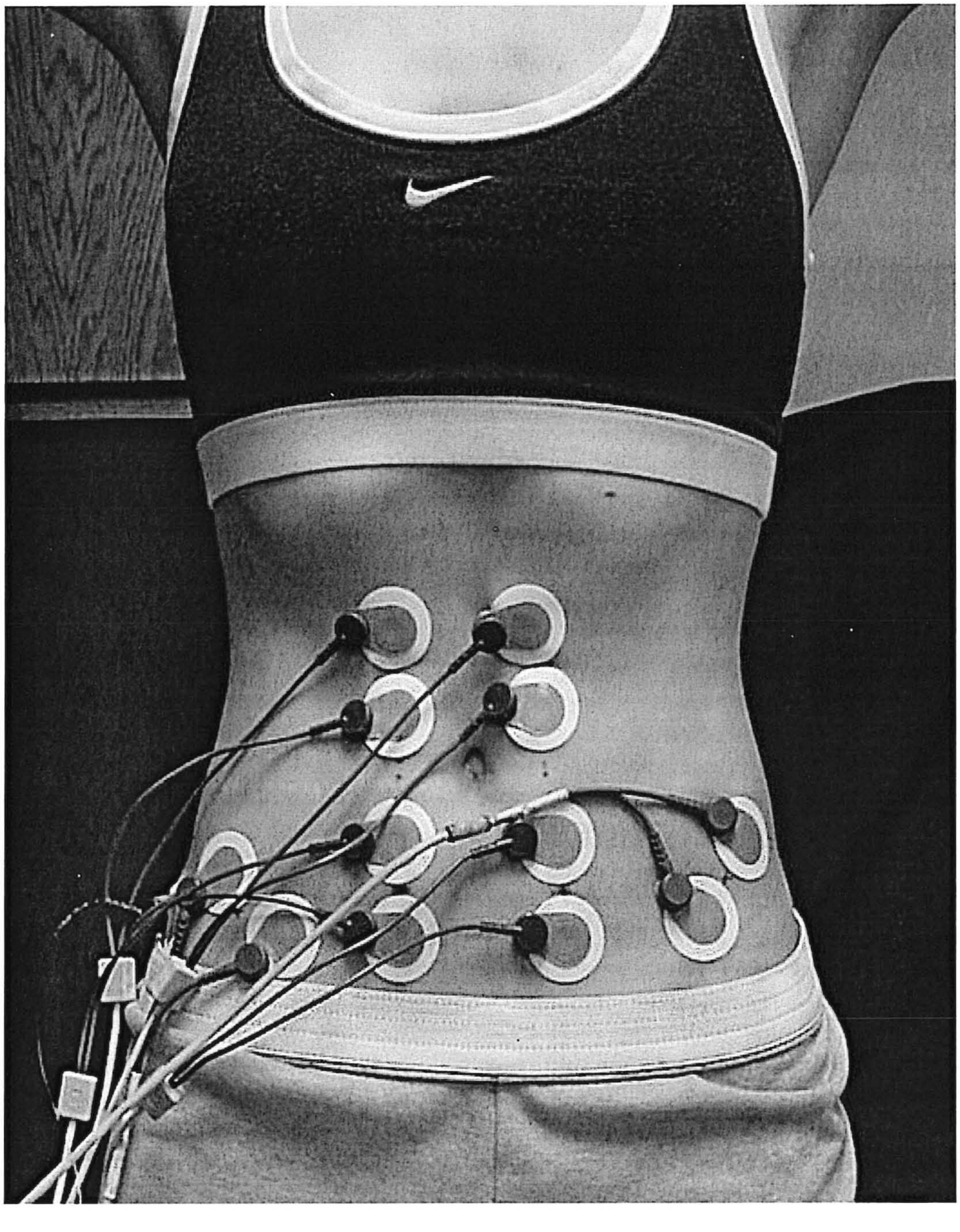


Figure 2. Electrode placement for trunk muscles.

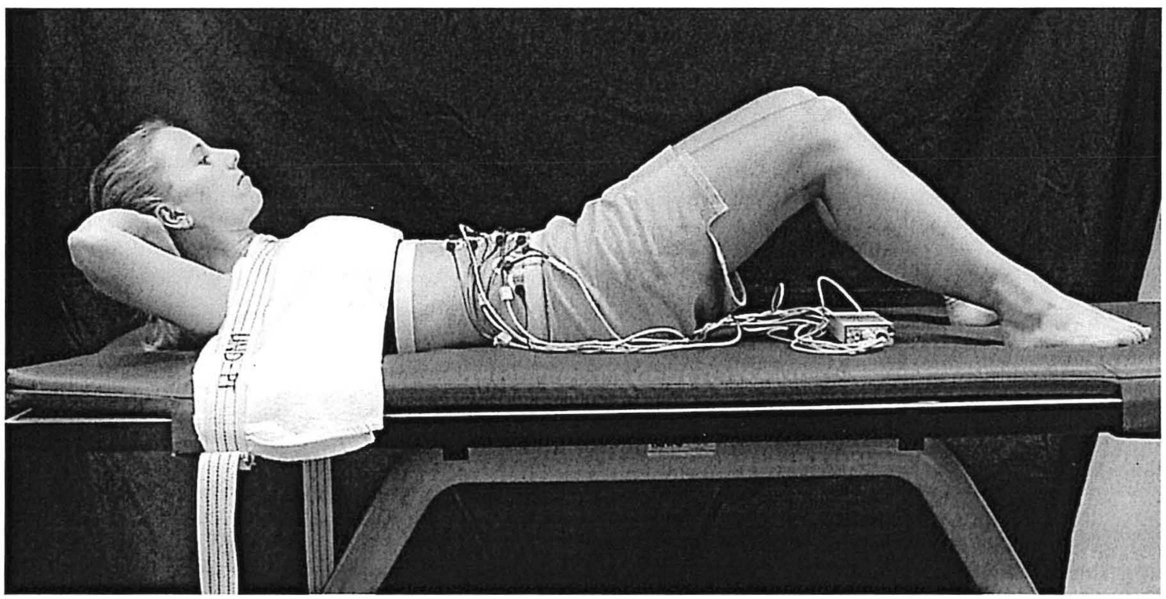


Figure 3. Maximal voluntary contraction.

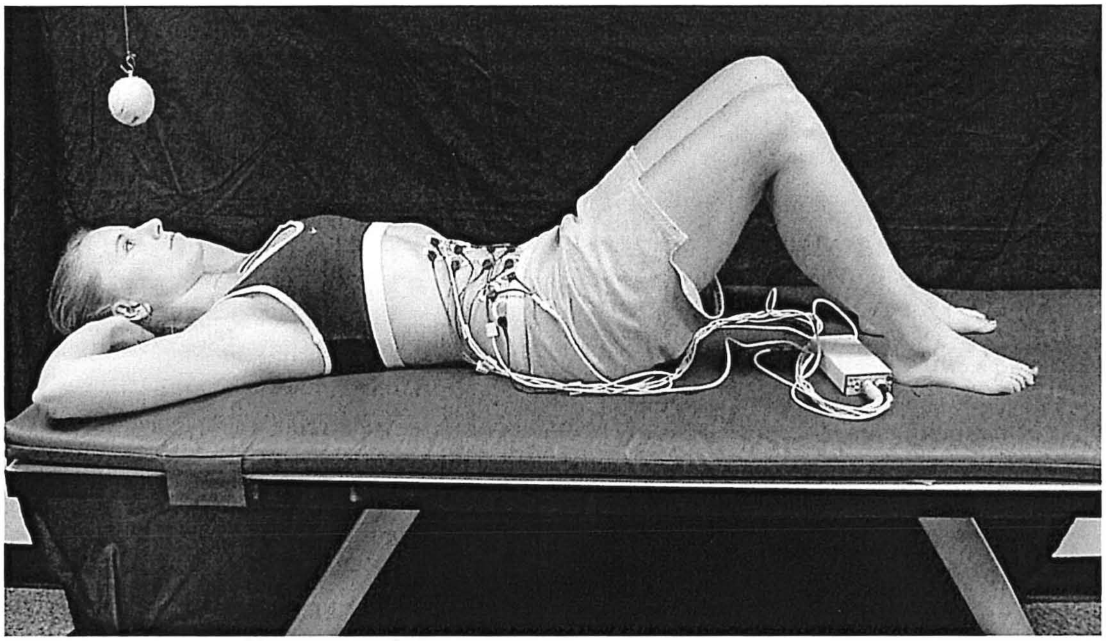


Figure 4a. Start position for crunch exercise.

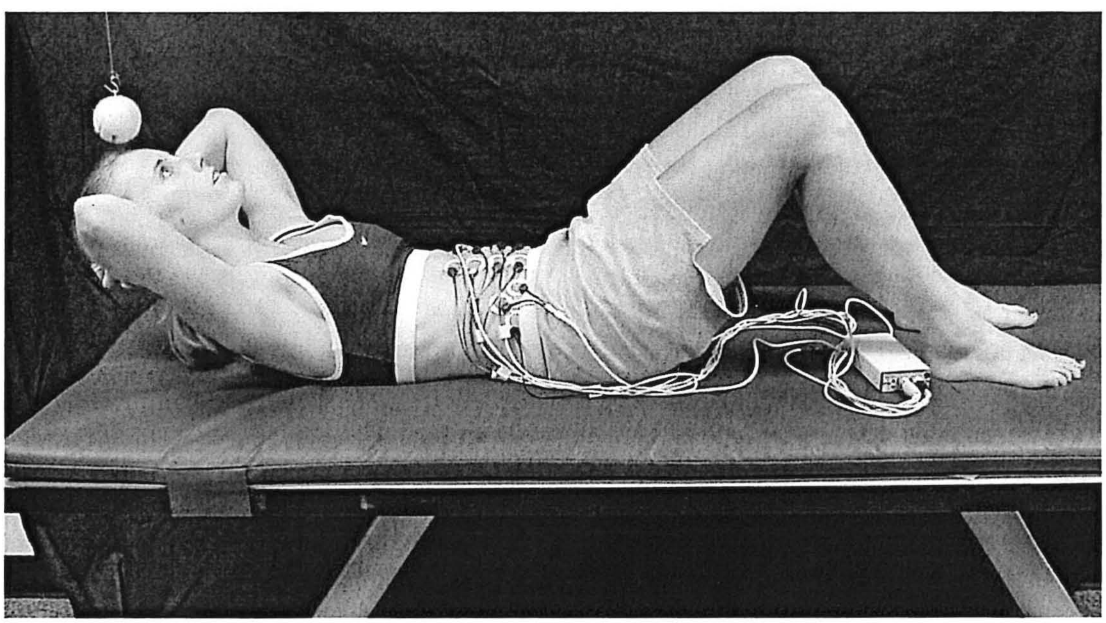


Figure 4b. End position for crunch exercise.

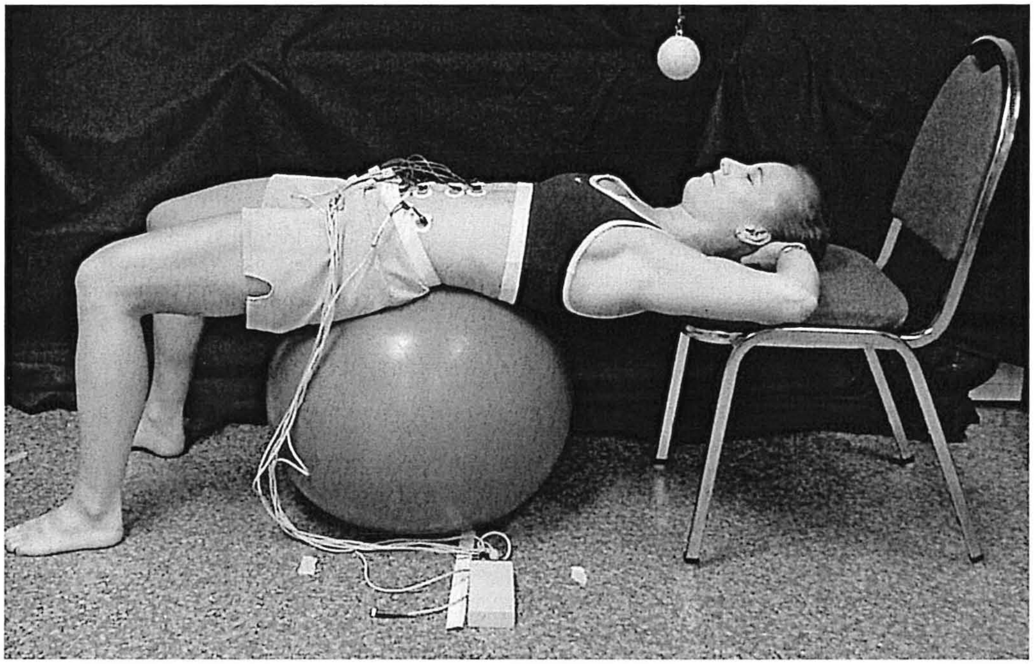


Figure 5a. Start position for crunch on ball exercise.

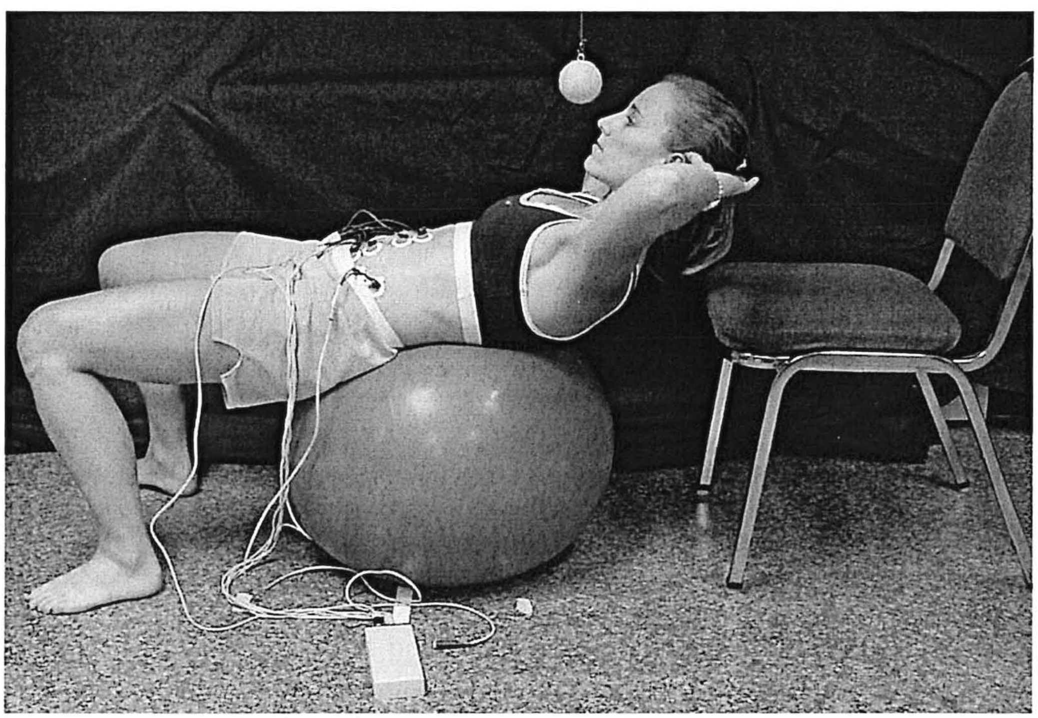


Figure 5b. End position for crunch on ball exercise.

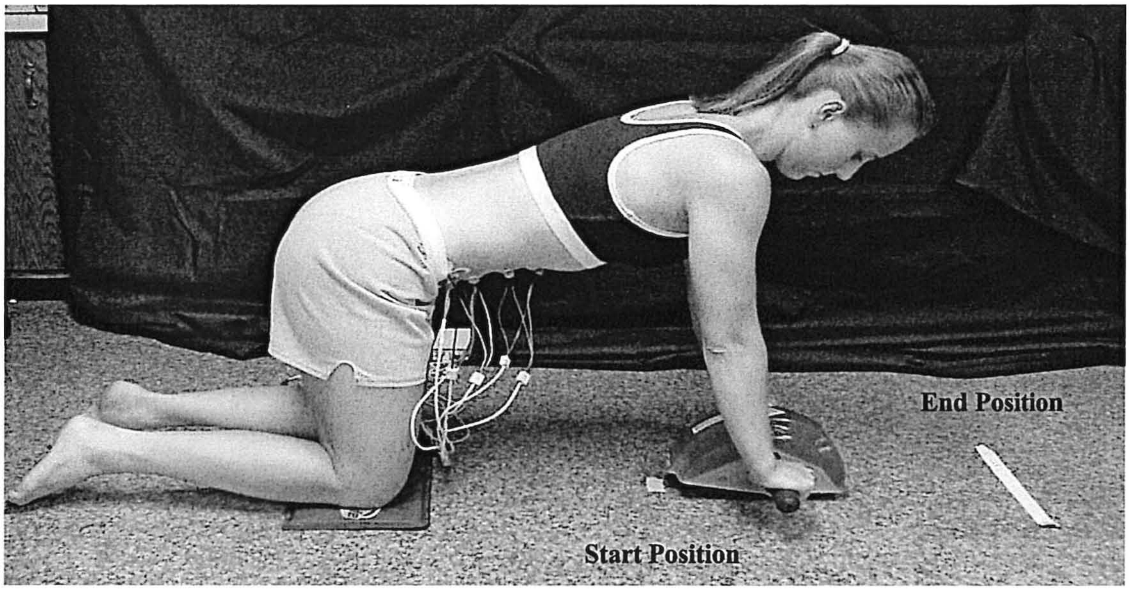


Figure 6a. Start position for AbSlide® exercise.

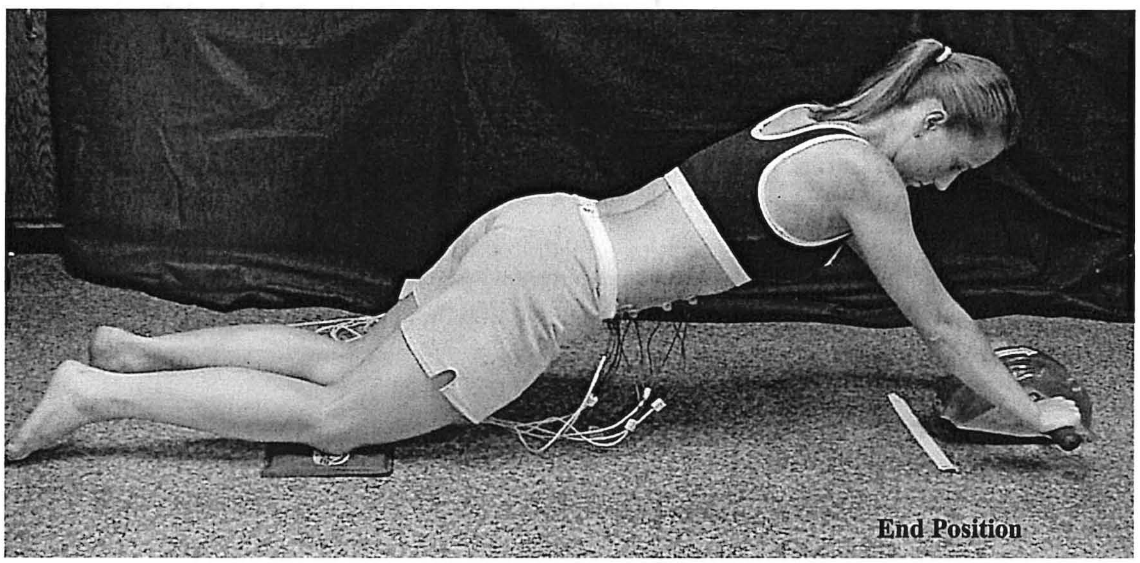


Figure 6b. End position for AbSlide® exercise.

Chapter IV

Results

The means, standard deviations, and ANOVA results are summarized in Table 3. There was no significant difference in %MVC between the URA, LRA, and EO muscles during the crunch, crunch on ball, and the AbSlide® exercises. Overall, the crunch had the lowest mean %MVC EMG activity for the URA, LRA, and EO. The URA and the LRA both had the highest mean %MVC EMG activity during the crunch on ball exercise. The mean EMG activity for the EO was highest during the AbSlide® exercise.

Upper Rectus Abdominis

The URA was most active during the crunch on ball exercise (mean %MVC = 85.476) as shown in Figure 7. It was least active during the crunch exercise (mean %MVC = 79.130). The URA had the lowest %MVC during the AbSlide® exercise compared to the LRA and EO. However, it had the highest EMG activity during the crunch exercise and the crunch on ball exercise compared to the other abdominal muscles.

Lower Rectus Abdominis

Figure 7 shows that the LRA was most active during the crunch on ball exercise (mean %MVC = 84.311). It was least active during the crunch exercise (mean %MVC = 76.615).

External Oblique

The EO demonstrated the most EMG activity during the AbSlide® exercise (mean %MVC = 86.889) as shown in Figure 7. The EO had the least muscle activity during the crunch exercise (mean %MVC = 74.724). It had the highest EMG activity during the AbSlide® exercise compared to the URA and the LRA.

Exercises

Figure 8 shows that the crunch on ball exercise produced the highest %MVC in the URA muscle. The crunch produced the lowest %MVC in the URA muscle. The crunch on ball exercise also produced the highest %MVC in the LRA and like the URA, the lowest level of activity in the LRA was seen in the crunch. However, the AbSlide® produced the highest level of activity in the EO and the crunch produced the lowest level.

Table 3. Means, standard deviations, and ANOVA summary table for differences in %MVC between abdominal exercises for each muscle group

Muscle Group	**Exercise**	**n**	**x**	**SD**	**df**	**F**	**ρ ***
Upper Rectus Abdominis	Crunch	30	79.130	21.903			
	Crunch on Ball	30	85.476	27.128	2,58	.962	.388
	AbSlide®	30	80.745	31.397			
Lower Rectus Abdominis	Crunch	30	76.615	24.809			
	Crunch on Ball	30	84.311	37.531	2,58	1.442	.245
	AbSlide®	30	83.319	34.767			
External Oblique	Crunch	30	74.724	43.007			
	Crunch on Ball	30	78.126	41.492	2,58	1.701	.191
	AbSlide®	30	86.889	52.676			

*$\rho > .05$ in all cases. There is no significant difference in %MVC between sit-up types for any of the muscle groups tested.

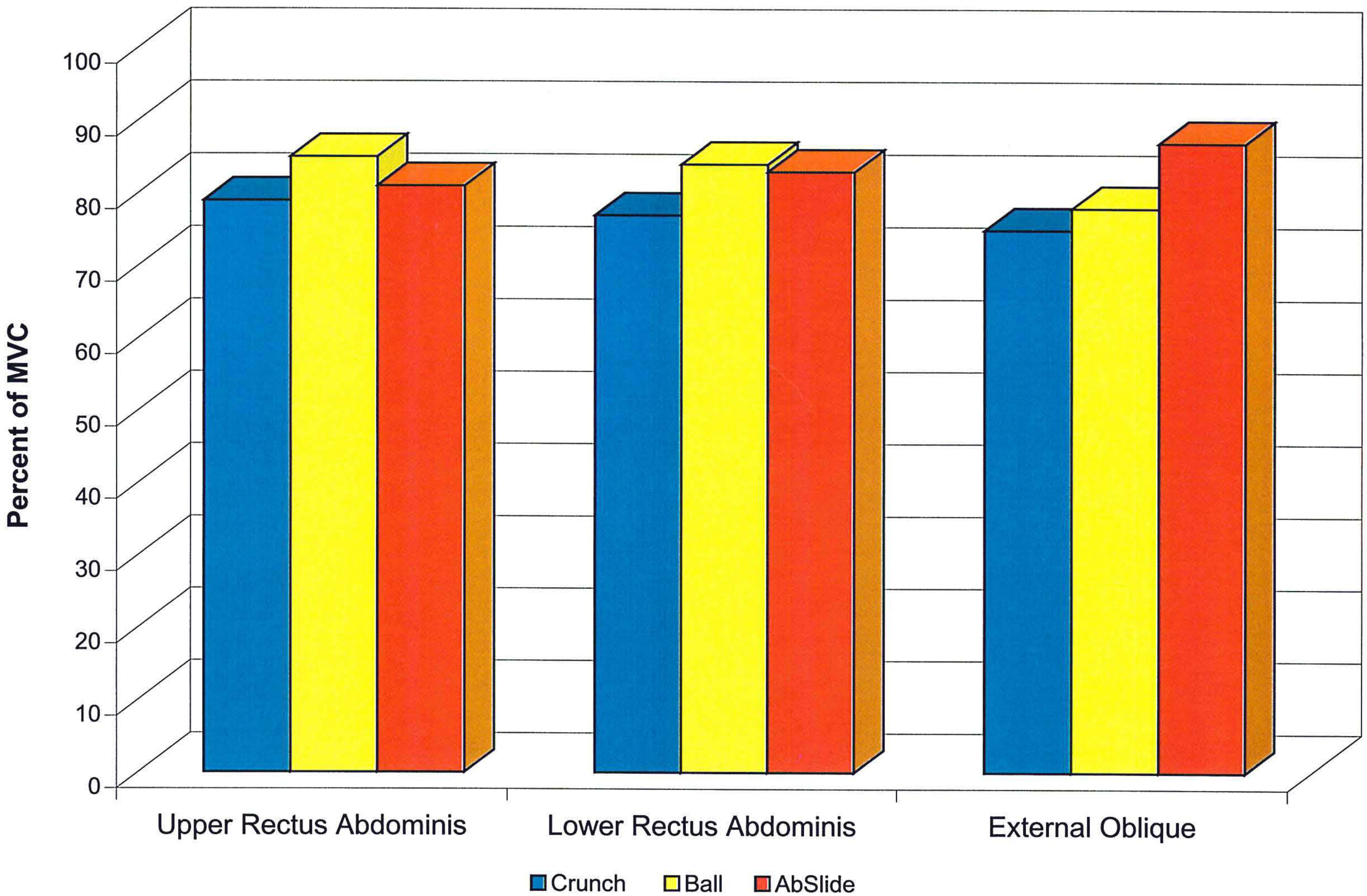


Figure 7. EMG activity of URA, LRA, and EO during abdominal exercises.

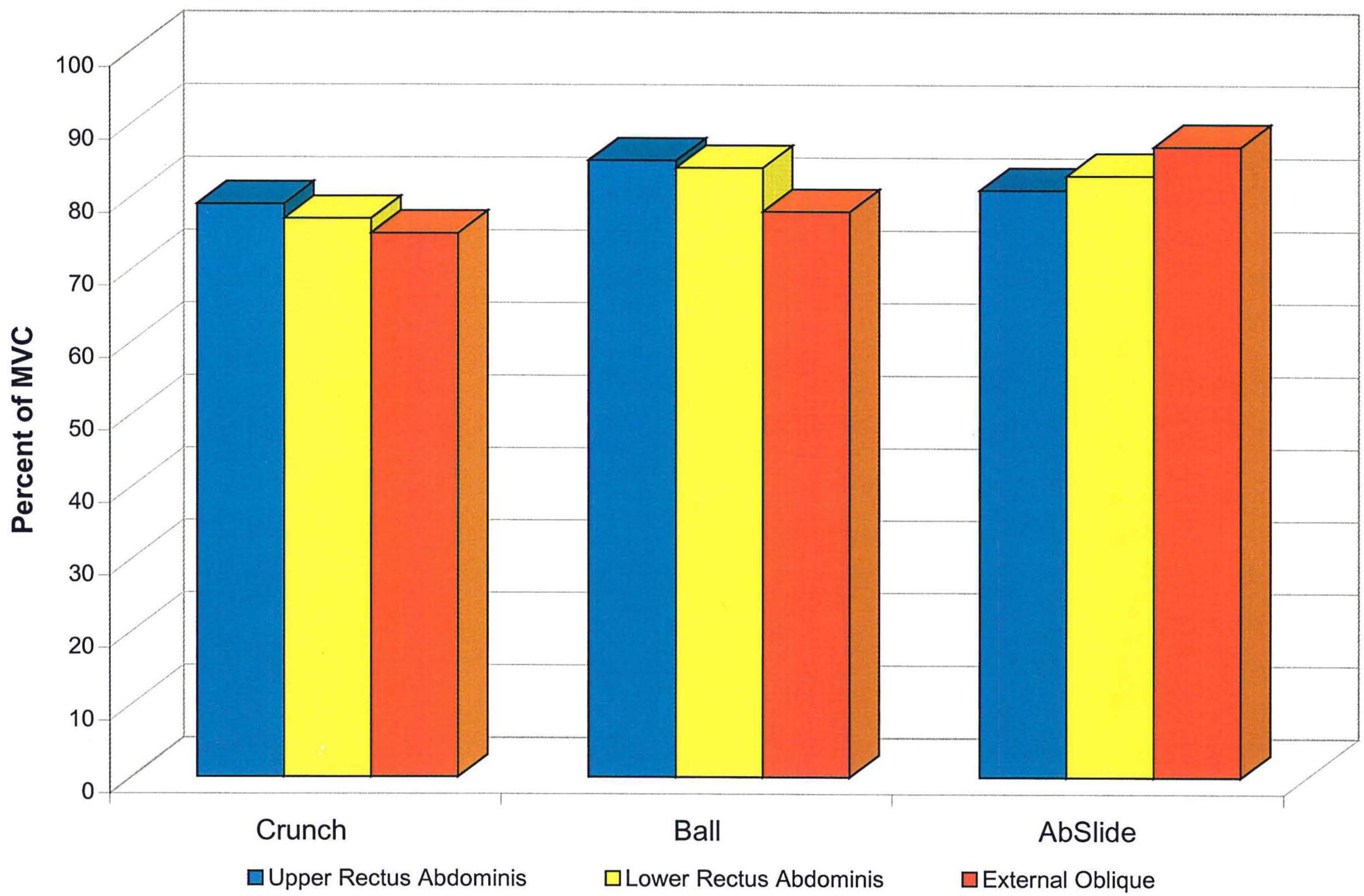


Figure 8. EMG activity of the abdominal muscles during the crunch, crunch on ball and AbSlide exercises.

Chapter V

Discussion

Crunch Exercise

The crunch exercise generated the highest level of activity (%MVC) in the URA muscle. Our findings are consistent with the results of previous studies in that the traditional crunch produced the highest %MVC in the URA compared to the LRA and the EO.[14,17] When comparing EMG activity, studies have also found the URA to produce the highest muscle activity during the crunch exercise.[3, 18]

Demont et al.[3] found the largest amount of muscle activity and Vera-Garcia et al.[14] found the highest %MVC in the URA during the crunch, followed by the LRA with the EO producing the least amount. These results agree with our study for the crunch exercise. Although they found a large difference in EMG activity between the three muscles during the crunch they didn't perform a statistical analysis. When comparing the traditional crunch, Abflex® and AbRoller® exercises, Demont et al.[3] found that there was no significant difference in EMG activity of the URA, LRA, and EO during those exercises, therefore, the effectiveness of the devices could not be supported.

There were studies that disagreed with the findings of our study. LaPier et al.[11] compared normalized EMG peak values during the partial sit-up and AbRoller® curl up. They found that during a partial sit-up the EO had a higher EMG peak value than the URA and the LRA. The EO not only had the highest EMG peak value during the partial sit-up but during the AbRoller® curl up exercise as well. The overall EMG peak activity for the abdominal muscles however, was greater during the partial sit-up than the AbRoller® curl up. These results suggest that the exercise equipment appeared to be no more effective than the traditional crunch. Even though the URA is the major trunk flexor[19], there is controversy over which muscles produce the highest %MVC during the traditional crunch exercise.

Crunch on Ball Exercise

The URA had the highest %MVC of all the abdominal muscles during the crunch on ball exercise. The EO had the lowest %MVC during this exercise.

Our results disagreed with those of Vera-Garcia et al.[14] who found the LRA to have the highest %MVC of all the abdominal muscles during the crunch on ball exercise. The URA had a slightly lower %MVC than the LRA with the EO having the lowest during this exercise. When comparing %MVC of the abdominal muscles during the crunch and the crunch on ball, they found that the lowest %MVC for the URA, LRA, and EO was recorded when performing the crunch on a stable surface. However, when on a labile surface, such as the therapeutic ball, the %MVC of the URA and the LRA approximately doubled, while the EO increased approximately fourfold. They claim that there is more co-contraction of the EO and the RA when performing a crunch on the ball because it is necessary for the subjects to stabilize themselves to reduce the risk of moving or falling off.

AbSlide® Exercise

The EO had the highest %MVC of all the abdominal muscles during this exercise followed by the LRA with the URA having the lowest %MVC. We speculate that the EO had the highest %MVC during the AbSlide® exercise due to the amount of trunk stabilization required to perform this task.

The American Council on Exercise sponsored a study by San Diego State University[15] that tested the AbRoller®, a device which is similar to the AbSlide®. They found that the AbRoller® was no more effective than the traditional crunch in recruiting the rectus abdominis and oblique muscles. This study's results agree with our findings.

Upper Rectus Abdominis

Even though there was no significant difference in %MVC found between the three modes of exercise in our study, the URA produced the highest mean %MVC during the crunch on ball exercise and the lowest during the crunch exercise. Vera-Garcia et al.[14] also found the URA to have the highest %MVC during the crunch on ball than during the crunch exercise.

Biem et al.[2] found the URA was most active during performance on the Abflex® machine. Muscle activation of the URA was significantly higher using the Abflex® compared to the crunch and during the crunch compared to the sit-up. Differences in our findings compared to Beim et al. may be attributed to single gender vs. mixed gender subjects and different abdominal exercises tested. Demont et al.[3] found the URA had the highest EMG mean during the crunch exercise. LaPier et al.[11] found the URA to have a higher EMG peak value during the AbRoller® curl up than a partial sit-up.

Lower Rectus Abdominis

We found the LRA to have the highest %MVC of all the abdominal muscles during the crunch on ball exercise and least active during the crunch exercise. LaPier et al.[11] found the partial sit-up to produce a higher %MVC in the LRA than the AbRoller® curl up.

Gilleard et al.[20] studied an abdominal muscle test with four progressively increasing levels of difficulty: 1) crooklying with the knees flexed to 90°, 2) hips flexed to 90° and one thigh supported by the hands, 3) and 4) hips flexed to 90° and unsupported. The goal during the exercises was to maintain a posterior pelvic tilt while lowering the legs from different positions. They found the LRA to have the highest %MVC throughout the four levels of the abdominal muscle test due to the effect of the additional posterior pelvic tilt.

We speculate that a slight posterior pelvic tilt is maintained during the crunch on ball exercise and this may be why the LRA was most active during that exercise, which would agree with above studies.

External Oblique

The EO had the highest %MVC during the AbSlide® exercise. The EO had the lowest %MVC compared to the URA and the LRA during the crunch and crunch on ball exercises.

LaPier et al.[11] found that the EO had the highest %MVC during the partial sit-up than during the AbRoller® curl up. Beim et al.[2] compared EMG activity of the abdominal muscles during the crunch exercise, the sit-up, and four exercises that utilized abdominal exercise equipment (Abflex® machine, AbRoller®, Nordic Track Ab Works®, and Nautilus® crunch machine). They found similar muscle activation of the EO during all of the abdominal exercises. With respect to recruiting the EO, they found the crunch exercise to be comparable to the sit-up and the exercise equipment they tested. This agrees with our study because the muscle activation of the EO was not significantly different during the crunch, crunch on ball, or AbSlide® exercises.

Limitations and Future Recommendations

There were several limitations to our study. Subjects were gathered through the method of convenience sampling and included young, healthy participants with high levels of fitness. Random sampling of the population would have probably yielded better representation for statistical analysis. Many of the subjects were also unfamiliar with the exercises and a longer period of training may have been helpful. Also a larger number of subjects would have been beneficial.

Another limitation would be the different lengths of the muscles during the isometric hold for which the EMG data were collected. During the crunch and crunch on ball exercises, the muscles were in a shortened position. In contrast, during the AbSlide® exercise, the muscles were in a lengthened position. This may have an effect on the muscle activity. Inman et al.[21] found that EMG activity decreased when the muscle is stretched, and increased when the muscle is shortened.

Skin and fat increase the impedence and reduce the recorded EMG signal levels.[22] It would be beneficial to take skin fold measurements prior to testing to help eliminate subjects with excessive subcutaneous tissue.

Future recommendations for abdominal studies should include using subjects of various ages and fitness levels. Furthermore, monitoring EMG activity during motion rather than an isometric hold may produce different results. Further studies should also investigate prone abdominal exercise machines, such as the AbSlide®.

Clinical Implications

Utilization of the AbSlide® or the therapeutic ball to perform exercises did not appear to significantly enhance abdominal muscle activity over the traditional crunch exercise. Because patients are inundated with infomercials and other advertisements for easy, quick methods of strengthening abdominal muscles, they often ask physical therapists about the "best" method to work their abdominals. Researchers have compared many different types of abdominal exercises and have found no consensus as to which exercise method trains the abdominals the "best." Even though our study didn't find a significant difference in muscle activity during the different exercises, we feel that the crunch on ball and AbSlide® exercises may not be appropriate for all patients.

When developing individualized exercise programs patient safety should be a top priority. In order to prevent injury, it is necessary to consider the patient's fitness level and past medical history. The ball is considered a dynamic or unstable surface, which is why we feel that adequate trunk stability and balance is needed to safely perform the crunch on ball exercise. Otherwise the patient may be at risk for falling off the ball causing injury.

It was reported during our testing that the AbSlide® exercise activated more muscles than just the abdominals. Many subjects reported feeling their arm and back muscles working hard. In order to utilize the AbSlide® safely, a patient should have significant upper extremity strength and no history of knee, shoulder, or back pathologies. Proper instruction on correct form is also recommended.

Products on the market available for the consumer use may not provide clear instruction on proper technique. For example, the AbSlide® came with very little instruction which could lead to improper use, thereby exacerbating and/or cause injuries to the back, shoulders, neck, wrists, or knees. This poses an ethical dilemma for physical therapists to recommend any abdominal equipment because they may be uncertain of the instructions that their patients are getting.

We feel that the traditional crunch exercise is the safest abdominal exercise as it posed no real threat of injury when performed correctly. The traditional crunch does not require a high level of fitness or balance skills.

It must also be taken into consideration that although a certain exercise may exhibit high levels of EMG activity, this does not necessarily mean that it is the most appropriate strengthening method. Physical limitations must be considered when prescribing an exercise program.

Since there was no significant difference in muscle activity during the crunch, crunch on ball, or AbSlide® exercises it may be beneficial for the clinician to instruct their patients on how to incorporate different training methods. This may help reduce boredom or redundancy in a home exercise program. According to our study, spending money on a therapeutic ball or AbSlide® is not justified because there was no significant difference in the muscle recruitment during any of the different exercise types. However, if these devices create motivation and compliance with an abdominal exercise program then the cost could be justified.[3]

Conclusion

The mean %MVC was highest for the URA and the LRA during the crunch on ball exercise and was highest for the EO during the AbSlide® exercise, but there was no significant difference found. Therefore, the use of a therapeutic ball or AbSlide® appeared to be no more effective than the traditional crunch exercise in recruiting the abdominal muscles.

APPENDIX

_X_ EXPEDITED REVIEW REQUESTED UNDER ITEM _3_ (NUMBER[S]) OF HHS REGULATIONS
___ EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Thomas Mohr, Jessica Norton, Sabrina Schantz, Lesley Splonskowski, Hayley Strauss **TELEPHONE:** 777-2831
DATE: 4/10/01

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: PO Box 9037, Dept. Of Physical Therapy, UND

SCHOOL/COLLEGE: Medicine & Health Sciences **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** 4/30/01 to 5/1/02 (Month/Day/Year)

PROJECT TITLE: A Comparison of Abdominal Muscle Activity During Sit-up and Abdominal Roller Exercises

FUNDING AGENCIES (IF APPLICABLE): None

TYPE OF PROJECT (Check ALL that apply):

_X_ NEW PROJECT ___ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr, PT, PhD

PROPOSED PROJECT: ___ INVOLVES NEW DRUGS (IND) ___ INVOLVES NON-APPROVED USE OF DRUG ___ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

___ PRISONERS ___ ABORTUSES _X_ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S),PLEASE LIST NAME OF BOARD(S):

Status: _________ Submitted; Date _____ Approved; Date_________ _________ Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

Physical therapists are always looking for techniques and devices that will make patient rehabilitation more efficient. Patients are often times looking for ways to make exercise easier and faster. As a result there is a constant barrage of new devices that come on the market that make claims that are often unsubstantiated. These devices are also often untested before marketing. Because of their role in physical fitness and exercise, physical therapists are often asked about these devices by their patients. One such device currently being marketed is the abdominal muscle strengthening devices that employ a hand held roller bar consisting of a wheel and an axle. The patient uses the device to roll forwards and backwards while on their knees as a means of strengthening their abdominal muscles. Although these devices are widely marketed, there does not appear to be any published data regarding their effectiveness.

Therefore the purpose of this study is to test an "abdominal roller" device against more traditional exercises such as sit ups and therapeutic ball exercises frequently used in physical therapy clinics. The outcome data will compare the effectiveness of the three different modes of exercises on recruiting the abdominal muscles.

Normal, healthy, adult subjects will be used in this research project. Human subjects are needed for this research study in order to determine when the selected muscles are active while exercising.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects:
It is anticipated that we will recruit 40 subjects (both male and female) between the ages of 18 and 40. The subjects for the study will be recruited from university students. These subjects will participate voluntarily. These subjects will be chosen because of their age and health status. Subjects will be excluded from the study if they have a history of abdominal, thoracic, or spinal surgery, a history of low back pain or injury, or hypertension. Subjects will also be excluded if they are pregnant. The project will be completed at the University of North Dakota Physical Therapy Department in Grand Forks. Prior to performing abdominal exercises, each subject will be asked to complete a consent form. The subjects will not be compensated.

Methods:
During the trial, we will measure EMG activity in the upper and lower rectus abdominis and external oblique muscles. We also measure the trunk motion by filming the subjects during the exercises. The study will be performed by Thomas Mohr, chairman of the physical therapy department and four graduate students: Jessica Norton, Sabrina Schantz, Lesley Splonskowski, and Hayley Strauss.

To record EMG activity, adhesive electrodes will be placed over each muscle. The precise electrode placement will be determined from standard electrode placement charts. Prior to placing the EMG electrodes, the skin over each placement site will be prepared by cleansing the skin with alcohol. The EMG signals will be transmitted to a receiver unit and then fed into a computer for display and recording of data. Prior to beginning the experimental trial, each subject will be asked to elicit a maximal voluntary contraction from each muscle being monitored in this study. The muscle activity recorded during the maximal voluntary contraction will be considered as a 100% EMG activity level to which the EMG activity during the three abdominal exercises can be compared. This procedure is done to normalize the EMG data for later analysis.

Video analysis will be used to measure upper extremity, lower extremity and trunk range of motion during the activity. Reflective markers will be attached to the trunk and extremities using double-sided adhesive tape. We anticipate placing markers on the shoulder, elbow, wrist, hip, knee and ankle. Video cameras will be placed on the side of the subject and will film the subject's trunk and extremity markers and motion during the experimental trial. This will be recorded on videotape and will be transferred to a computer for analysis.

Prior to data collection, each subject will be required to warm up for five minutes on a stationary bicycle followed by spine flexion and extension stretches. Each subject will be asked to perform a maximal voluntary contraction of the abdominal muscles against resistance in order to establish a baseline of activity. This baseline will be used to normalize the data.

The subjects will be instructed in the performance of a partial sit-up on a floor mat, a partial sit-up on a therapeutic ball, and the performance of a prone abdominal apparatus approximately one week before data collection. This will familiarize the subjects with equipment. The partial sit-up on the floor mat will be performed with knees bent, feet flat on the floor, and arms crossed over the chest. The partial sit-up on the therapeutic ball will be performed with knees bent, feet flat on the floor, arms crossed over the chest, and the trunk supported over the ball. The prone abdominal exercise will be performed using a roller device. The subjects will perform five consecutive repetitions of each abdominal exercise. The subjects will be required to rest for 30 seconds between the maximal voluntary contraction trials and three minutes between each of the three abdominal exercise trials to minimize the effects of fatigue. The order of the abdominal exercises will be determined by random assignment.

Data analysis:
Descriptive statistics describing the subjects' anthropometric profiles will be provided. The mean activity of each monitored muscle will be calculated. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the maximal contraction prior to the experimental trials (i.e. normalized). The video image will be converted to a stickman-like figure, from which we can determine joint angles and limb velocity. The EMG data is synchronized with the video data to determine the level of EMG activity during the various abdominal exercise trials.

3. BENEFITS: (Describe the benefits to the individual or society.)

The data collected throughout this research study will be analyzed to determine which muscles are active when the subject is performing abdominal exercises. The data should provide information on which abdominal exercise produces the most muscle activity in the rectus abdominis and external oblique muscles. This information will provide the basis for prescribing the most effective abdominal strengthening technique. The benefit to the participant will be the experience of being involved in a scientific study, and knowing that they will be contributing to the body of knowledge in exercise physiology and physical therapy.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks involved in this research project are minimal. The EMG and video analysis equipment causes no discomfort to the subject, since they are both monitoring devices. Because the video information is converted to stickman-like diagrams, the actual subject's video is not used in data reporting. Therefore, the subject is not recognizable.

The process of physical performance testing does impose a potential risk of injury to the muscle. The testing will occur in a controlled setting, and because only healthy subjects will be used, the risk of any injury is extremely low. The participant will be closely observed throughout the various abdominal exercises to decrease the potential of harm. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Since the electrodes are used for recording only, there is no risk of injury from them. There may be a slight redness of the skin following removal of the electrodes, but this will only be temporary.

In the event that this research activity (which will be conducted at the University of North Dakota Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by the subject's third party payor, if any.

The subjects' names will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with the subject will remain confidential and will be disclosed only with the subject's permission. The data will be identified by a number known only by the investigator.

All of the raw data will be stored in electronic format (computer files), in the Department of Physical Therapy for a period of three (3) years. After that time, the data will be erased. Some of the processed data and the consent forms will be in stored in paper format, in the Department of Physical Therapy for a period of three (3) years. After that time they will be shredded.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

Consent forms will be kept in the Physical Therapy Department at the University of North Dakota for a period of three (3) years, after which time they will be shredded.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

______________________________ ______________
Principal Investigator Date

______________________________ ______________
Project Director or Student Adviser Date

______________________________ ______________
Training or Center Grant Director Date

(Revised 3/1996)

INFORMATION AND CONSENT FORM

TITLE: A Comparison of Abdominal Muscle Activity During Sit-up and Abdominal Roller Exercises

You are being invited to participate in a study conducted by **Jessica Norton, Sabrina Schantz, Lesley Splonkowski, Hayley Strauss and Thomas Mohr from the physical therapy department at the University of North Dakota**. The purpose of this study is to study muscle activity in your abdominal muscles while you are doing sit ups in three different ways. We will also be measuring the angles of the joints of the upper extremity, lower extremity and trunk while you are exercising. We hope to describe the muscle activity that occurs during the three different exercises, and see if one mode of exercise is better than another in recruiting muscle activity. Only normal, healthy subjects will be asked to participate in this study. If you have any previous back injuries or if you are pregnant, you will not be eligible for this study. The benefit to you, as a participant, will be the experience of being involved in a scientific study and knowing that you will be contributing to the body of knowledge in exercise physiology and physical therapy.

You will be asked to perform sit-up exercises in three different ways: 1) performing a traditional sit up, 2) performing a sit up while on a therapeutic ball and 3) using an abdominal roller device. You will be asked to do five repetitions of each exercise. In addition you will be asked to perform a maximal voluntary contraction with your abdominal muscles. You will be given a rest period between trials and you will be allowed to warm-up prior to performing the exercises. In addition, you will be orientated on the use of the equipment prior to the actual experiment.

The study will take approximately one hour of your time on the day of the study and approximately ½ hour for the orientation session prior to the study. You will be asked to report to the Physical Therapy Department at the University of North Dakota at an assigned time. You will then be asked to change into gym shorts for the experiment. We will first record your age, gender, height and weight. During the experiment, we will be recording the amount of muscle activity and the angles of your joints when you perform the sit-ups.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing electrodes on your trunk. The recording electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your arm, leg and trunk. These devices only record information from your muscles and joints, they do not stimulate the skin. After we get the electrodes and markers attached, we will give you a brief training session to familiarize you with the exercises. The amount of exercise you will be asked to perform will be moderate. There may be a slight redness following removal of the electrodes, but this will only be temporary.

Your name will not be used in any reports of the results of this study. The video taped data will be analyzed by a computer and the markers placed on your body will be used to construct a "stick man" like figure. Your real, photographic image will not be used in reporting of the findings of the study. The computer files, and consent forms are kept in the physical therapy department for a period of three (3) years. After that time, the electronic media is erased and the paper files are shredded. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form is available to all participants in the study. If you have any ethical concerns regarding this study, contact the UND Institutional Review Board Chair at the Office of Research and Program Development, 701 7774279.

In the event that this research activity (which will be conducted at UND Physical Therapy) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION; I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by one of the investigators.

____

Participant's Signature Date

References

1. Krucoff C. There's no place like home: How to avoid exercise equipment rip-offs. *Nutrition Action Healthletter.* 1997;24:3.

2. Beim G, Giraldo J, Pincivero D, Borror M, Fu F. Abdominal strengthening exercises: A comparative EMG study. *J Sport Rehab.* 1997;6:11-20.

3. Demont R, Lephart S, Giraldo J, Giannantonio F, Yuktanandana P, Fu F. Comparison of two abdominal training devices with an abdominal crunch using strength and EMG measurements. *J. Sports Med Phys Fitness.* 1999;39:253-258.

4. Avakian J, Keresztes M, Oakley B, Millar L. EMG activity of the abdominal muscles using traditional crunches vs. an abdominal exercise assistive device. *Phys Ther.* 2000;80:33.

5. Warden S, Wajswelner H, Bennell K. Comparison of abshaper and conventionally performed abdominal exercises using surface electromyography. *Med Sci Sports Exerc.* 1999:1656-1663.

6. Miller M, Medeiros J. Recruitment of internal oblique and transversus abdominis muscles during the eccentric phase of the curl-up exercise. *Phys Ther.* 1987;67:1213-1217.

7. Floyd W, Silver P. Electromyographic study of patterns of activity of the anterior abdominal wall muscles in man. *J Anat.* 1950;84:132-145.

8. Ekholm J, Arborelius U, Fahlcrantz A, Larsson A, Mattsson G. Activation of abdominal muscles during some physiotherapeutic exercises. *Scand J Rehab Med.* 1979;11:75-84.

9. Godfrey K, Kindig L, Windell E. Electromyographic study of duration of muscle activity in sit-up variations. *Arch Phys Med Rehabil.* 1977;58:132-135.

10. Flint M. Abdominal muscle involvement during the performance of various forms of sit-up exercise. *Am J Phys Med.* 1965;44:224-234.

11. LaPier T, Creelman J, Cunningham D, Moore J, Whiles J. Abdominal muscle EMG activity during trunk flexion exercises: Partial sit-up vs. Ab roller curl-up. *Physiother Can.* 2000:158-162.

12. Halpern A, Bleck E. Sit-up exercises: An electromyographic study. *Clin Orthop Rel Res.* 1979;145:172-178.

13. Ab Slide, The complete abdominal workout. Available at: http://www.ab-slide-ab-workouts.com/ab-slide-workouts-how.htm. Accessed November 24, 2001.

14. Vera-Garcia F, Grenier S, McGill S. Abdominal muscle response during curl-ups on both stable and labile surfaces. *Phys Ther.* 2000;80:564-569.

15. American Council on Exercise (ACE)-sponsored study reveals best and worst abdominal exercises. Available at: http://www.acefitness.org/media/media_display.cfm?NewsID=119. Accessed on November 19, 2001.

16. Keck, Arnie. Anatomy for Allied Health. University of North Dakota. 1994. pg:86-87.

17. Lehman GJ, McGill SM. Quantification of the differences in electromyographic activity magnitude between the upper and lower portions of the rectus abdominis muscle during selected trunk exercises. Phys Ther. 2001;81:1096-1101.

18. Sarti M, Monfort M, Fuster M, Villaplana L. Muscle activity in upper and lower rectus abdominus during abdominal exercises. *Arch Phys Med Rehabil.* 1996;77:1293-1297.

19. Juker D, McGill SM, Kropf P, Steffen T. Quantitative intramuscular myoelectric activity of lumbar protions of psoas and the abdominal wall during a wide variety of tasks. Med Sci Sports Exerc. 1998;30:301-310.

20. Gilleard W, Brown M. An electromyographic validation of an abdominal muscle test. *Arch Phys Med Rehabil.* 1994;75:1002-1007.

21. Inman VT, Ralston HJ, Sannders JB, Feinstein B, Wright E. Relation of human electromyogram to muscular tension. *Electroenchephalog and Clin Neurophysiol.* 1952;4:187-194.

22. All abdominal exercises are not created equal. Available at: http://www.endureplus.com/abs.cfm. Accessed March 21, 2001.