Pilates –
A Biomechanical Approach

Enja Schenck

Biomechanics, Dr. Leung

Flow chart

The Hundred MAT

- Movement components
- Mechanical objective

The Hundred REFORMER

Torque

5 biomechanical principles

Comparison study

The Teaser MAT

- Movement components
- Mechanical objective

2 biomechanical principles &
1 impeding factor

The Teaser CADILLAC

2 comparison studies

EXTERNAL FORCES

Footwork REFORMER

- Movement components
- Mechanical objective
- Load measuring

Biomechanical study

INTERNAL TORQUE

Pilates principle: Centering

- Introduction

3 biomechanical studies


Pilates at 57


Pilates at 82

The Hundred

The Hundred

- **4 movement components:**
  - Isometric trunk flexion
  - Isometric hip flexion
  - Rapid upper limb movement in sagittal plane
  - Deep breathing with forced exhalations

The Hundred

Movement objective:

1.) Maximum effort –
Lengthening of moment
arm to maximal point
of challenge

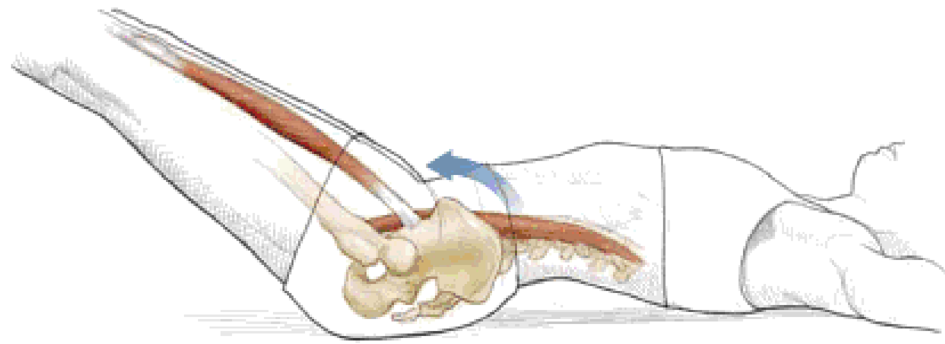
2.) Balance – maintaining stability

The Hundred

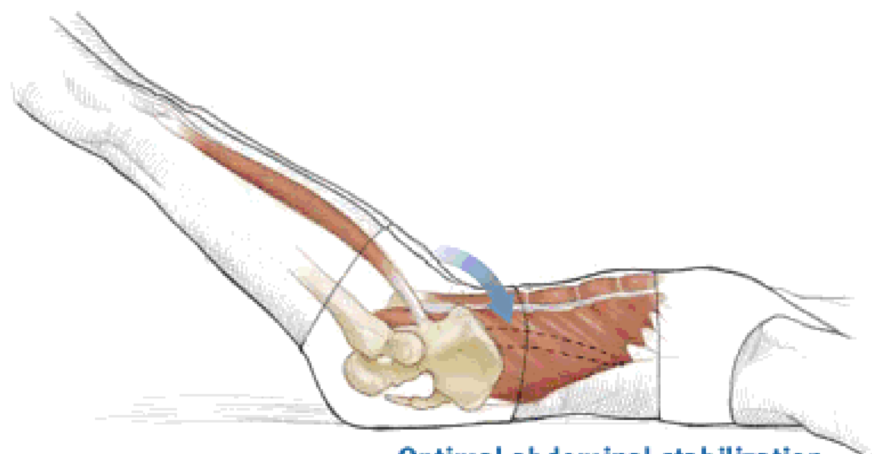
- **Mechanical Objective:**
  Angular torque
  equilibrium

- Newton's 3rd law of motion "**each action force has an opposing reaction force**" is the kinetic equivalent to the term *equilibrium* in kinematics.

Hip flexor torque



Inadequate abdominal stabilization.

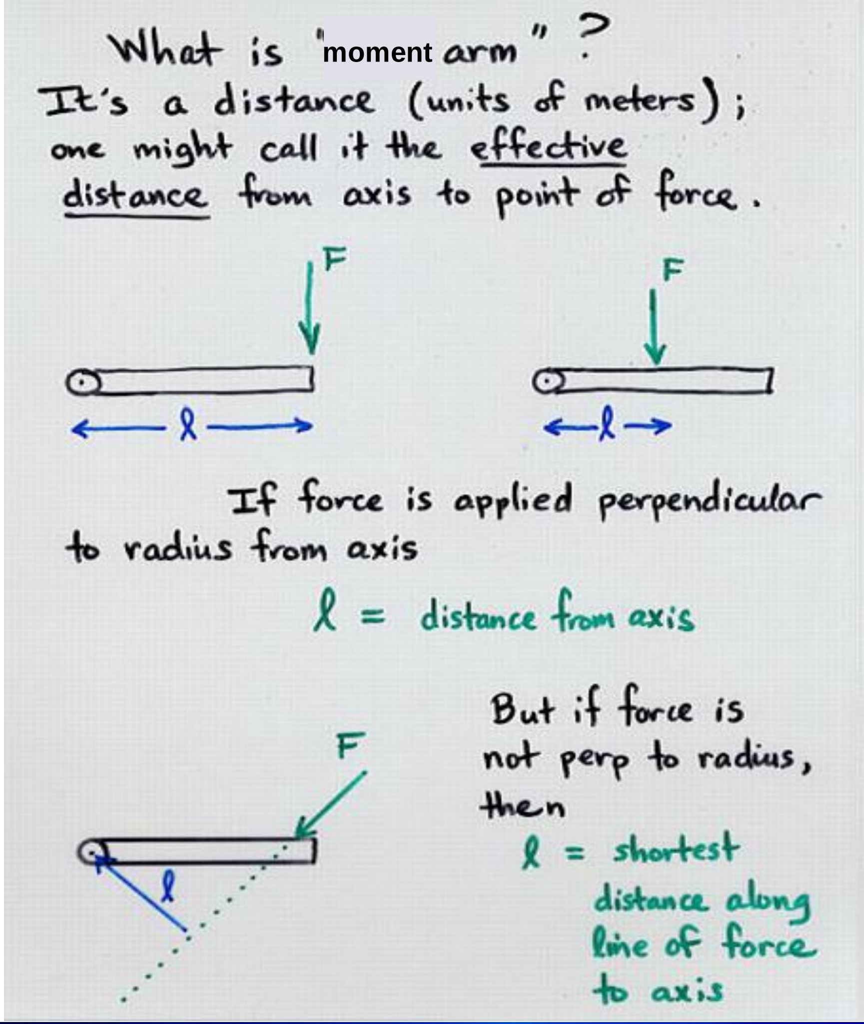


Optimal abdominal stabilization.

Torque

- **Torque is the angular equivalent of linear force.**
- It is a force applied over a distance (lever arm) that causes rotation about a fulcrum (axis of rotation).
- Torque is dependent on the amount of force, angle of application of force, and moment arm.
- Greatest Torque/Moment Arm = Force applied at 90 degree angle to its lever.

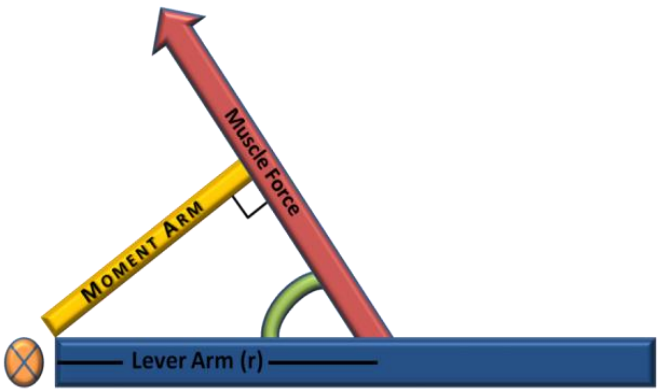
Biomechanical principles: 1) Moment arm

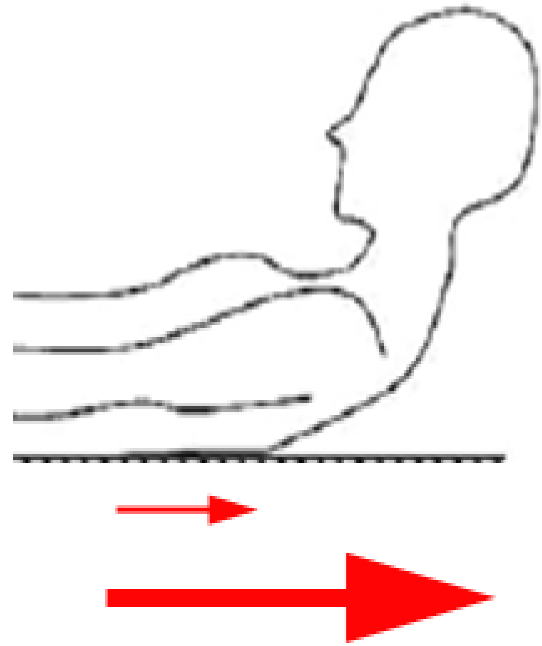


Biomechanical principles: 1) Moment arm

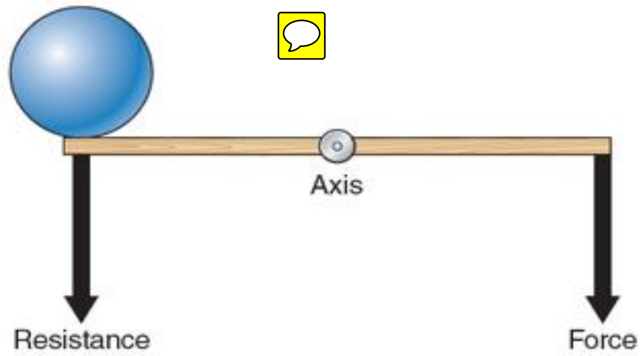
MOMENT ARM

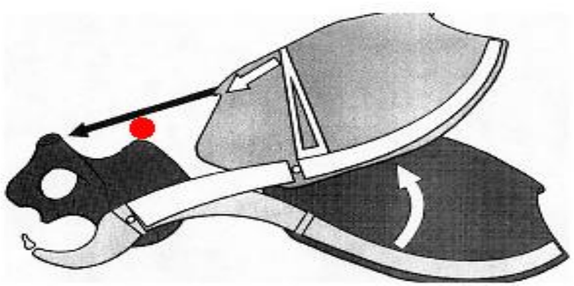
= THE PERPENDICULAR DISTANCE FROM AN AXIS TO THE LINE OF ACTION OF A FORCE



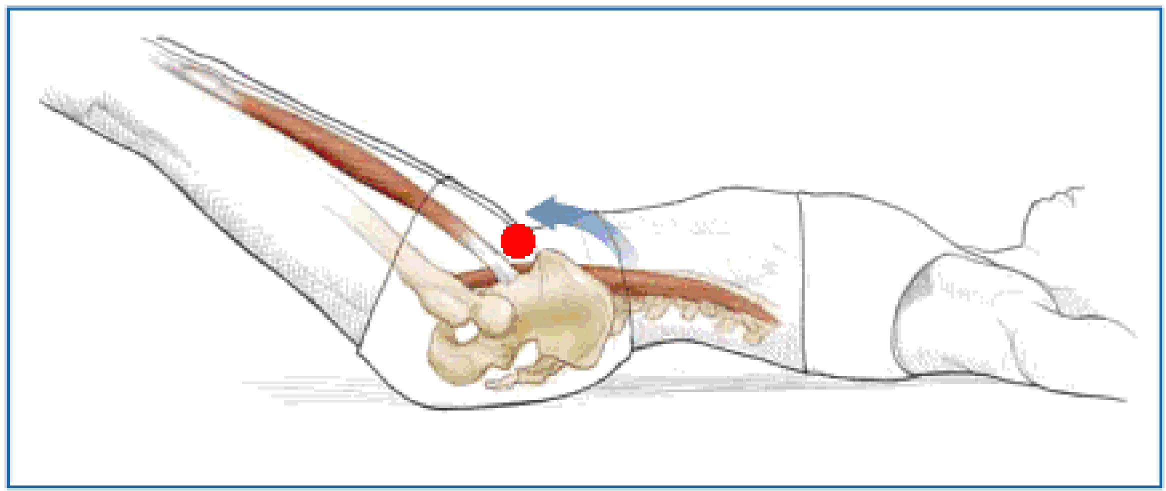


Biomechanical principles:
2) Levers





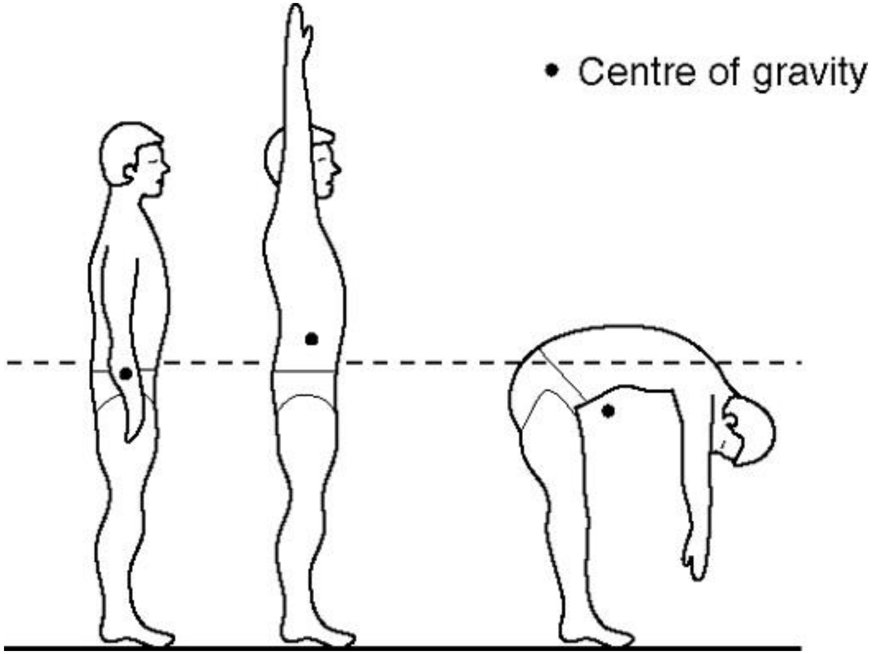
Trunk flexion



Hip flexion

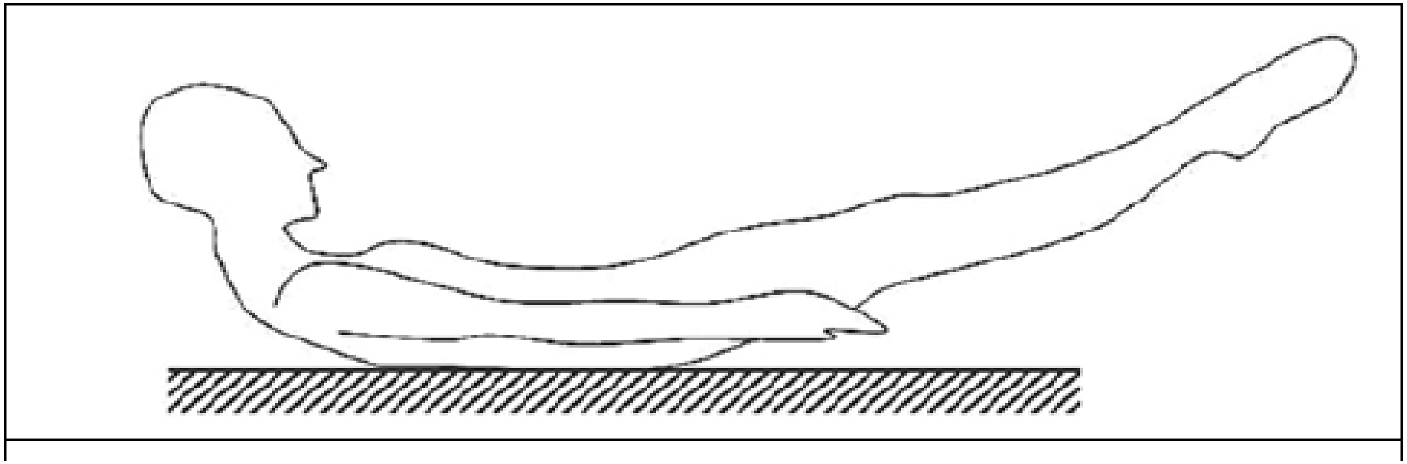
Biomechanical principles: 3) Center of mass

- Mass is balanced at the CM in all directions
- CM is used as the reference point in describing the angular motion of an object

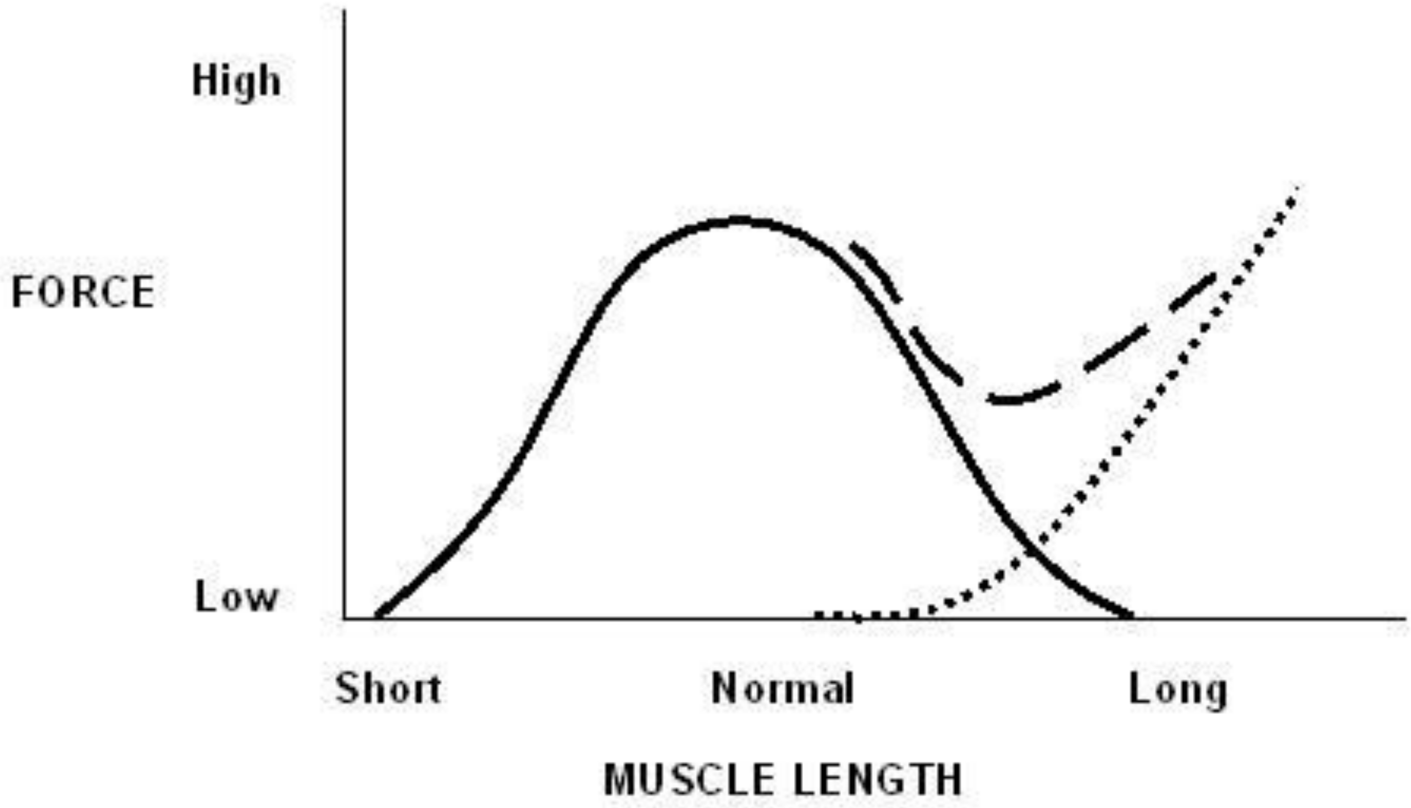


Biomechanical principles: 4) Balance

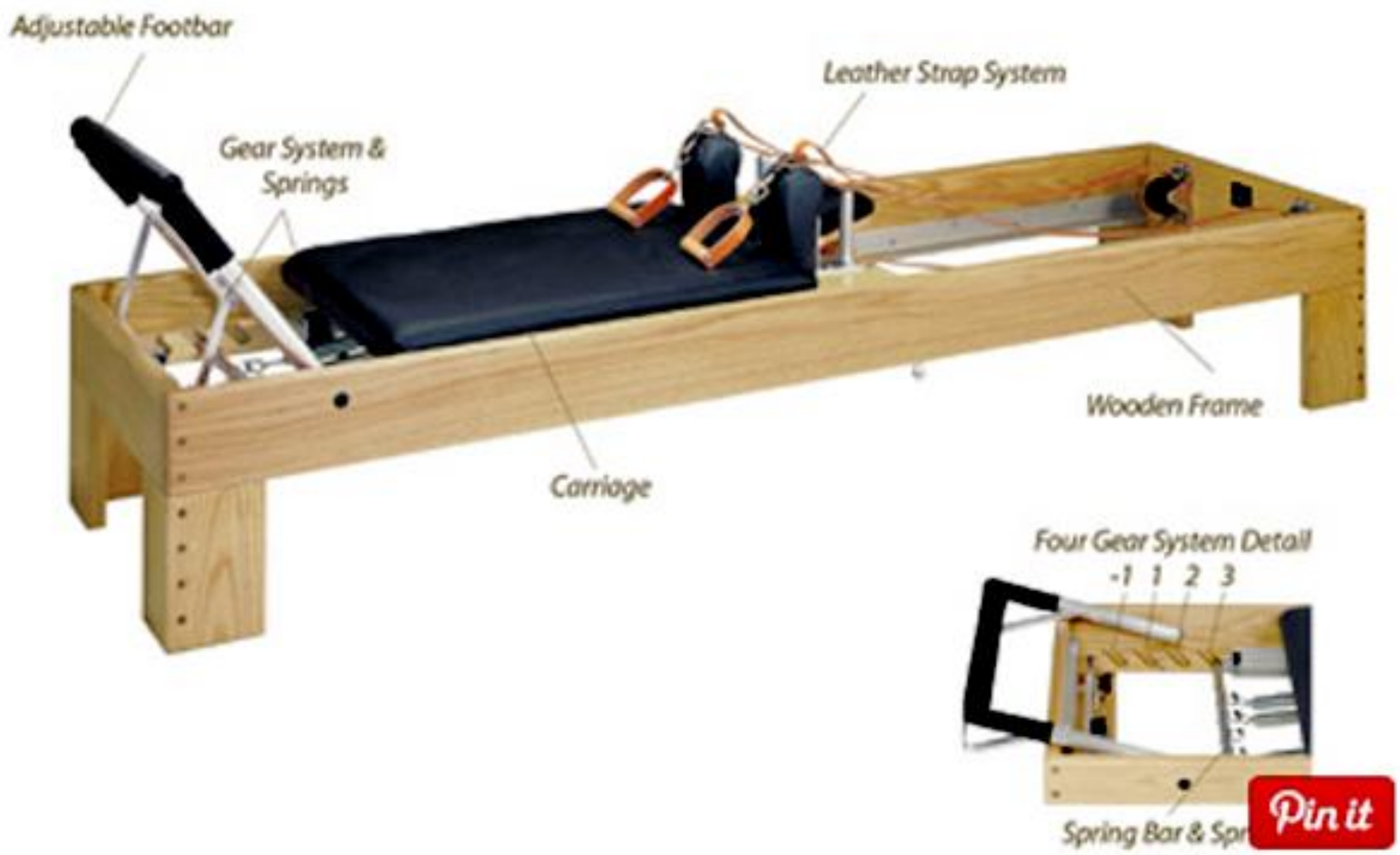
- Size and shape of the base of support
- Relation of the line of gravity to the base of support
- Height of the center of gravity



Biomechanical principles: 5) Force-length



The Reformer



The Hundred on the Reformer

Biomechanical study #1

ELECTROMYOGRAPHIC ANALYSIS OF THE RECTUS FEMORIS AND RECTUS ABDOMINIS MUSCLES DURING PERFORMANCE OF THE HUNDRED AND TEASER PILATES EXERCISES

LOCOMOTOR APPARATUS IN EXERCISE AND SPORTS

ORIGINAL ARTICLE

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ABSTRACT

The literature has shown that small modifications in a Pilates method exercise may change the muscles activation pattern. Moreover, few studies have evaluated Pilates' exercises from the kinesiology point of view. Therefore, this study aimed to compare a couple of exercises performed on the mat and in apparatus regarding electric activation of acting muscle groups. Eleven healthy Pilates trained women took part in the study. Electromyographic data were collected from the rectus femoris and rectus abdominis muscles, right and left portions, while keeping the isometric posture of the hundred on mat, hundred on the Reformer apparatus, teaser on mat and teaser on the Cadillac apparatus exercises. The

Biomechanical study #1

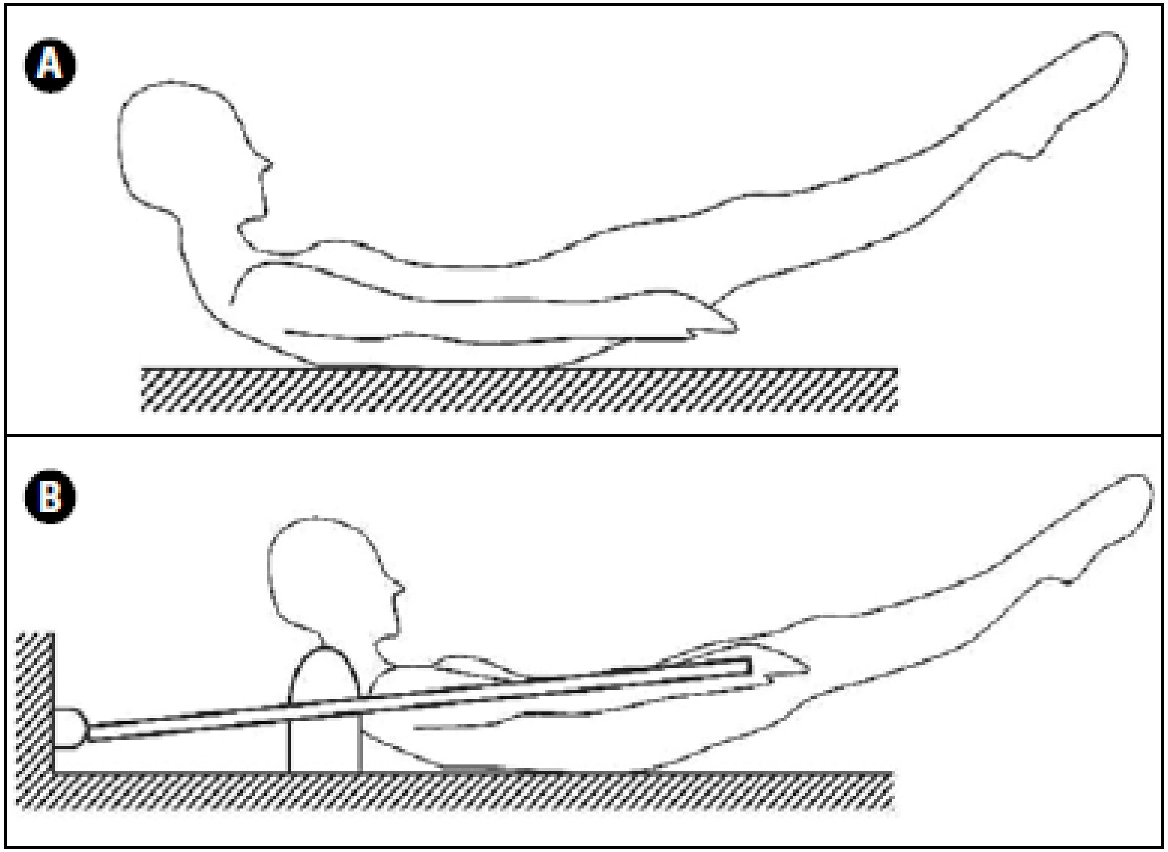
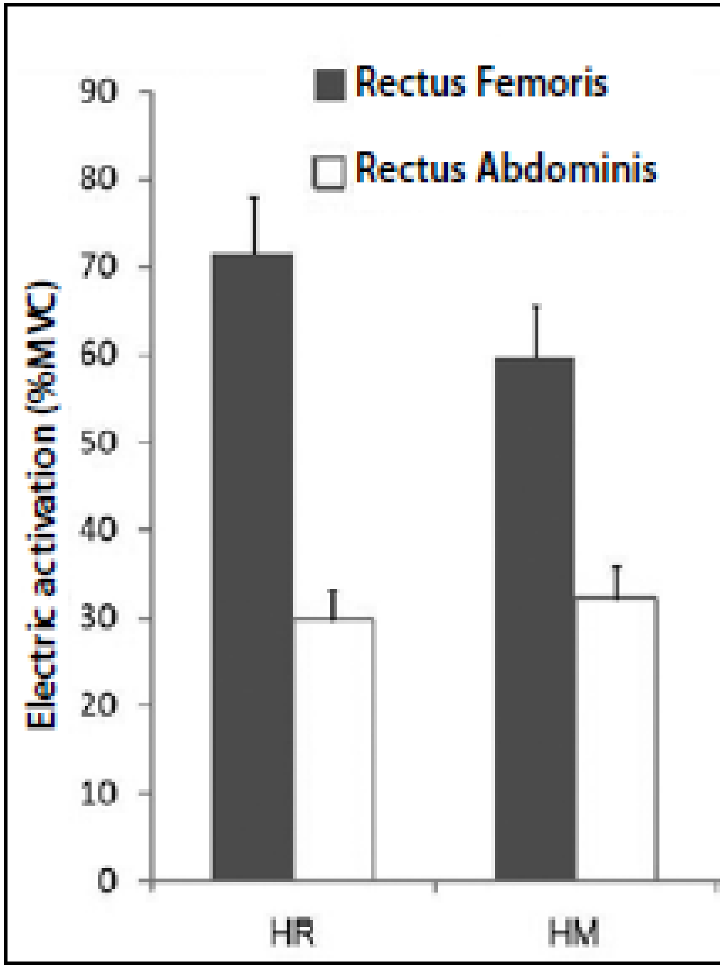


Figure 1.Scheme of the *hundred* on mat(A) and in the *Reformer* exercises (B).

Biomechanical study #1



The Teaser

The Teaser

- **Movement components concentric:** Sequential and simultaneous neck, trunk and hip flexion.

- **Eccentric:** Sequential and simultaneous hip trunk, neck and hip extension.

The Teaser

- **Mechanical Objective:** Angular torque maximization

Additional biomechanical principles in addition to those introduced in The Hundred:

1) Inertia

Inertia – resistance to motion changes.

In the same way that the torque causing angular motion depends on the *magnitude of force* and the *distance from the line of action of the force to the axis*, the inertia of a rotary body is affected by both the *mass* and the *distance between the mass and the axis of rotation*.

Additional biomechanical principles in addition to those introduced in The Hundred:

2) Angular momentum and impulse

Angular momentum: $I\omega$

Angular impulse:

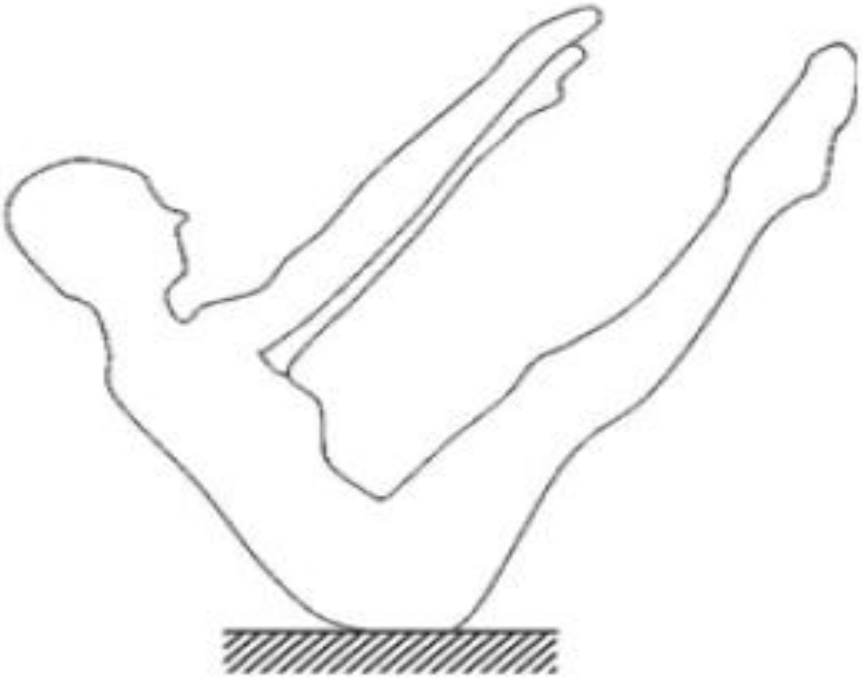
$T * t = I(\alpha)$

THUS:

$\text{Torque} * \text{time} = I(\omega f - \omega i)$

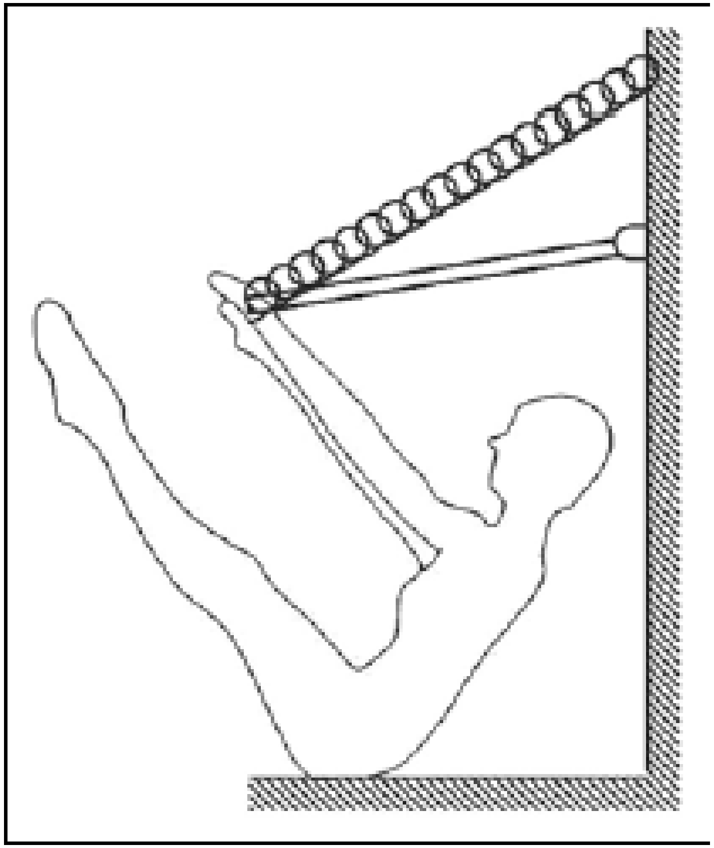
Impeding factor:

3) Range of motion -- ROM



The Cadillac

The Teaser on the Cadillac



Biomechanical study #2

Comparison of the electromyographic activity of the anterior trunk during the execution of two Pilates exercises – teaser and longspine – for healthy people

CrossMark

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A R T I C L E I N F O

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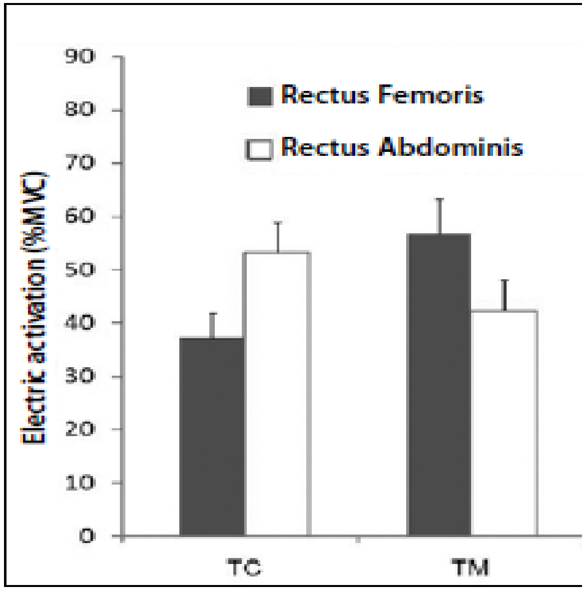
A B S T R A C T

This study compared abdominal electromyographic (EMG) activity during the performance of Pilates' exercises. 16 females participated in the study. EMG signals of the rectus abdominis (RA) and external oblique (EO) were recorded during Longspine performed on the mat, Cadillac, and Reformer and the Teaser performed on the mat, Cadillac, and Combo-chair. Values were normalized by the EMG peak of

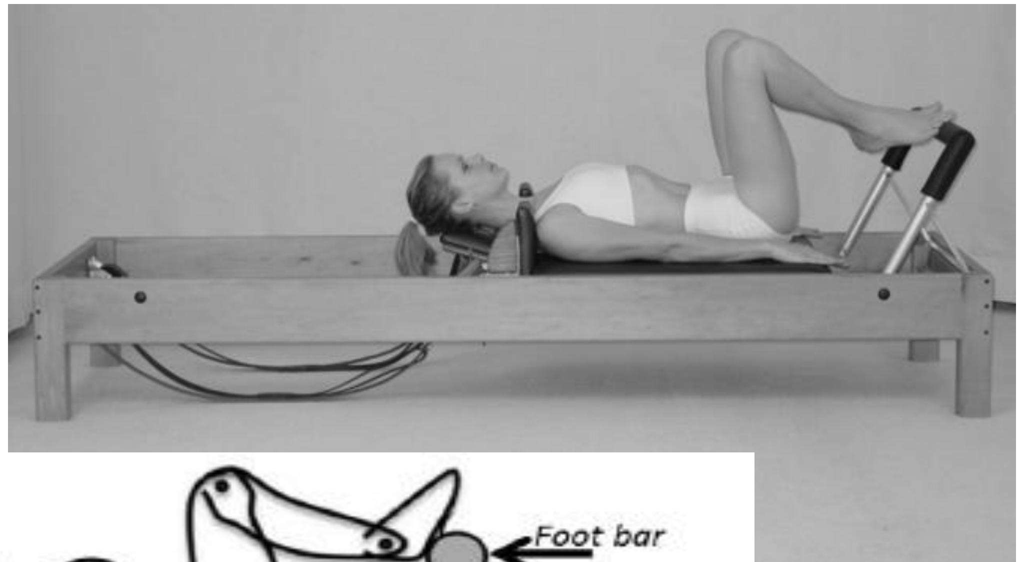
Biomechanical study #1 & #2

Table 4
Comparison of normalized RMS values between con

Muscle	Condition	
	Mat	Cadillac
RA	31.2 (12.7)	23.3 (7.1)
EO	53.2 (26.5)	54.5 (24.7)



The Footwork on the Reformer



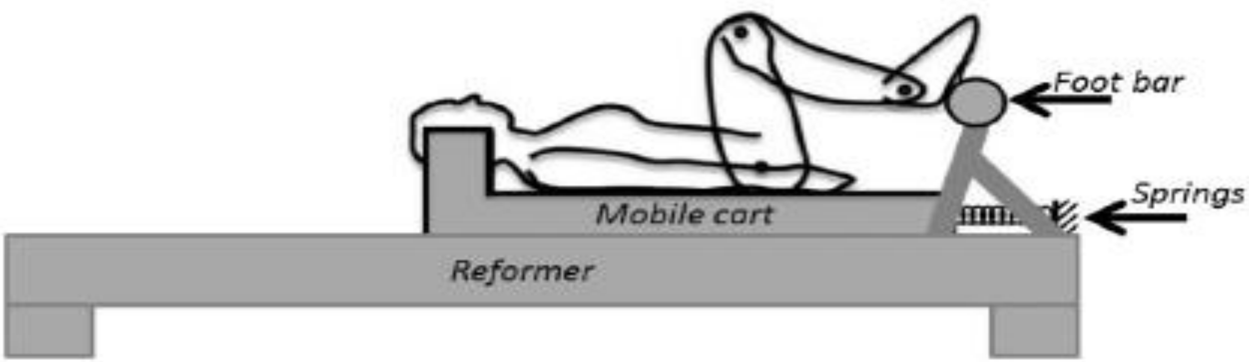
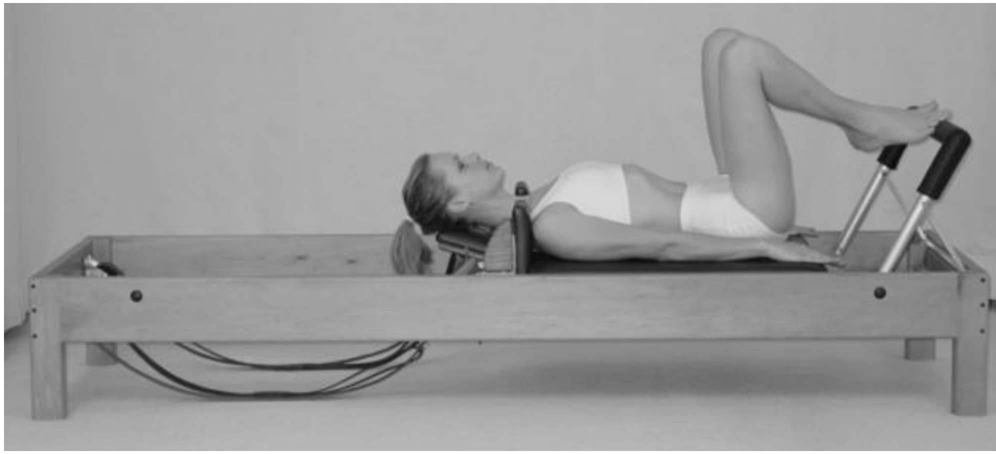


Fig. 1. Starting and finishing position for the leg extension exercise.

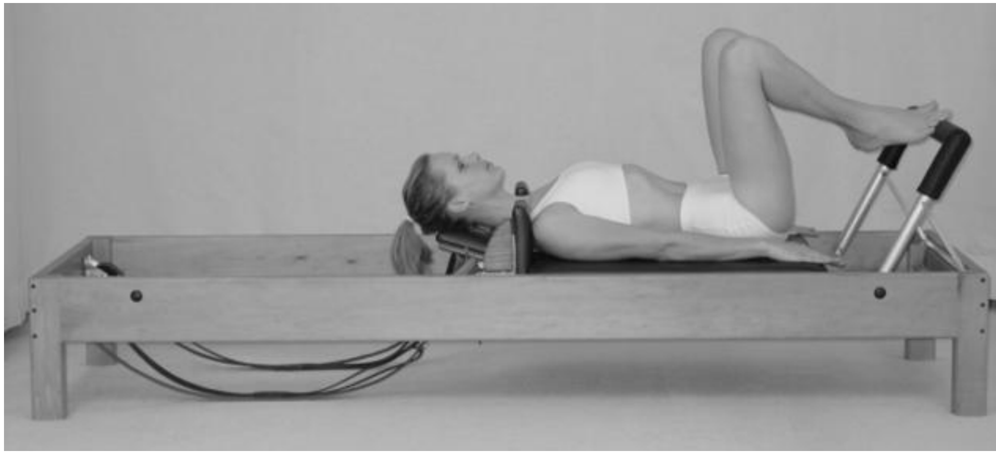
The Footwork on the Reformer



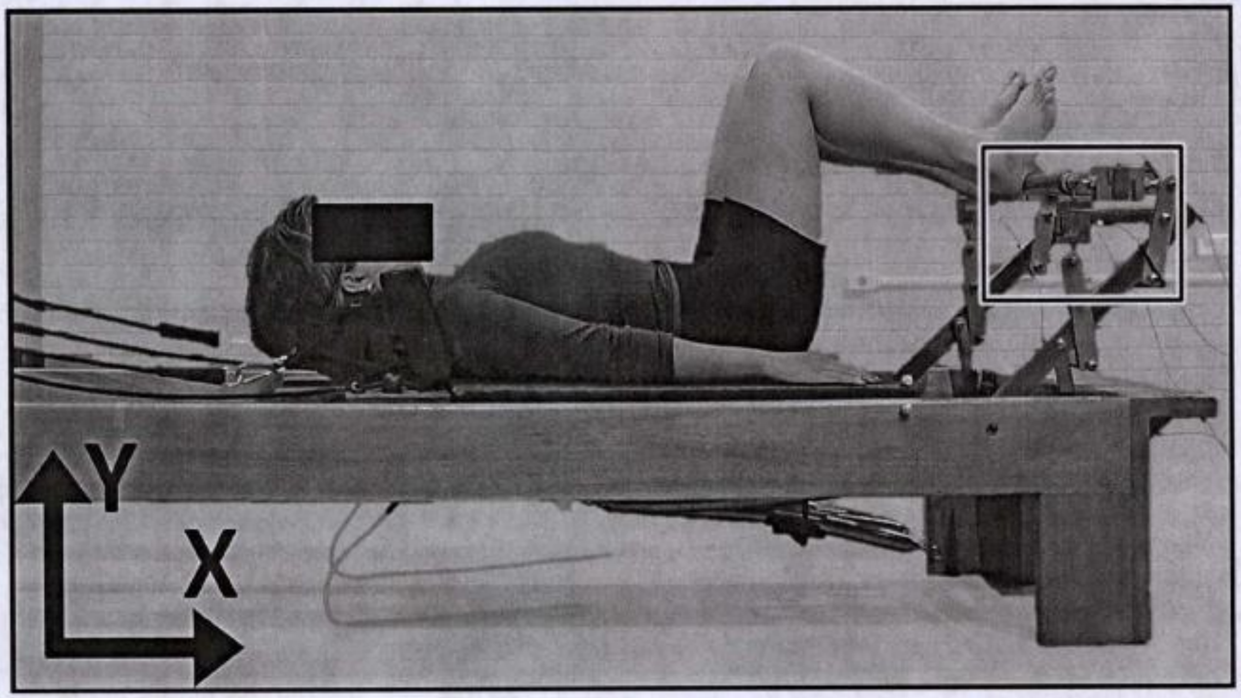
- **Movement compo-nents concentric:** Supine hip and knee extension
- **Eccentric:** Supine hip and knee flexion.

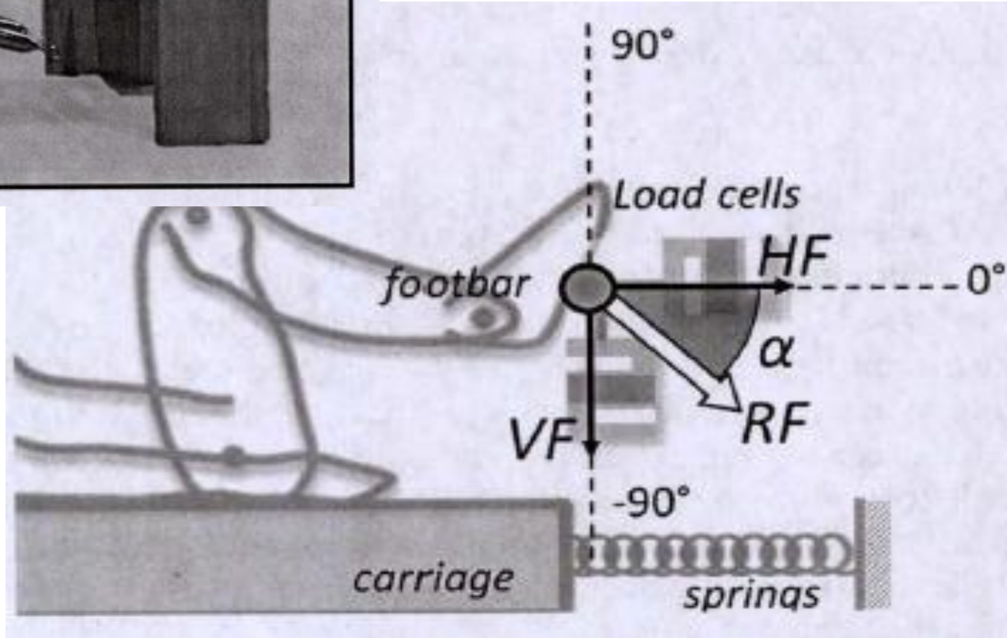
The Footwork on the Reformer

- **Mechanical Objective:**
  Angular torque against external force.



Load measuring





Biomechanical study #3

Muscle strategies for leg extensions on a "Reformer" apparatus

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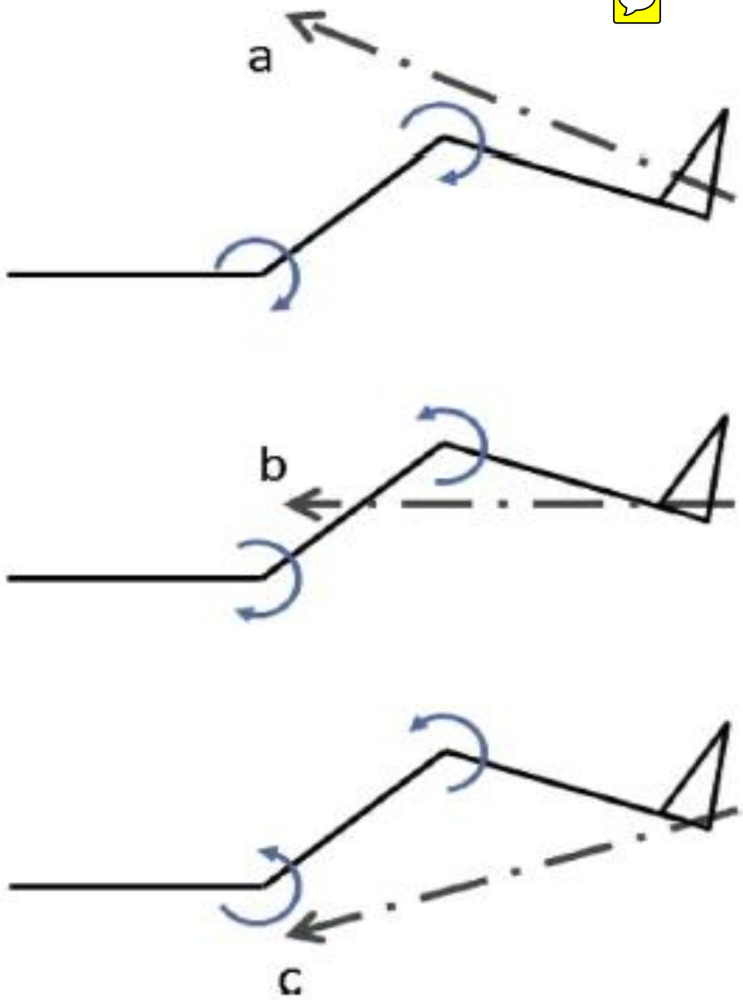
A B S T R A C T

Considering the kinematics of leg extensions performed on a Reformer apparatus, one would expect high activation of hip and knee extensor muscle groups. However, because of the bi-articular nature of some lower limb muscles, and the possibility to vary the direction of force application on the Reformer bar, muscles can be coordinated theoretically in a variety of ways and still achieve the desired outcome. Hence, the aim of this study was to determine the knee and hip moments during leg extensions performed on the Reformer apparatus and to estimate the forces in individual muscles crossing these joints using static optimization. Fifteen subjects performed leg extensions exercises on the Reformer apparatus using an individually chosen resistance. To our big surprise, we found that subjects performed the exercise using two conceptually different strategies (i) the first group used simultaneous hip and knee extension moments, (ii) while the second group used simultaneous hip flexion and knee extension moments to perform the exercise. These different strategies were achieved by changing the direction of the resultant

Biomechanical study #3

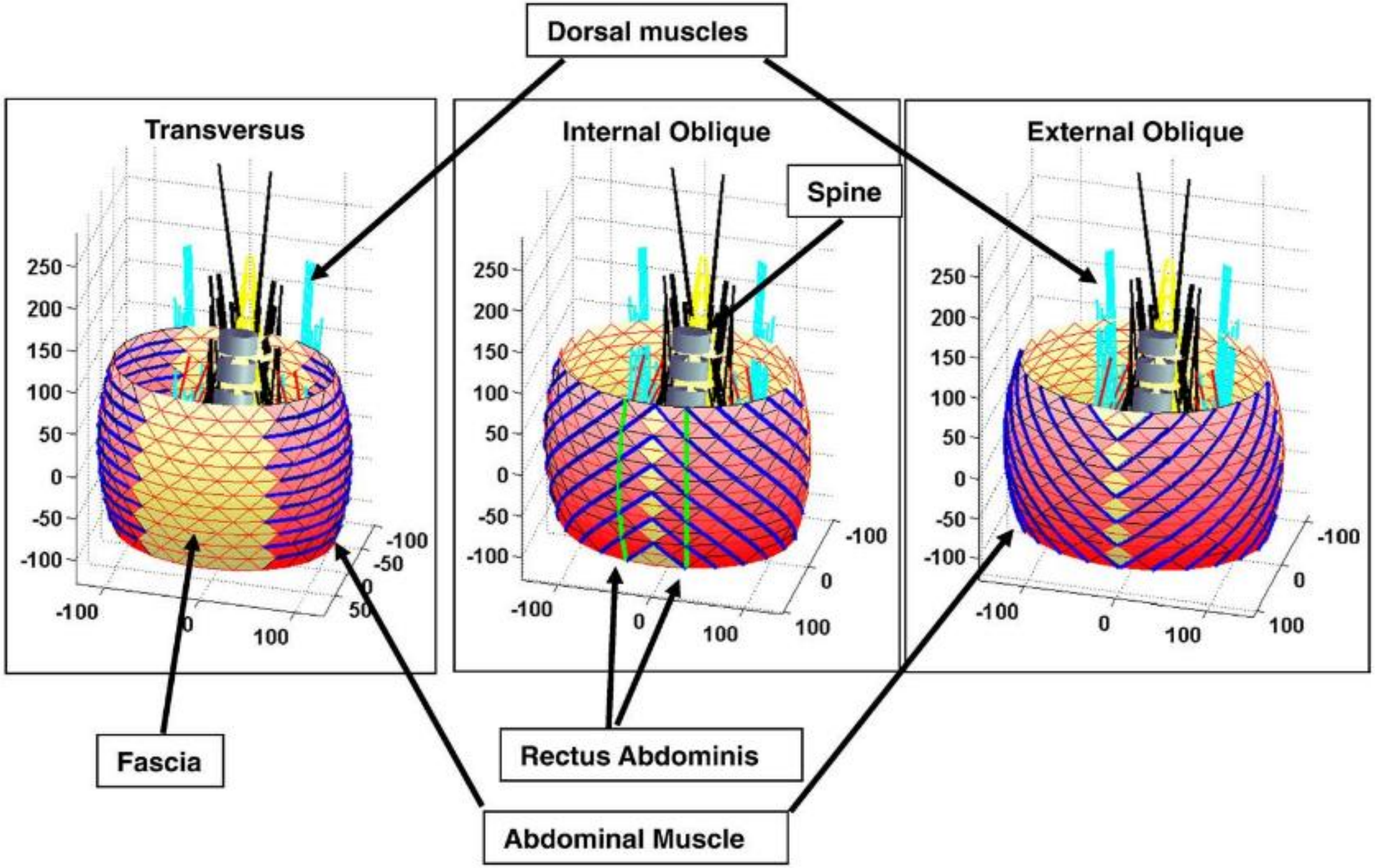


Reaction force directed:

(b) Between knee and hip, creating knee and hip extensor moments;

(c) below the hip, creating knee extensor and hip flexor moments.

Centering



Dorsal muscles
Transversus
Internal Oblique
External Oblique
Spine
Fascia
Rectus Abdominis
Abdominal Muscle

Biomechanical study #4

Immediate electromyographic changes of the *biceps brachii* and *upper rectus abdominis* muscles due to the Pilates centring technique

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KEYWORDS
Exercise;
Electromyography;
Pilates;
Physiotherapy

Summary *Objective:* To evaluate the electrical behaviour of the *biceps brachii* (BB) and *upper rectus abdominis* (URA) by surface electromyography (sEMG) during a forearm flexion with and without the Pilates centring technique.
Methods: Ten female subjects (with a minimum of one week of experience with the Pilates method) were recruited. The long head of the BB and URA were evaluated while an isotonic contraction of the BB was performed using the Pilates breathing technique and *powerhouse* contraction, followed by another contraction without these techniques. The data were nor-

Biomechanical study #4

Figure 3 Isotonic voluntary contraction of *biceps brachii*.

Biomechanical study #4

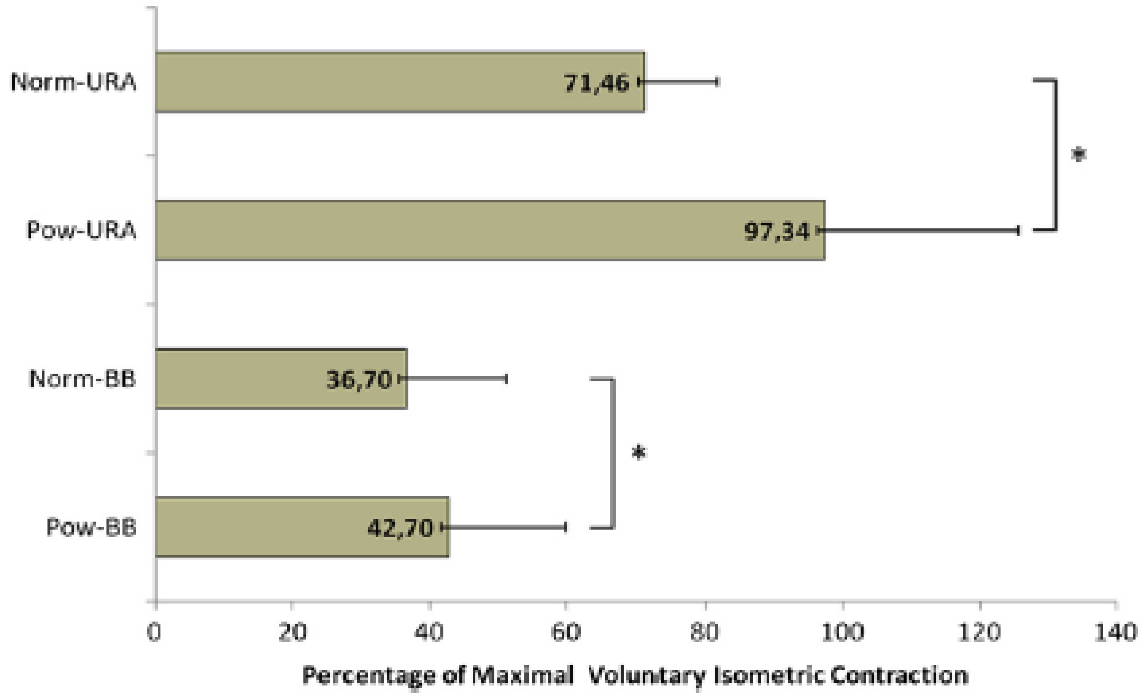

Figure 4 Percentage of maximal voluntary isometric contraction: *biceps brachii* and *upper rectus abdominis* forearm flexion with (Pow-BB and Pow-URA) and without (Norm-BB and Norm-URA) *powerhouse* contraction (*$p < 0.05$).

Biomechanical study #5

EMG activity of trunk stabilizer muscles during Centering Principle of Pilates Method

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KEYWORDS
Electromyographic;
Pilates Method;
Low back pain

Summary This study aimed to analyze the electromyographic (EMG) activity of iliocostalis lumborum (IL), internal oblique (IO) and multifidus (MU) and the antagonist cocontraction (IO/MU and IO/IL) during the performance of Centering Principle of Pilates Method. Participating in this study were eighteen young and physically fit volunteers, without experience in Pilates Method, divided in two groups: low back pain group (LBPG, $n = 8$) and control group (CG, $n = 10$). Two isometric contractions of IO muscles (Centering Principle) were performed

Biomechanical study #5

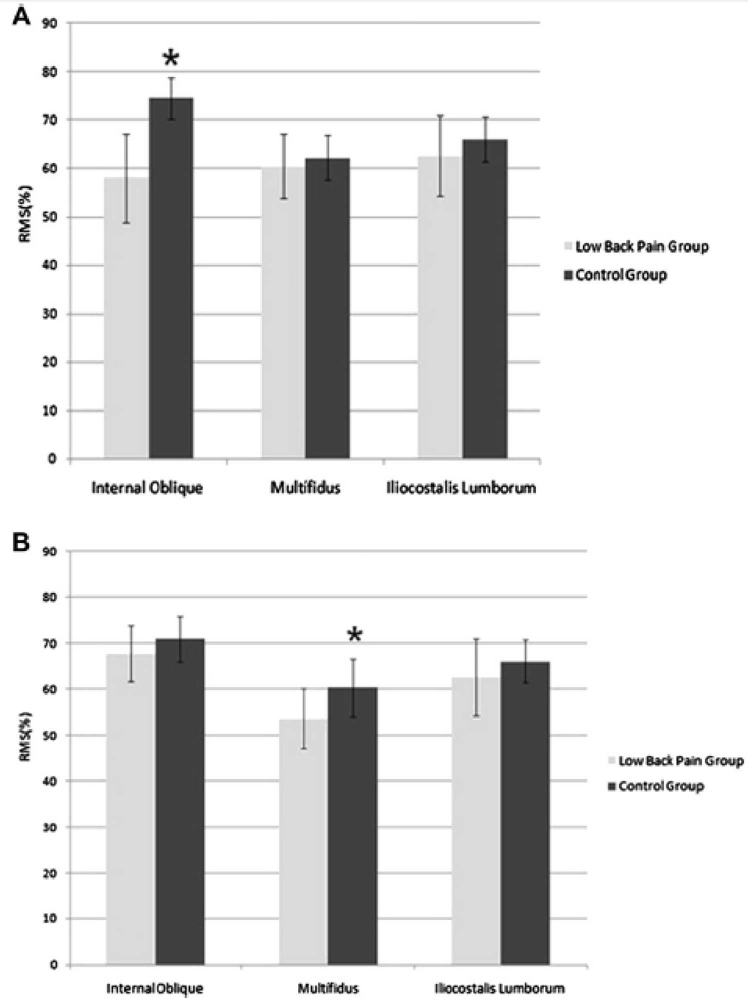

Figure 3 (A) Values of RMS of IO, MU and IL muscles during the first trial of Centering Principle, (B) and during the second trial of Centering Principle (* $p < 0.05$).

Biomechanical study #6

Antagonist coactivation of trunk stabilizer muscles during Pilates exercises

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KEYWORDS
Electromyography;
Stability;
Pilates method;
Physiotherapy

Summary The purpose of this study was to compare the antagonist coactivation of the local and global trunk muscles during mat-based exercises of Skilled Modern Pilates. Twelve women performed five exercises and concurrently, surface EMG from internal oblique (OI), multifidus (MU), rectus abdominis (RA) and iliocostalis lumborum (IL) muscles was recorded bilaterally. The percentage of antagonist coactivation between local (OI/MU) and global muscles (RA/IL) was calculated. Individuals new to the practice of these exercises showed differences in coactivation of the trunk muscles between the exercises and these results were not similar bilaterally. Thus, in clinical practice, the therapist should be aware of factors such as

Biomechanical study #6

Results: “Individuals new to the practice of the mat-based Pilates exercises showed differences in coactivation of the trunk muscles between the exercises.”

Quality of movement and biomechanical research

Cantergi et al.: Previous studies on the Pilates method showed

that small changes in body position or force direction can dramatically affect the resultant joint moments, and thus the muscle groups involved in the exercise.

Barbosa et al.: The Pilates method emphasizes a control of body position and movement, demanding subject's complete attention to the task. Thus, compelling evidence suggests that the stability of coordination is influenced profoundly by specific neuromuscular and skeletal behavior that determine how particular movement patterns are performed.