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EMG and Motion Analysis of Swiss Ball Abdominal Exercises and Pilates Multi-Chair Exercises

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This Scholarly Project, submitted by Kelly Almquist, Ember Bopp, and Chet Yoder 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)

PERMISSION

Title	EMG and Motion Analysis of Swiss Ball Abdominal Exercises and Pilates Multi-Chair Exercises
Department	Physical Therapy
Degree	Master of Physical Therapy

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Date 12/13/02

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Abstract

As the second most common reason for visits to primary care doctors, and a symptom that affects 80% of the general United States population, low back pain and its' treatment is a burdening cost on the American economy every year.[1] Various spinal stabilization exercises have emerged as a means to treat low back pain. One of the most recent forms of these stabilization exercises used in the physical therapy arena is Pilates, a form of dynamic spinal stabilization. Although numerous electromyographic (EMG) studies have been completed on abdominal exercises for spinal stabilization, minimal scientific research can be found on the efficacy of Pilates equipment in this realm. The purpose of this study is to analyze and evaluate the EMG activity in the rectus abdominis, external obliques, and internal obliques using four abdominal exercises: the abdominal crunch on a ball, the abdominal crunch with rotation on a ball, the abdominal crunch on the Pilates Multi-Chair, and the abdominal crunch with rotation on the Pilates Multi-Chair.

Fourteen, healthy subjects between the ages of 18 and 45 years of age performed a maximal voluntary contraction (MVC) and one trial 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 a significant difference in % MVC among exercises in the left external oblique, upper rectus abdominis, and lower rectus abdominis. There was no significant difference in % MVC among exercises in the right external oblique, and the right and left internal obliques. In general, exercises on the ball produced a higher % MVC in the rectus abdominis and the exercises on the Pilates Multi-Chair produced a higher % MVC in the external obliques.

CHAPTER I

INTRODUCTION

"Low back pain is a symptom that affects 80% of the general United States population at some point in life with sufficient severity to cause absence from work. It is the second most common reason for visits to primary care doctors, and is estimated to cost the American economy $75 billion every year."[1] Several studies have noted the importance of strong abdominal muscles (external obliques, internal obliques, rectus abdominis, and transversus abdominis), in preventing low back pain and aiding postural control.[2,3] Over the years, many forms of spinal stabilization exercises have emerged as a means to treat low back pain. With the staggering numbers of patients experiencing low back pain, physical therapists are constantly searching for more effective means of strengthening the muscles involved in spinal stabilization. Recently Pilates, a time-tested system of exercises, has re-emerged as a form of dynamic spinal stabilization in the physical therapy arena. [3] The Pilates Reformer and the Pilates Multi-Chair are two machines commonly used in Pilates-based rehabilitation.

Problem Statement:

Although numerous electromyographic (EMG) studies have been completed on abdominal exercises for spinal stabilization, minimal scientific research can be found on the efficacy of Pilates equipment in this realm.

Purpose of Study:

The purpose of this study is to analyze and evaluate the EMG activity in the rectus abdominis, external obliques, and internal obliques using four abdominal exercises: the abdominal crunch on an exercise ball, the abdominal crunch with rotation on an exercise ball, the sagittal exercise on the Pilates Multi-Chair, and the oblique exercise with rotation on the Pilates Multi-Chair.

Significance:

Since, there has been minimal scientific research on the Pilates Multi-Chair, it is difficult for physical therapists to knowledgeably and confidently prescribe spinal stabilization exercises (for low back pain), using Pilates equipment and methods as opposed to the more traditional approaches. This study will reflect EMG data directly obtained from the rectus abdominis, external obliques and internal obliques. McGill and associates[4] showed that EMG data from the transversus abdominis could be predicted by internal oblique EMG data [error of 2% to 15% RMS (root mean square) difference]. Therefore, in addition to directly obtained EMG data, this study will attempt to indirectly analyze the activity of the transversus abdominis among the four abdominal exercises.

Research Question:

Which abdominal exercise produces the most EMG activity for each of the six studied muscle groups (upper rectus abdominis, lower rectus abdominis, right and left external and internal oblique muscles)?

Null Hypothesis:

The EMG data of each muscle group is not dependent on abdominal exercise studied.

CHAPTER II

LITERATURE REVIEW

Pilates:

According to Ungaro,[5] Joseph Pilates defines Pilates as "a movement system that uses spring-driven machines as well as a series of floor exercises to increase strength, flexibility, stamina, and concentration."

Joseph Pilates, the founder of Pilates techniques, was born in Germany in 1880.[6] It was actually while in a prison camp during WWI that he developed many of his principles. Some of these traditional principles are the following: concentration, control, centering, flowing movement, precision, and breathing.[7] Later, Joseph Pilates came to New York where he taught his Pilates techniques to ballet dancers.

Recently, Pilates has evolved and has taken on many forms and subtypes. Currently, there are almost as many variations on Pilates as there are people who use it.[7] Pilates is used by the general public as a means to strengthen and tone the body—especially the "core" or the abdominal muscles. Pilates techniques are also used by physical therapists for spinal stabilization purposes to treat and prevent low back pain.

Many articles refer to the "power house," which Pilates teachers use to describe the collective muscles of your abdominals, gluteals, and low back.[5,6,8,9] Winsor,[6] author of several Pilates-related books, defines the power house as the center of strength and control for the rest of the body. She goes on to elaborate about the "power house" with this statement, “The exact musculature we refer to as the power house is located beneath these muscles, deeper within the abdomen, and is called the transversus abdominis.”

Many Pilates practioners claim that a complete Pilates routine will reduce injuries, especially in the low back area.[6,8] Winsor[8] explains that with this routine there is nearly constant initiation and recruitment of the “power house”; as a result, the area becomes stronger and plays a fundamental role in reducing injury.

Winsor[6] expounds further by stating it is possible to completely eliminate low back pain if the “power house” is very strong. She states many people have low back pain because their center is not strong and they do not understand how to engage and utilize it. When they attempt to pick up a heavy object or take part in another labor-intense activity, they are not utilizing their “power house” to initiate that task.

Pilates instructors refer to the “B-line” exercise as a method to contract the transversus abdominis and thus initiate the contraction of the “power house.” Menezes[9] states that when doing the B-line, one envisions an imaginary line between the front of the hip bones (anterior superior iliac spines) and then pulls the abdominal muscles back behind this line.

In summary, Pilates is a form of exercise that requires concentration and focuses on quality of movement. All movements are accompanied by proper breathing techniques and the B-line contraction in addition to other movements. Pilates evolved conditioning involves recruitment of the most effective motor unit, which encourages one to focus on efficiency and quality of movement.[3]

Tranversus Abdominis Importance:

The transversus abdominis muscle serves to compress and support the abdominal viscera. However, since it lies deep to the rectus abdominis and both obliques, the EMG activity of the transversus abdominis is difficult to measure with surface electrodes. The origin of the transversus abdominis is on the internal surfaces of the seventh through the twelfth costal cartilages, thoracolumbar fascia, iliac crest, and lateral third of the inguinal ligament; it inserts on the linea alba (meshed with the aponeurosis of the internal oblique), pubic crest, and pectin pubis via the conjoint tendon.[10] Porterfield and DeRosa[11] state that the transversus abdominis actions include compressing the abdominal contents and increasing tension to the thoracolumbar and abdominal fascia such as would occur when one attempts to "pull their abdomen in " away from their beltline. The authors proceed to state that the transversus abdominis and internal oblique provide stability of the spine by a laterally directed pull on the vertebrae.

Recent literature has also shown that the transversus abdominis has an important role in lumbar stabilization and sacroiliac joint stabilization. [12] An independent transversus abdominis contraction increased SI joint stiffness to a significantly greater degree than did a general abdominal exercise pattern.

Other research has shown that the transversus abdominis is often the first trunk muscle active in functional tasks. [13,14] Individuals with low back pain were shown to have a significant delay in EMG onset of transversus abdominis contraction as compared to healthy subjects. Thus, the authors concluded that this delay in the onset of transversus abdominis contraction was a problem in motor control and proposed that this resulted in inefficient stabilization of the spine.

Literature also supports the theory that the transversus abdominis and internal oblique abdominal muscles often have the same action and purpose. Porterfield and DeRosa[11] state that the muscles have a common origin in the thoracolumbar fascia and share similar actions. In addition, the fiber orientation of the two muscles is thought to be similar at a point medial to the ASIS. Therefore, the muscles may act in a similar manner.[15] Additionally, a study comparing the differences in EMG muscle activation between fine wire electrodes and surface electrodes showed that the transversus abdominis had a similar activation profile to the internal obliques. The area measured was just superior to the inguinal ligament. The authors concluded that EMG activity of the transversus abdominis could be predicted (with recognized error of 2% to 15% RMS difference in clinical tasks) with a well-placed surface electrode over the internal oblique.[4]

Thus, in this study we are attempting to analyze the entire abdominal musculature by using various exercises and EMG data collected by surface electrodes. In doing so, we will use the relationship between the IO and transversus abdominis to gain a concept of the transversus abdominis contraction.

Swiss Ball:

The use of the exercise, or "Swiss," exercise ball is common practice in many rehabilitation settings today.[16] Used in Switzerland since the 1960's and introduced in the United States in the 1970's, the Swiss ball was originally used for the treatment of neuromuscular, neurological and pediatric patients. Today, its use has expanded to include orthopedics, sports medicine, and the fitness industry. Improved trunk control and posture, increased range of motion, strength, proprioception, and improved cardiovascular function are the more common indications for the use of ball exercises. Schorn and Kucera, incorporated the exercise ball into spinal stabilization exercise programs in the 1980's, with Schorn bringing the program to the United States in 1983.[16] The use of the Swiss ball has now become a common practice for enhancing spinal strength, stability, and conditioning after back injury.

Until the early 1990's, there had been little literature available regarding the use of the Swiss ball. One study done by Liggett and Randolph[17] tested the difference in strength gains between abdominal exercises (traditional sit-up) on a mat and a sit-up on a Swiss ball (with feet planted firmly on the ground) when used as a weekly exercise regimen. The study found that abdominal exercises on a ball, when compared to abdominal exercises performed on a mat, showed significantly more gains in abdominal strength.

Vera-Garcia et al[18] found that abdominal exercises performed on labile surfaces, such as a Swiss ball, produced differences in muscle activity compared to a traditional sit-up on a mat. Muscle activity was recorded through EMG from surface electrodes on the participants' skin and recorded as a percentage of the maximal voluntary contraction (MVC). The study showed that when lying on a Swiss ball, with feet planted on the floor, abdominal muscle activity nearly doubled that of the mat exercises. This exercise on the labile surface was found to be the most demanding regarding whole-body stability and showed the most significant gains in muscle activity in the external oblique when compared to the other abdominal muscles. This study found that when there is increased need for the body to stabilize, there is a greater co-activation of muscles, resulting in greater muscle activity.

CHAPTER III

METHODS

Subjects:

Fourteen healthy subjects volunteered to participate in this study (n=7 female, n=7 male). All subjects were between 18 and 45 years of age. The participants were screened by verbal questioning to ensure they did not have a history of cardiac problems, low back pain/injury, blood pressure abnormalities, and were not currently pregnant, conditions which could put the subjects at risk for injury during exercise sessions. Subjects were informed of the testing procedure, and their rights in accordance with the Institutional Review Board Procedures at the University of North Dakota. A signed consent form was received from each participant (Appendix).

The participants were trained at HealthSouth in Grand Forks, ND and were tested at the University of North Dakota Physical Therapy Department in the School of Medicine and Health Sciences.

Instrumentation:

Testing Devices:

The Pilates Combo Chair (Balanced Body, Sacramento, CA) and a 65-cm Swiss ball (PhysioGymnic, Smith & Nephew, Germantown, WI) were used for the trials.

Electromyography:

The EMG data were collected using a Noraxon Telemyo8 telemetry unit (Noraxon USA, Scottsdale, AZ). This data was sent to a Noraxon Telemyo8 receiver and then was digitized by an analog digital interface board in the Peak Analog Module (Peak Performance Technologies, Englewood, CO). Electromyographic data and video data were synchronized using the Peak Event Synchronization Unit.

Motion analysis:

Four reflective markers were used to outline each subject's anatomical movement. The markers were placed on the left side of each subjects body as follows: thorax (2 inches lateral to the nipple), lateral most portion of the iliac crest, greater trochanter, and lateral joint line of the knee over the clothes on the left side of the subject's body. The camera used to film the exercise movements was a Peak High Speed Video 60/120 Hz Camera (Peak Performance Technologies, Englewood, CO). The camera was set at a frequency of 60 Hz with a shutter speed of 1/250 of a second. The trials were taped on a JVC model SR-V1OU videocassette recorder (JVC of America, Wayne, NJ). The videotape was encoded with a SMPTE time code generator.

Once the trials were recorded, the movements were digitized using the Peak Motus Software package. The tapes were played on a Sanyo Model GVR-S955 (Sanyo, Capton, CA) videocassette recorder for the purpose of digitization.

Electrode Placement:

Before the electrodes were placed, the abdominal area was prepared by shaving any excess hair with an electric razor, and by cleansing the skin with rubbing alcohol to decrease the impedance of the skin.

Twelve electrodes were used over the musculature and one ground electrode was placed over the participant's left ASIS. The muscles tested were the right upper rectus abdominis (URA), right lower rectus abdominis (LRA), right and left external obliques (EO), and right and left internal obliques (IO). The placement of the electrodes for the URA was 2 cm superior and 2 cm lateral to the umbilicus, while the LRA electrodes were 2 cm inferior and 2 cm lateral to the umbilicus. The electrodes for the EO muscles were placed 15 cm lateral to the umbilicus and at the transverse level of the umbilicus. The IO electrodes were placed below the EO electrodes and just superior to the inguinal ligament.[4] The placement of the electrodes is shown in Figure 1.

Exercises:

Maximal Voluntary Contraction - After preparation and electrode placement, the participants were asked to perform a maximal voluntary contraction (MVC). The participant was positioned supine on a plinth with the knees bent to 90° and the hips at 45°. The subject's hands were held in a relaxed manner behind the head with the elbows directed laterally. The subject was then asked to perform a partial crunch bringing the scapula off the plinth and contracting the abdominals in this position for 6 seconds (Figure 2).

Pilates Multi-Chair –The Pilates Multi-Chair is an apparatus designed to assist Pilates practitioners and physical therapists in proper strengthening of the abdominals and various other muscles of the body. Many different exercise options are available, but the two that were tested were a "pike" position in the sagittal plane and an oblique "pike" position. The Multi-Chair uses spring tension to assist the user in the various movements desired.

All subjects were trained in the proper use of the Pilates Multi-Chair through two prior training sessions. In these sessions, a specific spring tension was set for each subject. This was the least amount of spring assist needed to correctly perform the exercise.

In the sagittal movement, each subject began with the feet flat on the bar of the Multi-chair and the hands at the two opposite corners of the pad (Figure 3). Before initiating the exercise, subjects were instructed to assume the B-line contraction and then to breath out as they came up to the "pike position" (Figure 4). The participants were also instructed to raise themselves as high as possible while still maintaining the B-line contraction throughout. Finally, the subject would inhale during the descent while maintaining the B-line contraction. This activity was performed at a constant pace for 10 seconds of testing.

With the oblique exercise on the Multi-Chair, the subject would begin by crossing the left foot over the right on the bar and by moving both hands to the right corner of the pad (Figure 5), resulting in the subject arriving at a side bent position. All other instructions were the same for the participant as in the sagittal Multi-Chair exercise, and the participant would end in the "pike" position (Figure 6).

Crunch on Ball—The participant assumed the supine position with the ball under the low back. The subject's feet were flat on the floor and hands were held in a relaxed manner behind the head with the elbows directed laterally. The subjects were asked to perform sagittal crunches on the ball for the 10-second testing period (Figures 7 and 8).

For the oblique version of the crunch on the ball, the subject was positioned in the same starting position but then was asked to crunch obliquely (rotating the torso to the right so the left shoulder was directed to the right knee). This exercise was also repeated throughout the 10-second testing period (Figures 7 and 9).

Procedure:

After the preparation and electrode placement, the first exercise performed by the participant was the MVC. This contraction was held for six seconds, and then the subject was allowed adequate rest time before initiation of the other exercises. The sagittal Combo Chair, oblique Combo Chair, sagittal crunch on ball, and oblique crunch on ball exercises were performed in a randomized order. Each subject was allowed to practice each exercise briefly, if desired, before testing occurred. Adequate time was allowed between each subsequent exercise to allow for muscle recovery.

Data Analysis:

Prior to videotaping, the camera was calibrated by videotaping a meter stick. Then, the video footage for each abdominal exercise was calibrated in meters, cropped to one full cycle of the abdominal exercise, and digitized using the Peak system. The software calculated the joint angles and segmental motion. The raw analog data was scaled and matched to the video.

The EMG data was analyzed using the MyoResearch version 2.02 software (Noraxon USA, Scottsdale, AZ) package to make comparisons between the four modes of abdominal exercise. The EMG data was quantified by the software which selected the highest ten second period of continuous data values during the trial period. The MVC trials and experimental trials followed this same method of analysis. First, the MVC for a individual muscle was quantified and that data was saved in a temporary file on the computer hard drive. Then, each of the trials for that muscle was analyzed using the same ten second period of activity. A percent of the MVC, which was automatically calculated by the software, compared the muscle activity in the trial with the muscle activity during the MVC. The procedure was used for each trial and each muscle in order to normalize the data.

The percent MVC values were entered into the SPSS 10.0 software (SPSS, Chicago, IL) package for statistical analysis following the quantification of the EMG data. A repeated measures analysis of variance (ANOVA) was performed using a two-way analysis of variance design with $\alpha = .05$ to determine the significant difference in EMG Scheffe's Post hoc test was performed to analyze the data. The subjects and sit-up type were used as independent variables. The % MVC, the dependent variable, was used in the calculations for each muscle group (REO, LEO, RIO, LIO, URA, and LRA). Standard deviation for each muscle group and mean % MVC for each muscle group and abdominal exercise were also calculated.

Table 1. Origin, insertion, and action of selected muscles.

Muscle	Origin	Insertion	Action	Innervation
External Oblique	Ribs 5-12	Linea Alba, Pubic Tubercle, Anterior ½ of Iliac Crest	Rotates Trunk to the Opposite Side, Lateral Trunk Flexion, Trunk Flexion (Bilaterally)	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal
Internal Oblique	Lumbar Fascia, Anterior 2/3 of the Crest of the Ilium, Inguinal Ligament	Lower Anterior Ribs 10-12, Linea Alba	Rotates Trunk to the Same Side, Lateral Trunk Flexion, Trunk Flexion (Bilaterally)	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal
Rectus Abdominis	Pubic Symphysis, Pubic Crest	Xiphoid, Costal Cartilages of Ribs 5-7	Trunk Flexion	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal
Transversus Abdominis	Ribs 7-12, Lumbar Fascia, Crest of Ilium, Inguinal Ligament	Linea Alba, Pubic Crest	Compresses Abdominal Contents	Intercostals T7-T12 & L1, Iliohypogastric, Ilioinguinal

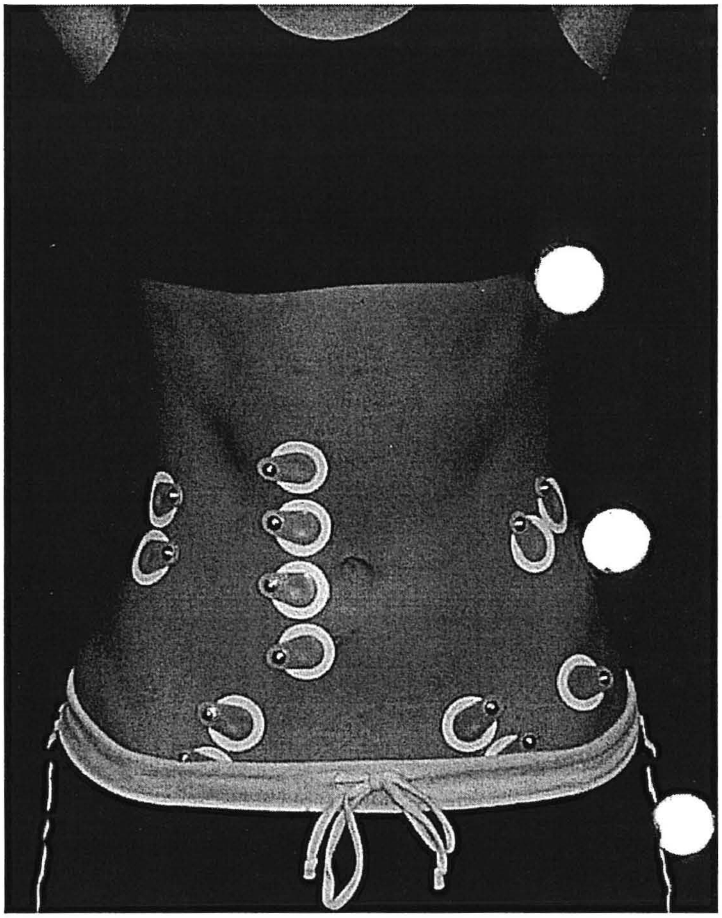


Figure 1. Electrode placement for trunk muscles.

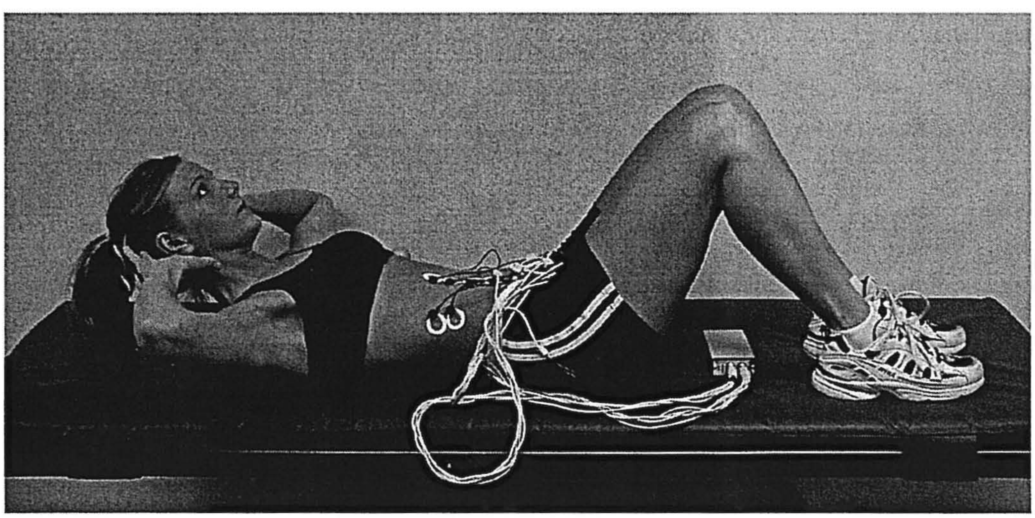


Figure 2. Maximal Voluntary Contraction

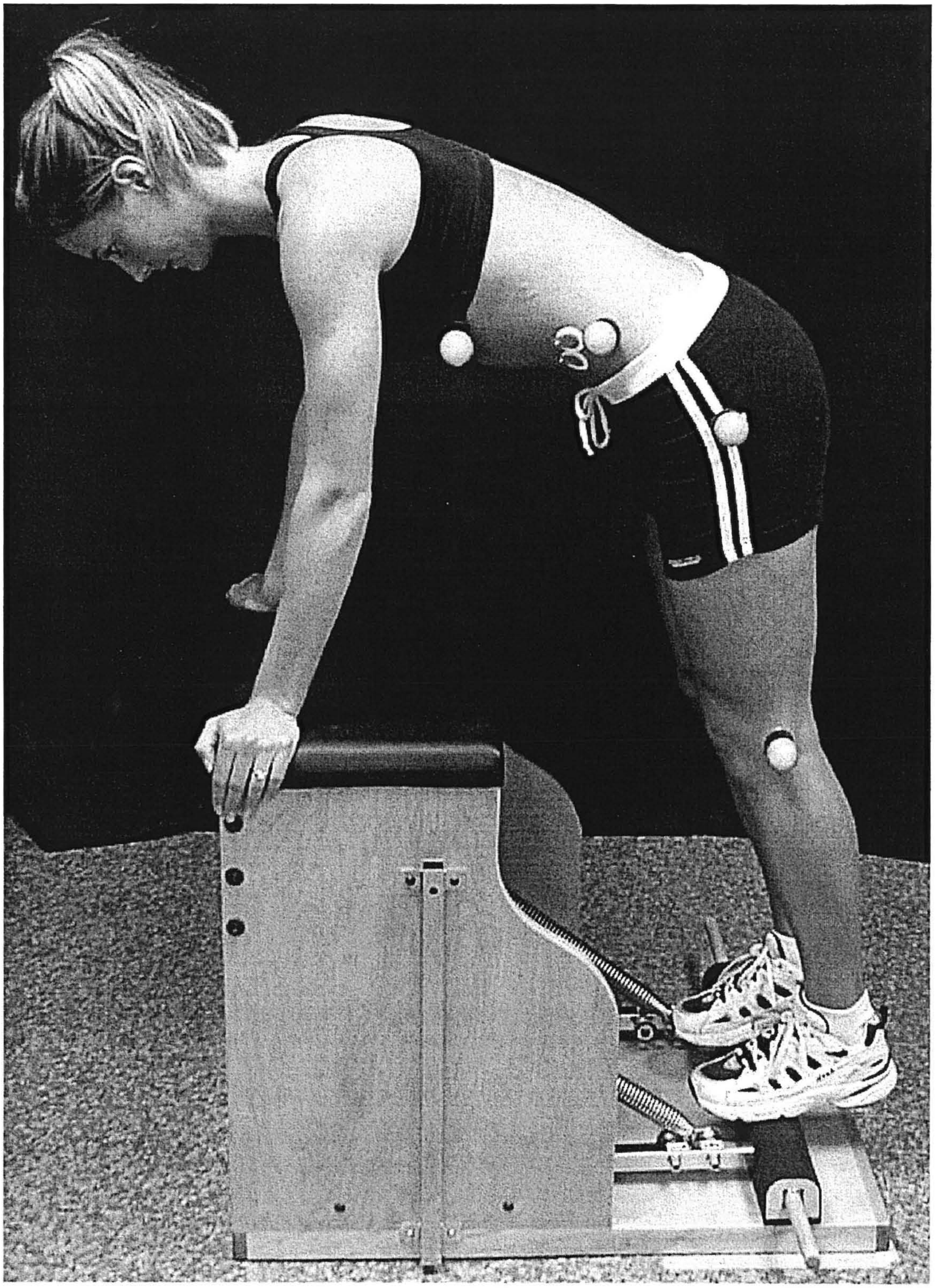


Figure 3. Start position for Pilates Sagittal exercise.

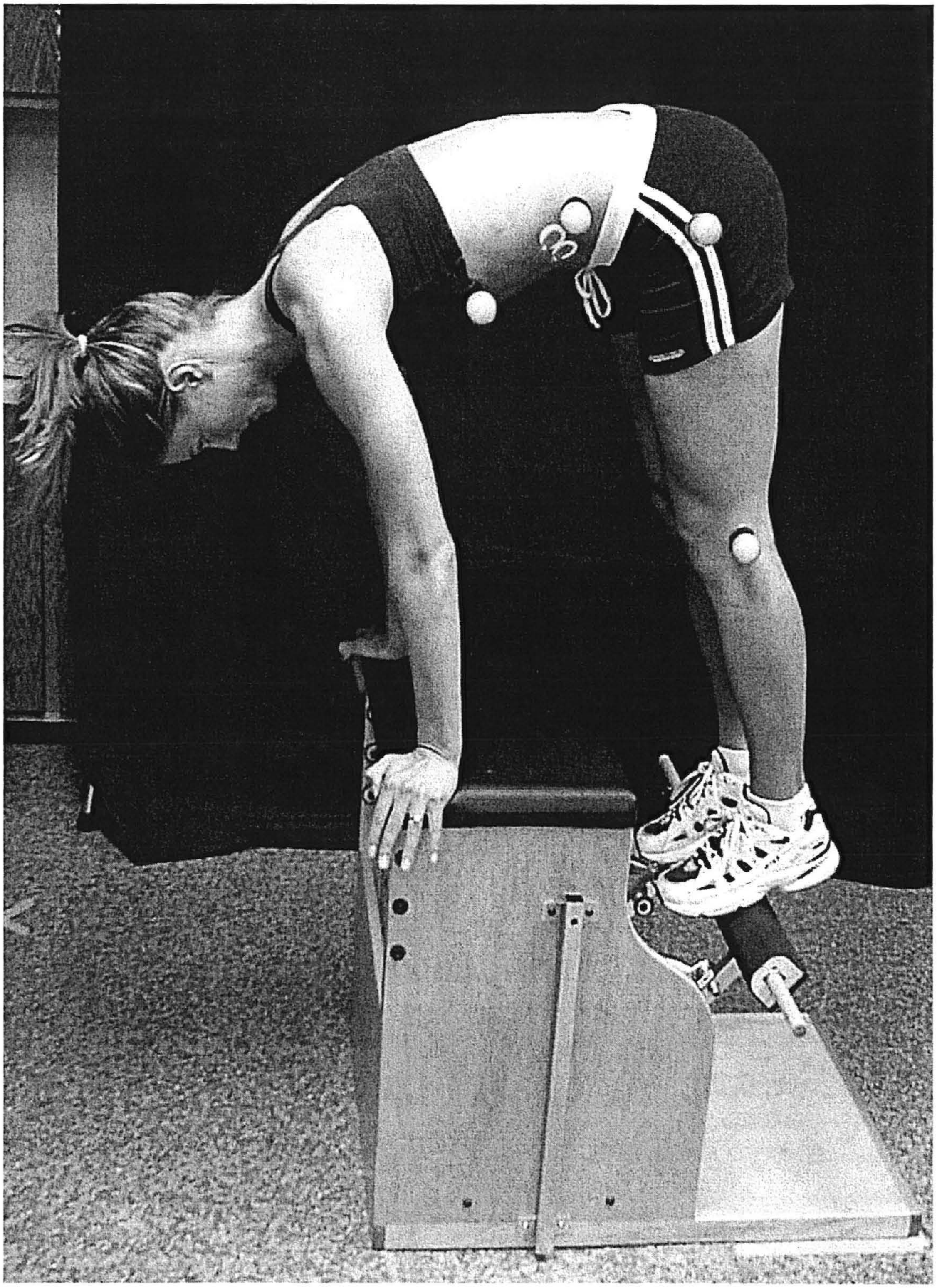


Figure 4. End position for Pilates Sagittal exercise.

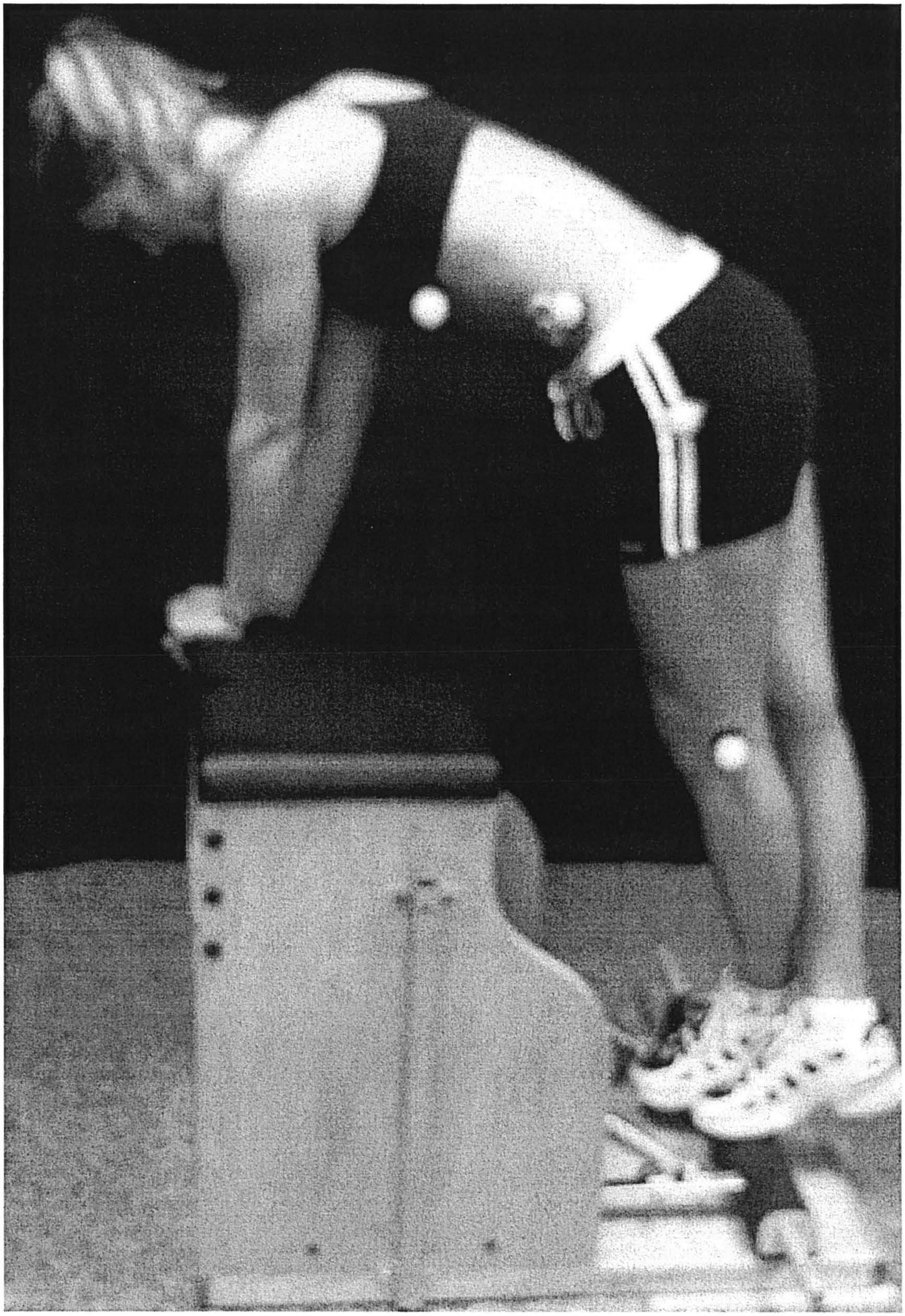


Figure 5. Start position for Pilates Oblique exercise.

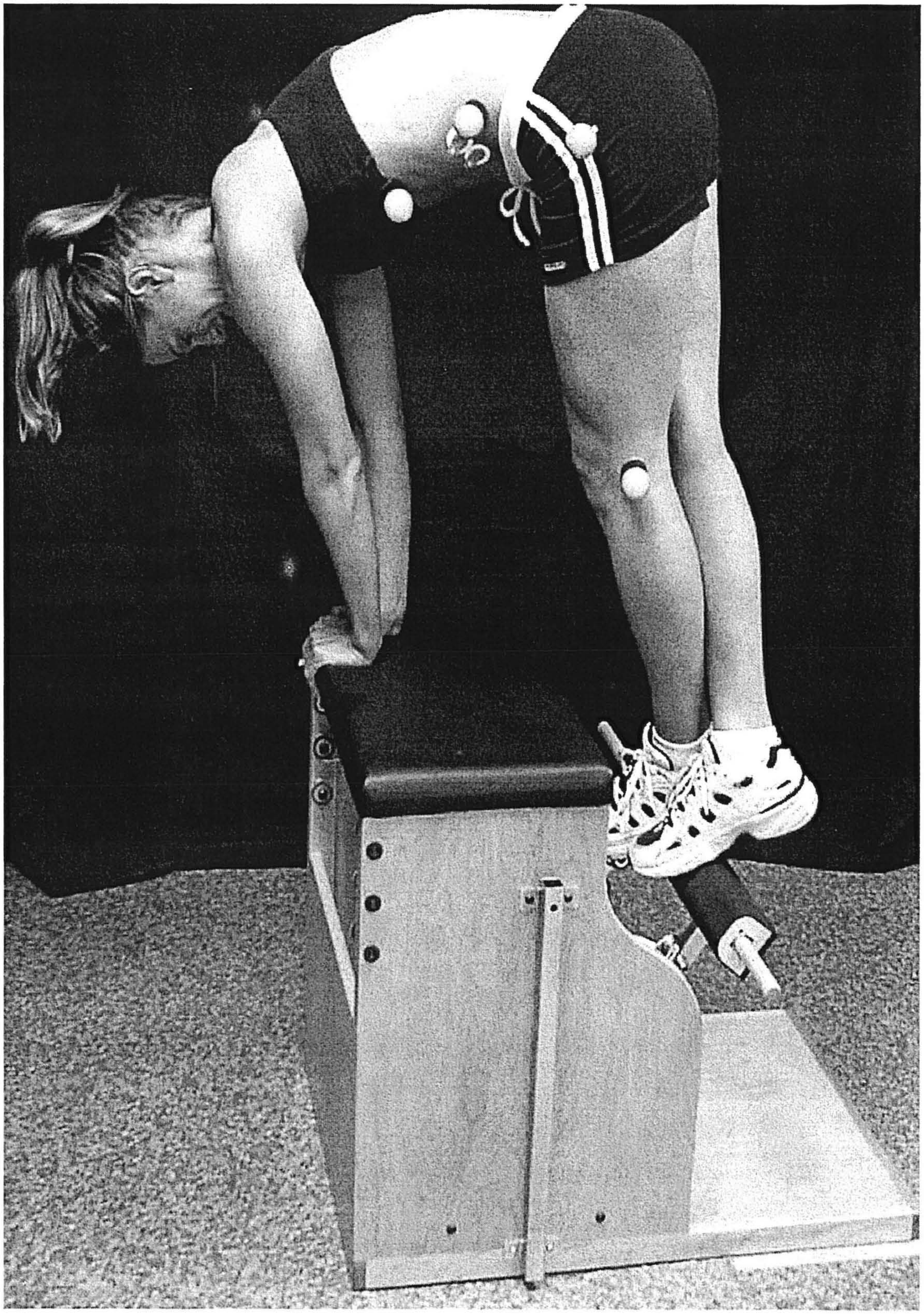


Figure 6. End position for the Pilates Oblique exercise.

Figure 7.
Start position
for both ball crunch
exercises.

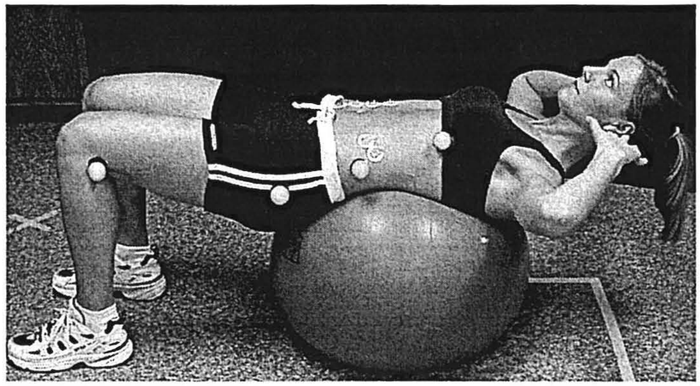


Figure 8.
End position for the
Sagittal Ball Crunch
exercise.

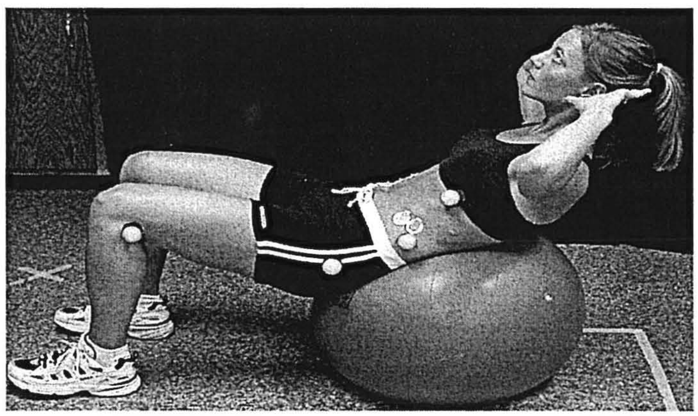
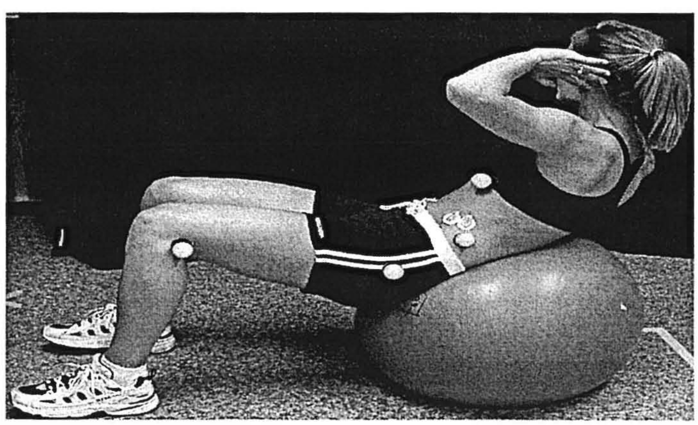


Figure 9.
End position for the
Oblique Ball Crunch
exercise.



CHAPTER IV

RESULTS

The number of subjects reported, means, standard deviations, and the ANOVA results are summarized in Table 1. When analyzing each muscle separately, there was no significant difference in % MVC among the REO, RIO, and LIO during the Pilates Oblique, Pilates Sagittal, Sagittal Ball Crunch, and Oblique Ball Crunch exercises. However, the LEO, URA, and LRA demonstrated significant differences among exercise types.

Right External Oblique:

The REO was most active during the Pilates Sagittal exercise, and it was the least active during the Oblique Ball Crunch exercise (Mean values in Table 2)

Left External Oblique:

There is a significant difference in LEO EMG activity between exercise types. Post hoc analysis demonstrated a significant difference between the Pilates Sagittal and the Sagittal Ball Crunch exercises (Figure 10). The EMG activity of the LEO was highest during the Pilates Sagittal exercise compared to the Sagittal Ball Crunch which had the lowest EMG activity. (Means and significance values in Table 2)

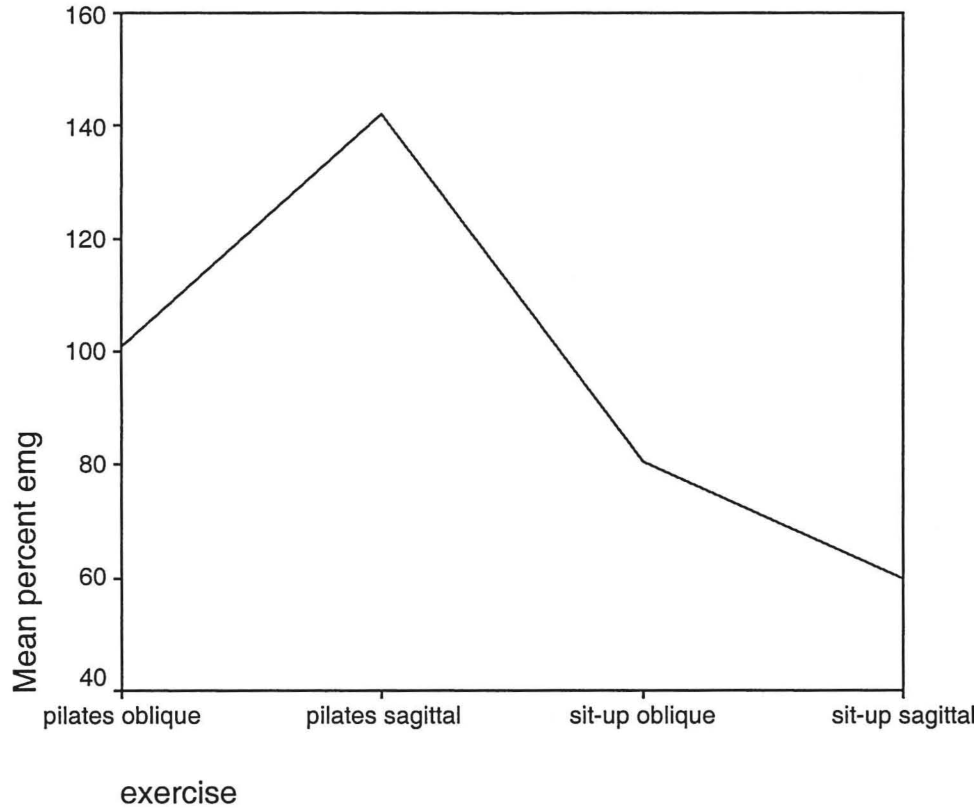


Figure 10. Mean EMG of LEO by exercise type.

Right Internal Oblique:

The RIO was most active during the Oblique Ball Crunch exercise, and it was least active during the Pilates Oblique exercise. (Means in Table 2)

Left Internal Oblique:

The LIO was most active during the Pilates Sagittal exercise and least active during the Pilates Oblique exercise (Means in Table 2).

Upper Rectus Abdominis:

There was a significant difference in URA EMG activity between exercise types. Post hoc analysis demonstrated a significant difference between the Pilates Sagittal and

Sagittal Ball Crunch exercises (Figure 11). The EMG activity of the URA was higher during the Sagittal Ball Crunch compared to the Pilates Sagittal exercise. Post hoc analysis demonstrated a significant difference between the Oblique Ball Crunch and the Pilates Sagittal exercises with EMG activity higher during the Oblique Ball Crunch exercise. In addition, the post hoc analysis showed a significant difference between the Pilates Oblique and the Oblique Ball Crunch as the EMG activity was higher during the Oblique Ball Crunch. Finally, a significant difference was shown between the Pilates Oblique and the Sagittal Ball Crunch, with the EMG activity higher during the Sagittal Ball Crunch (Means in Table 2).

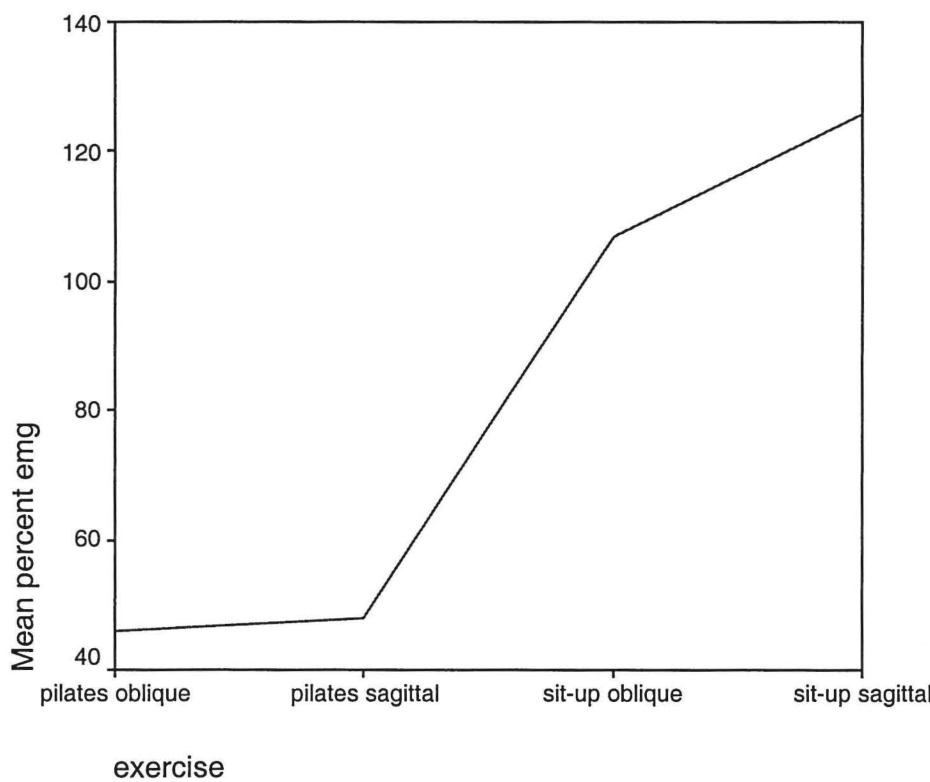


Figure 11. Mean EMG of the URA by exercise type.

Lower Rectus Abdominis:

There was a significant difference in LRA EMG activity between exercise types. Post hoc analysis demonstrated a significant difference between the Pilates Sagittal and Sagittal Ball Crunch exercises (Figure 12). The EMG activity of the LRA was higher during the Sagittal Ball Crunch compared to the Pilates Sagittal exercise. Post hoc analysis demonstrated a significant difference between the Oblique Ball Crunch and the Pilates Sagittal exercises with EMG activity higher during the Oblique Ball Crunch exercise.

In addition, the post hoc analysis showed a significant difference between the Pilates Oblique and the Oblique Ball Crunch as the EMG activity was higher during the Oblique Ball Crunch. Finally, a significant difference was shown between the Pilates Oblique and the Sagittal Ball Crunch, with the EMG activity highest during the Sagittal Ball Crunch (Means in Table 2).

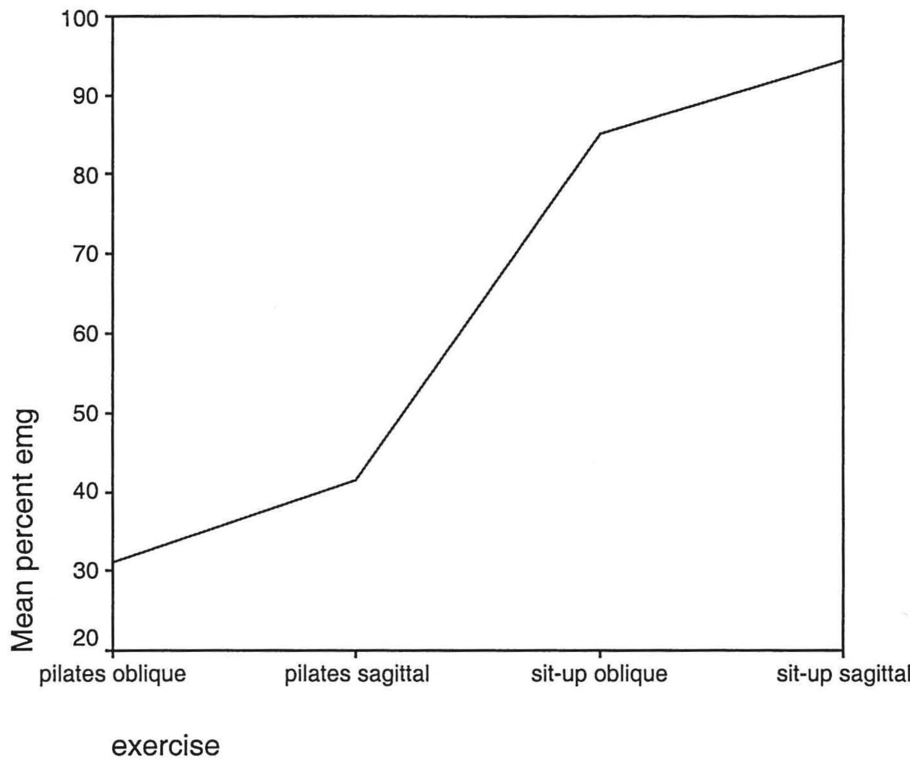


Figure 12. Mean EMG of LRA by exercise type.

Table 2. 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	p*	Partial η^2
Right External Oblique	Pilates Oblique	13	99.85	82.86	3,34	2.64	.065	.189
	Pilates Sagittal	11	105.82	64.89				
	Oblique Ball Crunch	13	56.62	23.52				
	Sagittal Ball Crunch	13	66.92	31.68				
Left External Oblique	Pilates Oblique	14	100.64	89.38	3,37	4.19	.012[a]	.254
	Pilates Sagittal	12	142.08	126.72				
	Oblique Ball Crunch	14	80.43	68.04				
	Sagittal Ball Crunch	14	60.00	20.56				
Right Internal Oblique	Pilates Oblique	14	58.07	22.12	3,38	1.50	.23	.106
	Pilates Sagittal	13	68.85	20.99				
	Oblique Ball Crunch	14	70.00	22.50				
	Sagittal Ball Crunch	14	66.50	23.31				
Left Internal Oblique	Pilates Oblique	13	64.00	38.59	3,35	.32	.813	.026
	Pilates Sagittal	12	73.50	28.52				
	Oblique Ball Crunch	13	68.69	24.49				
	Sagittal Ball Crunch	13	72.92	29.75				
Upper Rectus Abdominis	Pilates Oblique	13	46.08	24.77	3,37	28.20	.00[b]	.70
	Pilates Sagittal	13	48.00	28.09				
	Oblique Ball Crunch	14	106.79	36.01				
	Sagittal Ball Crunch	14	125.86	50.35				
Lower Rectus Abdominis	Pilates Oblique	13	31.08	29.54	3,36	17.12	.00[c]	.59
	Pilates Sagittal	12	41.33	31.93				
	Oblique Ball Crunch	14	85.07	35.67				
	Sagittal Ball Crunch	14	94.50	44.34				

*$p \leq .05$ in all cases

Table 2 (continued). Means, standard deviations, and ANOVA summary table for differences in % MVC between abdominal exercises for each muscle group

[a]: Post Hoc analysis demonstrated a significant difference between Pilates Sagittal (PS) and Sagittal Ball Crunch (SBC). (Means in Table 2)

[b]: Post Hoc analysis demonstrated the following:

1. A significant difference between PS and SBC. (Means in Table 2)
2. A significant difference between PS and Oblique Ball Crunch (OBC). (Means in Table 2)
3. A significant difference between Pilates Oblique (PO) and OBC. (Means in Table 2)
4. A significant difference between PO and SBC. (Means in Table 2)

[c]: Post Hoc analysis demonstrated the following:

1. A significant difference between PS and SBC. (Means in Table 2)
2. A significant difference between PS and Oblique Ball Crunch (OBC). (Means in Table 2)
3. A significant difference between Pilates Oblique (PO) and OBC. (Means in Table 2)
4. A significant difference between PO and SBC. (Means in Table 2)

CHAPTER V

DISCUSSION

Although there was no significant difference in the right external oblique % MVC between the exercises, the right external oblique produced the highest mean % MVC during the Pilates Sagittal exercise. This was expected due to the fact that the oblique exercise chosen did not incorporate left trunk rotation which is one of the main actions of the right external oblique.[10]

The significant difference found in the left external oblique between the Pilates Sagittal and the Sagittal Ball Crunch exercises was unexpected. In addition, the EMG activity was higher in the Pilates Oblique than either of the ball exercises, however, the difference was not significant. The researchers presumed LEO EMG activity would be highest during an oblique exercise incorporating right trunk rotation. This significant difference between the Pilates Sagittal and Sagittal Ball Crunch exercises could have been due to an increased need for stability in the "pike" position of the Pilates Multi-Chair. The "pike" position raises the body's center of gravity as compared to the ball activities. Thus, the external oblique muscle may need to be more active to compensate for any rotary forces. As expected (due to the anatomical orientation), there was higher EMG activity in the Oblique Ball Crunch as compared to the Sagittal Ball Crunch due to the rotary nature of the oblique exercise; yet, this difference was not significant.

When looking at the external obliques together, our study results demonstrated higher EMG activity during Pilates machine exercises as compared to either ball crunch exercise. These results agreed with other studies that found higher EMG activity of the external obliques in exercises initiated in the lower extremities as compared to curl-up/crunch exercises.[19, 20] Previous research by Vera-Garcia et al[18], demonstrates higher % EMG activity of the external obliques during exercises performed on labile surfaces (i.e. Swiss ball). To the best of our knowledge, there are currently no studies analyzing abdominal muscle activity during the use of Pilates machines to compare with our study.

No significant difference in EMG data was found in either the right or left internal oblique muscles among the abdominal exercises. The EMG data was closely distributed among the four exercises. According to Beith et al,[15] increased activity of the internal oblique was noted when the abdominal hollowing maneuver/ "B-line" exercise was performed. In our study, higher EMG activity was expected in the internal obliques during the two Pilates exercises due to the "B-line" contraction of the internal obliques and transversus abdominis. Inexperience and unfamiliarity of the participants in performing this maneuver could have contributed to these results. In addition, the spinal stabilizing nature of the internal obliques and transversus abdominis could have led to minimal variation of EMG activity among exercises.

Post hoc results showed similar mean % EMG for the upper and lower rectus abdominis. These results would agree with Lehman and McGill[19] who found that there was no significant difference between the upper and lower rectus across various abdominal exercises.

When comparing the four abdominal exercises, both ball exercises showed higher % EMG activity than the Pilates exercises. The Sagittal Ball Crunch was found to have higher EMG activity when compared to the Oblique Ball Crunch, but the difference was not significant. Less rectus abdominis EMG activity was noted in the Pilates activities. This again agrees with Willett et al [21] who found minimal rectus activity with the vacuum exercise (another name for "B-line" exercise). The decreased activity of the upper and lower rectus abdominis during Pilates activities would be expected because as the external obliques increase their activity, the force that the rectus abdominis would need to exert would be decreased.

Limitations and Future Recommendations:

There were several limitations to our study. First, the subjects were gathered through convenient sampling as opposed to random sampling of the population. The majority of the subjects were young and healthy. However, a random sampling of the population may have produced a more accurate statistical analysis. In addition, a larger number of subjects (> 30 subjects) may also have yielded a better statistical representation. Another limitation of the study may have been the subject's unfamiliarity with the "B-Line" contraction, Pilates breathing techniques, and Pilates Multi-Chair. Subjects had two mandatory training sessions prior to testing, but additional training periods may have made the subjects more accustomed to the principles and prepared for Pilates testing.

Skin and fat increase the impedence and reduce the recorded EMG signal levels.[22] Taking skin fold measurements prior to testing may help eliminate subjects with excessive subcutaneous tissue. The internal oblique is deep to other musculature and is difficult to reach with the use of surface EMG. Using fine wire electrodes would have been more accurate with EMG readings for the IO and would have possibly allowed for reading from the transversus abdominis. Furthermore, previous studies have shown delayed EMG onset of the transversus abdominis in subjects with low back pain when compared to healthy subjects.[13,14] An added recommendation would be to study subjects with low back pain/injury and analyze the timing of all abdominal muscular contractions in addition to using mean % EMG.

Clinical Implications:

This study introduced several key clinical implications. When desiring to target the upper and lower rectus abdominis, the crunch on ball exercises appear to elicit greater EMG activity. However, if the external obliques are the muscles desired to target, using the Pilates Multi-Chair in a sagittal or oblique orientation should produce higher EMG activity. The use of the Pilates Multi-Chair also allows clinicians to recruit the stabilizing oblique muscles without overuse of the rectus abdominis. This could be useful for clinicians when working with clients who have low back pain.

The internal obliques appeared to play a stabilizing role due to the consistency of the EMG activity among all four exercises. As mentioned above, due to the use of surface electrodes, we were unable to accurately measure the transversus abdominis. Therefore, clinical implications cannot be made from this study regarding the use of the "B-line" or abdominal hollowing maneuver in conjunction with other abdominal exercises.

Clinicians who choose to implement the Pilates Multi-Chair and methods must be aware of the need for client training in the "B-line" contraction, proper form and breathing, and Pilates equipment. Clinicians also need to be cognizant of the substantial price of the Pilates equipment and weigh the benefits along with the costs.

Conclusion:

The mean % MVC was highest for the external obliques during the Pilates exercises with a significant difference in the left EO between the Pilates Sagittal and Sagittal Ball Crunch exercises. Thus, Pilates exercises using the Multi-Chair would be more beneficial for recruiting the external oblique muscles.

There was no significant difference among the four exercises when analyzing the mean % MVC of the internal obliques, and EMG data was closely distributed. Further research possibly using fine wire electrodes would provide more accurate analysis of the deep abdominal muscles (internal obliques and tranversus abdomisis).

The mean % MVC was highest for the upper rectus abdominis and lower rectus abdominis for the sagittal and oblique ball crunch exercises. Significant differences were found between the following: Sagittal Ball Crunch and Pilates Sagittal exercises, Oblique Ball Crunch and Pilates Sagittal exercises, Oblique Ball Crunch and Pilates Oblique exercises, and Sagittal Ball Crunch and Pilates Oblique exercises. The results of this study verify the traditional belief that ball crunch exercises effectively recruit the upper and lower rectus abdominis. Furthermore, this study enhances existing research by demonstrating the Pilates Multi-Chair to be more effective in recruiting the external obliques and internal obliques without a corresponding increase in rectus abdominis muscle activity. Clinicians may find this information useful to target specific muscles for spinal stabilization rehabilitation in various client populations.

APPENDIX

University of North Dakota Human Subjects Review Form

Please Note: The policies and procedures of the University of North Dakota apply to all activities involving the use of Human Subjects performed by faculty, staff and students 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 procedure governing the use of human subjects. When preparing your Human Subjects Review Form, use the attached "IRB Checklist".

Please provide the information requested below:

Principal Investigator: Kelly Almquist, Ember Bopp, Chet Yoder, Mark Romanick

Telephone: (701)777-2831 Address: Box 9037 Physical Therapy Department

E-mail address: mromanic@medicine.nodak.edu

School/College: Univeristy of North Dakota Department: Physical Therapy

Student Adviser (if applicable): Mark Romanick

Telephone: (701)777-2831 Address: Box 9037, Physical Therapy Department

E-mail address: mromanic@medicine.nodak.edu

School/College: University of North Dakota Department: Physical Therapy

Project Title: EMG/Motion Analysis of mat abdominal exercises and Pilates machine exercises

Proposed Project Dates: Beginning Date: 3/22/02-12/20/02 Completion Date: 12/20/02

Funding agencies supporting this research:

(A copy of the funding proposal for each agency identified above MUST be attached to the proposal when submitted.)

___ YES or x___ NO Does the Principal Investigator or any researcher associated with this project have a financial interest in the results of this project? If yes, please submit on a separate piece of paper an additional explanation of the financial interest (other than receipt of a grant)

If your project has been or will be submitted to another Institutional Review Board (s), Please list those boards below along with the status of each proposal.

________________ Date Submitted: ___ Status: ___ Approved ___ Pending
________________ Date Submitted: ___ Status: ___ Approved ___ Pending

Type of Project: Please Check Yes or No to the following.

x___ YES or ___ NO New Project

___ YES or x___ NO Dissertation/Thesis

___ YES or x___ NO Continuation/Renewal

x___ YES or ___ NO Student Research Project

___ YES or x___ NO Protocol Change for previously approved project
(resubmit "Human Subjects Review Proposal" with changes bolded or highlighted and signed)

Cooperating Institution: HealthSouth

x___ YES or ___ NO **Will any institution of agency personnel assist in the Proposed Project?**
Copies of letters indicating the willingness of the institution/agency to cooperate in the study and an understanding of the study MUST be attached. Letters must include the name and title of the individual signing the letter and, if possible, should be printed on letterhead.

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

______Minors (<18 years)
______Prisoners
______Pregnant Women/Fetuses
______Persons with impaired ability to understand their involvement and/or consequences of participation in this research
__x__ UND Students
______Other ____.

For information about protections for each of the special populations please refer to the protected populations section on the Office of Research and Program Development website.

This study will involve: Check all that apply.

______New Drugs (IND)
______Non-approved Use of Drug(s)
______Recombinant DNA
______Fetal Tissue
______Stem Cells
______Other (Discarded tissue, fluids, blood, etc.)
__x__ None of the above will be involved in this study

I. Project Overview

Please provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as minors, prisoners, pregnant women/fetuses).

Abdominal strengthening has been shown to improve core stability and prevent or treat low back pain. Pilates is a system of exercises invented at the turn of the 20th century, focusing on dynamic core stabilization. Pilates trains muscles including the rectus abdominis, abdominal obliques, transverse abdominis, quadratus lumborum, back extensors and other deep postural trunk muscles.

This study will investigate the muscle recruitment of mat abdominal exercises compared to Pilates based machine exercises designed to exercise abdominal muscles. A total of 15-25 subjects between the ages of 18-45 are required for this study. All subjects will undergo a 1 time training period to provide instruction regarding the exercises to be performed prior to recorded EMG/Motion Analysis. Surface EMG electrodes will be placed on the abdominal musculature and computer read outs will be analyzed as the human subjects perform the instructed exercises.

The results of this study will add to the current body of knowledge regarding the use of abdominal strengthening exercises in improving core stability and in the prevention or treatment of low back pain.

II. Protocol Description

Please provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories. Individuals conducting clinical research please refer to the "Guidelines for Clinical-Research Protocols" on the Office of Research and Program Development website.

1. Subject Selection.

a) Describe recruitment procedures (i.e., how will subjects be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects.
The investigators will recruit subjects from the University of North Dakota and the surrounding area by written advertisements and by speaking with various classes on campus.

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the "Subject Classification" section above.

It is anticipated that we will recruit 15-25 subjects (both male and female) between the ages of 18-45. The subjects for this study will be recruited from university students. These subjects will participate voluntarily. These subjects will be chosen because of their age and health status. University of North Dakota students were chosen because they are readily accesible.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.
All subjects who are currently pregnant or those with current low back injury, cardiac problems, or abnormalities in blood pressure will be excluded from our study.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.
A total of 15-25 subjects are required for this study in order to decrease the risk of research error.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.
We chose to use 15-25 subjects in order to decrease risk of sample error. Due to accurate testing procedures and computer analysis, the study results will be valid.

2. Description of Methodology.

a) Describe the procedures used to obtain informed consent.
Informed consent will be obtained through an information and consent form (see attached form). All individuals participating in this study will be competent and independent in their decision-making and will sign the consent form in relation to participation in this study.

b) Describe where the research will be conducted.
HealthSouth
2617 Columbia Rd. S.
Grand Forks, ND 58201

c) Indicate who will carry out the research procedures.
Kelly Almquist, Ember Bopp, Chet Yoder, Mark Romanick

d) Briefly describe the procedures and techniques to be used and the time required to complete them.
During the trial, we will measure EMG activity using surface electrodes placed over the rectus abdominis, external oblique, and internal oblique. The precise electrode placement will be determined from standard electrode placement charts. Prior to placing the electrodes, the skin over each placement site will be prepared by cleansing the skin with alcohol. Video analysis will also be used to analyze trunk motion. Reflective markers will be attached to the trunk using double sided adhesive tape. Video cameras will be placed at the sides of the subject and will film the subject's motion. The data will then be to the computer for analysis. All subjects will initially complete a 1 time training period to provide instruction regarding the exercises to be tested prior to recorded EMG/Motion Analysis. Prior to beginning the experimental trial, each subject will be asked to elicit a maximal voluntary contraction from each muscle being monitored in the study. The exercises tested are then compared back to this maximal voluntary contraction. This procedure is done to normalize the EMG data for later analysis. The subject will perform no more than five abdominal exercises and testing should require no longer than 1 hour.

e) Describe audio/visual procedures and proper disposal of tapes.
The video tape will be used in conjuction with a computer to analyze markers placed on the subject's body and will construct a stickman like figure. The real photographic image will not be used when reporting findings of this study. All data, computer files and films, will be kept in a locked office in the Physical Therapy Department at the University of North Dakota and will be destroyed after three years.

f) Describe the qualifications of the individuals conducting all procedures used in the study.
Kelly Almquist, Ember Bopp, and Chet Yoder are all Senior Physical Therapy students from University of North Dakota. Mark Romanick is an instructor in the University of North Dakota Physical Therapy Department.

g) Describe compensation procedures (payment or class credit, etc.)
There will be no compensation received for participating in this study.

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.

3. **Risk Identification.**

a) Clearly describe the anticipated risks to the subject/others including any physical, emotional, and financial risks that might result from this study.
Pilates and abdominal mat exercises tested are commonly used forms of exercise in physical therapy clinics; consequently there is very minimal risk of personal injury. An example of this type of injury may be a slight muscular starin. However, as mentioned below, these risks will be minimized through proper warm-up, supervision, etc. The investigators expect no such injury to occur during the course of the study. All subjects who are currently pregnant or those with low back injury, cardiac problems, or abnormalities in blood pressure will be excluded from our study. Should a personal injury occur during exercise, the individual will be encouraged to seek prompt medical attention. All medical expenses will be the responsibility of the individual and his/her third party payer.

b) Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).
This risk will be minimized by proper instruction, warm-up and supervision. All principle investigators will be present for the study administering continuous supervision in all phases of the study. In addition, all subjects will be informed that they may stop the activity at any time

c) Indicate whether there will be a way to link subject responses and/or data sheets to consent forms, and, if so, what the justification is for having that link.
There will be no way to link subject response to the data/consent forms; the participants will be assigned a random identification number at the start of the project.

4. **Subject Protection**

a) Describe procedures you will implement to protect confidentiality (such as coding subject data, removing identifying information, reporting data in aggregate form, etc.).
The information obtained for this study will be kept confidential. The subjects' names and personal information will not be revealed at any time throughout the study. A hard copy of statistics of this study will be secured in a locked office in the Physical Therapy Department at the University of North Dakota. Unless these records are required for future studies they will be destroyed three years after the study has ended.

b) Indicate that the subject will be provided with a copy of the consent form and how this will be done.
The subject will be asked to sign a consent form prior to testing and will be given a copy of the consent form upon

request.

c) Describe the protocol regarding record retention. Please indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study. The information obtained for this study will be kept confidential. The subjects' names and personal information will not be revealed at any time throughout the study. A hard copy of statistics of this study will be secured in a locked office in the Physical Therapy Department at the University of North Dakota. The consent forms and data will be stored separately. Access to the data from the study will only be accessible to the principle investigators. Unless these records are required for future studies they will be destroyed three years after the study has ended. The data and consent forms will be shredded and the tapes will be erased.

Describe: a) the storage location of research data (separate from consent forms and subject personal data)
b) who will have access to the data
c) how the data will be destroyed
d) the storage location of consent forms and personal data (separate from research data)
e) how the consent forms will be destroyed

d) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma etc.). Should an adverse reaction occur during the testing, the subject will be asked to stop the exercise. All investigators are CPR certified. Medical treatment will be available including first aid, emergency treatment and follow-up care as it to a member of the general public in similar circumstances.

e) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.
. Should a personal injury occur during exercise, the individual will be encouraged to seek prompt medical attention. All medical expenses will be the responsibility of the individual and his/her third party payer.

III. Benefits of the Study

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). **Please note:** payment is not a benefit and should be listed in the Protocol Description section under Methodology.

The effects of this study will add to the current body of knowledge regarding spinal core stabilization and will specifically determine the recruitment of abdominal muscles using Pilates machines and abdominal mat exercises. Minimal scientific research exists relating the effects of Pilates on core stabilization. The goal of this study is to provide further information and create awareness of Pilates techniques as an additional means of core strengthening and injury prevention.

Further benefits for the subjects include knowledge and training in the proper form of mat abdominal exercises and Pilates machine exercises

IV. Consent Form

A copy of the Consent Form must be attached to this proposal. If no Consent Form is to be used, document the procedures to be used to protect human subjects. Refer to the ORPD website for further information regarding Consent Form Regulations.

See Attatched

Please note: Regulations require that all Consent Forms, and all pages of the Consent Forms, be kept for a minimum of 3 years after the completion of the study, even if subject does not continue participation. The Consent Form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. It is recommended that the Consent Form be written in the third person (please see the examples on the ORPD website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp. The consent form must include the following elements:

a) An introduction of the principal investigator

b) An explanation of the purposes of the research.

c) The expected duration of subject participation.

d) A brief summary of the project procedures.

e) A description of the benefits to the subject/others anticipated from this study

f) A paragraph describing any reasonably foreseeable risks or discomforts to the subject.

g) Disclosure of any alternative procedures/treatments that are advantageous to the subject

h) A description of how confidentiality of subjects and data will be maintained. Indicate that the data and consent forms will be stored separately for at least three years following the completion of the study. Indicate where, in general, the data and consent documents will be stored and who has access. Indicate how you will dispose of the data. Be sure to list any mandatory reporting requirements that may require breaking confidentiality.

i) An explanation of compensation/medical treatment available if injury occurs

j) The names, telephone numbers and addresses of two individuals to contact for information (generally the student and student adviser). This information should be included in the following statement: "If you have questions about the research, please call (insert Principal Investigator's name) at (insert phone number of Principal Investigator)or (insert

Adviser's name) at (insert Adviser's phone number). If you have any other questions or concerns, please call the Office of Research and Program Development at 777-4279."

k) If applicable: an explanation of who to contact in the event of a research-related injury to the subject.

l) If applicable: an explanation of financial interest must be included.

m) RE: Participation in the study:

1) An indication that participation is voluntary and that no penalties or loss of benefits will result from refusal to participate.

2) An indication that the subject may discontinue participation at any time without penalty with an explanation of how they can discontinue participation.

3) An explanation of circumstances which may result in the termination of a subject's participation in the study.

4) A description of any anticipated costs to the subject.

5) A statement indicating whether the subject will be informed of the findings of the study.

6) A statement indicating that the subject will receive a copy of the Consent Form.

By signing below you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

____ Date: ____________________________

(Principal Investigator)

____ Date: ____________________________

(Student Advisor)

Requirements for submitting proposals:

Additional information can be found at Office of Research and Program Development website at www.und.nodak.edu/dept/orpd

Original Proposals and all attachments should be submitted to: Office of Research and Program Development (ORPD), P. O. Box 7134, Grand Forks, ND 58202-7134, or drop off at Room 105, Twamley Hall.

The criteria for determining what category your proposal will be reviewed as is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require Full Board review, you will need to provide additional copies. Further information can be found on the ORPD website regarding required copies and IRB review categories or you may call the ORPD office.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Please Note: Student Researchers must complete the attached "Student Consent to Release of Educational Record".

Federal regulations require that key personnel involved in human subject research complete educational training. The UND IRB has chosen an online educational course, which can be found at www.miami.edu/citireg, for this training. The online Educational Modules must be completed before approval is granted for a proposal. In addition, Principal Investigators must provide a list of the key personnel involved in the project to ORPD, so the office can maintain records of those individuals that have completed training.

Revised 7/27/2001

Information and Consent Form

An EMG/Motion Analysis of mat abdominal exercises and Pilates machine exercises

Principal Investigators: Kelly Almquist, Ember Bopp, Chet Yoder, and Mark Romanick from the Department of Physical Therapy at the University of North Dakota

You are being invited to participate in this study of abdominal muscle activity during mat and Pilates machine exercises. The purpose of this study is to determine which exercises best recruit the abdominal muscles and at what stage of the exercise this recruitment occurs. We hope that the results of this study will aid physical therapists in choosing the proper abdominal strengthening exercises for core strengthening and the care and prevention of low back injury. We also hope to further determine the necessity for Pilates machines as compared to traditional or Pilates mat exercises.

You were chosen because: 1) your age (18-45 y/o) 2) you lack a history of cardiac problems, current low back injury, or blood pressure abnormalities and have stated you are not pregnant. If a subject is unable to complete the exercises this will result in exclusion from the study.

As a subject for this study, you will be asked to report to the HealthSouth facility located at 2617 Columbia Road. You will be required to complete 2-3 training sessions prior to the testing. During these training sessions you will be instructed in how to do the exercises, the exercises will be demonstrated to you, and you will be supervised as you perform the exercises. During the actual testing procedure, your age, height, and weight will be recorded. The exercises to be monitored will be demonstrated and practiced prior to data collection. Following this, you will be asked to lift up your shirt to allow for application of electrodes and reflective markers. This may involve some clipping of excess hair and cleaning of the area with an alcohol swab. Electrodes will be placed over the rectus abdominis, external and internal obliques.
The electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your trunk. Your muscle activity and movement will be monitored and cameras will be filming your activity. You will be asked to perform 2-5 different exercises and the testing should take no longer than one hour.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that, because of your lack of risk factors and close supervision and training, the risk of injury or discomfort is minimal. Minor muscle soreness may result following the repeated activity. However, to minimize this, you will be taken through a brief warm-up during the practice sessions and also prior to the testing procedure.

Your name will not be used in any reports of the results of this study. The real photographic image will not be used when reporting findings of this study. 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 and consent forms will be stored separately for 3 years in locked files. The Student advisor will have access to the data. The data will be identified by a number known only to the investigators. The investigators 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 at the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigators involved are available to answer 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 contacting the following:

Mark Romanick
(701) 777-2831
c/o Physical Therapy Dept
PO box 9037
Grand Forks ND 58202

Ember Bopp or Kelly Almquist
(701) 777-9366
917 Northwestern Dr.
Grand Forks ND 58203

If you have any other questions or concerns, please call the Office of Research and Program Development at (701) 777-4279. At your request, you will be given a copy of this form and/or the study results.

In the event that this research activity results in a physical injury, medical treatment will be as available as it is to a member of the general public in similar circumstances. You and you third party payer must provide payment for any such treatment.

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. I have read all of the above and willingly agree to participate in this study as it is explained to me by Kelly Almquist, Ember Bopp or Chet Yoder.

____

Subject's signature   Date

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