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Lower Body Neuromuscular Activation During Dynamic Squats on an Indo Board

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LOWER BODY NEUROMUSCULAR ACTIVATION DURING DYNAMIC SQUATS ON AN INDO BOARD

By

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Melissa Weirich entitled "Lower Body Neuromuscular Activation during Dynamic Squats on an Indo Board". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Movement Science.

Dr. Claire Egret, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

Accepted:

Chair of Department of Sport and Exercise Sciences

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TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

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ABSTRACT

Lower Body Neuromuscular Activation during Dynamic Squats on an Indo Board

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Despite the wide use of balance training devices in exercise or rehabilitation programs, there is no published research on the Indo Board. Results from this study could help determine a plan of action for strength training and injury prevention through use of this stability training device. The purpose of this study is to compare differences in mean peak EMG activity in the quadriceps, hamstrings, and gastrocnemius during dynamic squats on and off an Indo Board (B) with a roller (R) or an IndoFlo® Balance Cushion (C). Fourteen healthy male and female adults (aged 18-38 years) were recruited from Miami-Dade and Broward County to participate in this study. Electromyography (EMG) was used to measure peak neuromuscular activity in the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, and medial gastrocnemius during the squat conditions. A multivariate of analysis of variance (MANOVA) was calculated to examine the five dependent variables at all levels of the independent variable with a significance level of $p < .05$. No significant effect was found (Lambda(10,70) = .736, $p = .333$). These findings suggest that despite the increased instability, squats on an Indo Board will produce similar neuromuscular results to normal flat surfaced squats in beginner Indo Board users. Beginner Indo Board users should not expect to see increased muscle activity and proprioception benefits until the Indo Board can be used independently from all stability assistance. . Further investigation is needed to determine if experience level or a different form of exercise will affect lower body neuromuscular activity on an Indo Board.

CHAPTER I

INTRODUCTION

With the rapid growth of health and fitness technology comes the development of a variety of exercise devices that claim to have the solution to all the fitness needs. Some are well worth the time and money spent, while others do not hold true to their end of the bargain. According to the American College of Sports Medicine's annual survey, core training, stability ball workouts, and balance training are some of the most popular fitness trends of 2009 (Thompson, 2007). These concepts are all inter-related. Stability ball routines focus on core muscles and require a great deal of balance to perform (Marshall & Murphy, 2006). A stability, or Swiss, ball is an air-filled ball constructed of elastic, soft PVC with a diameter of 35 to 85cm. Originally, the stability ball was invented as a children's toy, but was later developed into a pediatric neurological rehabilitation tool by Dr. Susanne Klein-Vogelbach. The biggest benefit of core training is to develop functional fitness - that is, fitness that is essential to both daily living and regular activities (Quinn, 2009). Using the concept of functional kinetics (which is observing, analyzing, and teaching human movement), the stability ball was incorporated into programs to treat adults with orthopedic problems. Other devices that stress core muscles and challenge balance through neuromuscular activation include the BOSU ball, wobble board, balance pods, Dyna Disc, whole-body vibration (WBV) platform, and the Indo Board. The BOSU ball, which stands for "both sides utilized," was created by David Weck (Figure 1). It focuses on the human fundamental concept of alternating bilateral coordination of both sides of the body (Weck, 2009).

Figure 1: BOSU ball (Weck, 2009).

The wobble board is similar to the BOSU ball. It has a round, flat, hard surface on one side and a rounded surface on the opposite side (Figure 2). The rounded surface of the wobble board is smaller and made of solid plastic. The biggest difference between these two devices is the wobble board can only be used on one side (round surface down).

Figure 2: Wobble board.

Balance pods are the opposite of a wobble board. These inflatable, dome-shaped pods lie flat side down with a rounded bumpy surface on top (Figure 3).

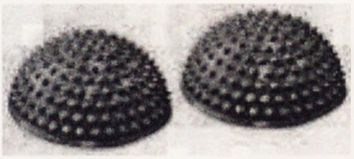

Figure 3: Balance pods.

A Dyna Disc is similar to a balance pod in that it is an inflatable disc-shaped training device (Figure 4). It has a bumpy surface on one side to help with traction. It can be used by itself or with another Dyna Disc, such as a squat with one foot on each disc. Compared to the other training devices, the Dyna Disc and BOSU ball do not provide sufficient challenges to the neuromuscular system of highly resistance-trained athletes (Wahl & Behm, 2008).

Figure 4: Dyna Disc.

A balance training device that is different from all the others is the whole-body vibration (WBV) platform (Figure 5).

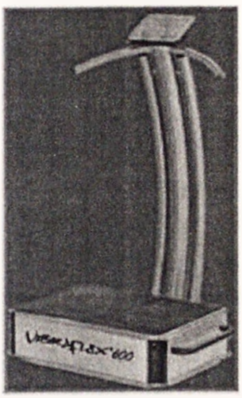

Figure 5: Vibraflex whole-body vibration platform.

Whole-body vibration is a form of exercise that uses a mechanical platform device to elicit a rapid series of muscle contractions by the involuntary muscle stretch reflex (IMSR). The platform vibrates rapidly side-to-side like a teeter-totter motion. Previous research has shown that a single bout of WBV improves muscle performance of the lower body and balance in young healthy adults by increasing neuromuscular activation (Abercromby et al., 2007; Roelants, Verschueren, Delecluse, Levin, & Stijnen, 2006; Torvinen et al., 2002). The root mean square of the soleus and gastrocnemius EMG activity increased significantly on average 21.6% and 35.2% respectively with the use of an unstable platform (Torvinen et al., 2002). Whole-body vibration was used as a pilot study for this research. Use of surface EMG electrodes on 4 lower body muscles during dynamic squats on and off a WBV platform was sufficient to measure neuromuscular activation during the activity; so similar methods can be used during dynamic squats on an Indo Board. The balance training device used in this study (an Indo Board) will not be vibrating; however, it is still an unstable object on which the dynamic squats will be performed.

The Indo Board inspiration originated from a World War II pilot named Stanley Washburn Jr. During his travels, Washburn stumbled across some African children who were balancing themselves on a wooden plank and a log. He made his first proto-type in his woodshop for his daughter for Christmas. He called it the Bongo Board. As the board's popularity grew in the 1960's, skiers and other athletes started to use this board for balance training. The Bongo Board stayed in production until 1980. Five years prior to the end of the Bongo Board, Hunter Joslin (an experienced surfer) developed the first form of the Indo Board. Joslin worked in a surfboard shop making surfboards, skateboards, skimboards, and balance boards. The unique Indo Board design appeared when he mounted a skimboard on a roller. The original design was similar to the Bongo Board but more of a surfing simulator (Figure 6) (Joslin, 2009).

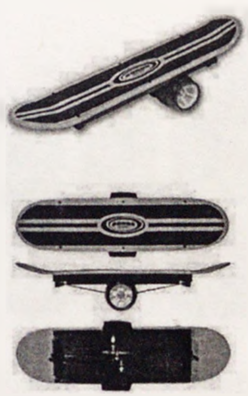

Figure 6: Bongo Board with the attached roller.

The wider deck allowed for a more stable ride and an increased range of motion. He invested nine months to research and development to create a functional and more versatile deck and roller. In 1998, the first Indo Board Balance Trainer was out on the market. Users reported increased leg strength and flexibility from use of this device, so it quickly became a cross trainer for all sports and fitness disciplines. In 2004, the Indo Board won the ISPO Innovative Product of the Year award. Since then, the Indo Board has continued to develop and improve on the balance training technology. There are two devices that the Indo Board deck (Figure 7) can balance on: the IndoFlo® Cushion (Figure 8) and the roller (Figure 9) (Joslin, 2009).

Figure 7: Indo Board deck.

Figure 8: 14" diameter IndoFlo® Cushion.

Figure 9: 3 sizes of Indo Board rollers (5.0", 6.5', and 8.5' diameter).

When the deck is placed on an IndoFlo® Cushion, there is instability in all directions; whereas with the roller, there is instability only in one plane. The size of the Indo Board roller determines the height that the Indo Board is off the ground, which can increase the difficulty level of this device. The Indo Board, whether it is on the IndoFlo® Cushion or the roller, requires a high level of skill to successfully use it. Balance training devices similar to the Indo Board stress the neuromuscular system to stabilize the body but to what extent?

Statement of the Problem

Despite the extensive use of the Indo Board, there is no published research about this product according to the literature search for this study and Hunter Joslin, the creator of the Indo Board. Beneficial outcomes of Indo Board use have only been recorded by product reviews and creator developmental research. Results from this study could help determine a plan of action for strength training and proprioception benefits through use of a stability training device.

Purpose of the Study

There is still plenty of research to be done on the effects of Indo Board balance training for specific sports and how it can be used as an alternative to traditional resistance training. The purpose of this study is to compare differences in mean peak EMG activity in the quadriceps, hamstrings, and gastrocnemius during dynamic squats on and off an Indo Board (B) with a roller (R) or an IndoFlo® Balance Cushion (C). The other variable being collected, gender, is for purpose of discussion and may have an effect on any variance in the results.

Research Hypothesis

In order to determine differences between neuromuscular activation between devices, the following hypotheses will be investigated:

1. Mean neuromuscular activation will be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats.

2. Mean neuromuscular activation will be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface.

Operational Definitions

Advanced Indo Board User: At least once a month of Indo Board use through the year.

Balance Pods: Inflatable, dome-shaped pods that lie flat side down with a rounded bumpy surface on top used in balance training.

Bongo Board: Similar to the Indo Board except the roller is attached by a string to the underside of the skateboard-shaped platform.

BOSU Ball: A training device with a round, flat hard surface on one side and a soft, semi-circle surface on the opposite side.

Dyna Disc: An inflatable, disc-shaped training device with a bumpy surface on one side to help with traction.

Dynamic Squat: A closed kinetic chain exercise, which begins with the individual in an upright position with the knees and hips fully extended. The individual then squats down in a continuous motion until the desired squat depth of 60° knee flexion is obtained and then in a continuous motion ascends back to the upright position (Escamilla, 2001a).

Electromyography (EMG): Continuous recording of the electrical activity of a muscle by means of electrodes strategically placed on the skin or inserted into the muscle fibers (Martin & McFerran, 2004).

Indo Board Deck: A 30" x 18" oval wood platform used with either an Indo Board roller or IndoFlo® Cushion for balance training.

Indo Board Roller: A 5.0", 6.5", or 8.5" cylinder-shaped device used with an Indo Board platform causing instability in one plane of motion.

IndoFlo® Cushion: An inflatable cushion (similar to a Dyna Disc) used with an Indo Board platform to cause instability in all planes of motion.

Maximum Isometric Voluntary Contraction (MVIC): The peak force produced by a muscle as it contracts while pulling against an immovable object (Mosby, 2006).

Novice Indo Board User: Zero to once every 3 months of Indo Board use through the year.

Stability or Swiss Ball: An air-filled ball constructed of elastic, soft PVC with a diameter of 35 to 85cm.

Vibraflex Whole-body Vibration (WBV) Platform: An exercise platform that uses a mechanical device to elicit a rapid series of muscle contractions by the involuntary muscle stretch reflex (IMSR).

Wobble Board: A training device made of a round, solid wood platform with a hard, plastic semi-circle attached to the bottom.

Assumptions

The present study will be performed under the following assumptions:

1. Subjects have been free from injury for the past 6 weeks and do not have any balance issues, such as inner ear problems, at the time of the study.
2. Subjects performed to the best of their ability.
3. Subjects are truthful about their experience level.
4. The equipment is reliable.

5. There is adequate literature in existence to support the reliability of the procedures of this study.

Limitations

The following limitations may apply to the present study and will be considered:

1. Subjects may drop out of the study at anytime.

2. Wearing the EMG unit during the balance activity may inhibit movement.

3. Stability assistance to ensure safety during Indo Board use may affect true peak neuromuscular activation values.

Delimitations

The following delimitations will be made in this study:

1. Subjects will be limited to novice and advanced Indo Board users in Miami-Dade and Broward County between the ages 18 to 38 years old.

2. All testing will be performed in a laboratory setting.

3. All subjects will use the same Indo Board, roller, and IndoFlo® Cushion.

Significance of the Study

This study may provide information on muscle behaviors during dynamic movements on an Indo Board and how they compare to traditional, stable surface dynamic movements. This study may also provide insight on the efficacy of an Indo Board as a training tool for fitness. Peak electromyography activity in five lower body muscles (rectus femoris, vastus lateralis, vastus medialis, rectus femoris, and medial gastrocnemius) were the dependent variables for this study. The independent variable was squat condition (Indo Board on a roller (B+R), Indo Board on an IndoFlo® Cushion (B+C), or baseline (B)).

CHAPTER 2

LITERATURE REVIEW

This study will investigate differences in neuromuscular activation of the biceps femoris, rectus femoris, vastus medialis, vastus lateralis, and gastrocnemius of novice and advanced individuals during dynamic squats on an Indo Board. In order to have a well-rounded review of the literature on this topic, the following subtopics will be discussed: (1) neuromuscular training, (2) biomechanics and EMG of a squat, and (3) EMG reliability.

Neuromuscular Training

There are many different types of balance training devices. Consumers assume these devices provide the same outcomes for strength, balance, and stability improvements. The usage concepts are similar between devices, but the outcomes vary. The basic concept for neuromuscular development is to create an unstable environment which promotes increased neuromuscular signaling and heightens proprioception. The level of instability in different planes of motion is one of the mechanical causes of variability between devices. Some devices have instability in only one plane (front to back or side to side) where as others have instability in all planes. Physiological differences between demographics (example: age or athletic ability) can also account for the variability between devices.

Neuromuscular training can be beneficial for people of any age but the results will differ. Balance has an inverse relationship with age (Bohannon, Larkin, Cook, Gear, & Singer, 1984). One hundred eighty-four subjects between the ages 20 to 79 performed eight balance tests to examine the relationship between test performance and age (Bohannon et al., 1984). Performance seemed to decline for healthy adults over 39 years old (Bohannon et al., 1984). Reaction time for balance recovery increases with increasing age as well (Luchies et al., 2002).

These measures were taken from healthy, regular exercising adults; so balance recovery time could be even greater for the sedentary adult population (Bohannon et al., 1984; Luchies et al., 2002). Balance training can help reduce the effects of aging on balance through increased proprioception and strength (Anderson & Behm, 2005; Schilling et al., 2009; Mattacola & Lloyd, 1997).

Balance and postural stability are essential to everyone for performance enhancement and injury prevention. Static and dynamic proprioceptive training through the use of a wobble board and other balance training devices can significantly reduce sports-related injuries among healthy adolescents (DiStefano et al., 2009; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; McGuine & Keene, 2006; McLeod, Armstrong, Miller, & Sauers, 2009). Balance is generally defined as the ability to maintain the body's center of gravity within its base of support (DiStefano, Clark, & Padua, 2009). Some training programs incorporate a balance training device to engage the core muscles and try to improve the proprioceptive response. These devices train its user the proper distribution of body weight to achieve a consistent equilibrium. An interruption or deficit in any part of the sensorimotor system can result in a loss of balance, which can result in injury (DiStefano et al., 2009). A sensorimotor deficit causes proprioception problems, such as a lack in ability to reposition a joint to a predetermined position or a lack of coordination during single limb or whole-body movements. This is commonly seen in people with functional ankle instability (FAI) and chronic ankle instability (CAI) (Arnold, Motte, Linens, & Ross, 2009; Docherty, McLeod, & Shultz, 2006; Hiller, Refshauge, & Beard, 2004; Riemann, 2002). Both static and dynamic balance require effective integration of visual, vestibular, and proprioceptive inputs to produce an efferent response to control the body within its base of support (Guskiewicz & Perrin, 1996; Irrgang, Whitney, & Cox, 1994). Alterations in postural control could be attributed to deficits in the peripheral afferent input from mechanoreceptors in the ankle ligaments and capsule (Freeman, 1965; Freeman & Wyke, 1967). Balance training can help reduce the severity of a sensorimotor deficit by strengthening the supportive musculature in the joints.

A number of studies have reported increased muscle electromyographic (EMG) activity when an exercise was performed with an unstable rather than a stable base (Anderson & Behm, 2004b). During squatting, there was more EMG activity in the soleus on the wobble board than in the stable, Dyna Disc, BOSU up, and BOSU down conditions (Wahl & Behm, 2008). However, there were no significant differences in EMG activity among the conditions on the balance devices in the rectus femoris and biceps femoris (Wahl & Behm, 2008). Similar to previously published research, the greater instability of the Swiss ball and wobble board did result in greater muscle activation than found on a stable surface and generally greater muscle activation than Dyna Discs and BOSU balls (Table 1) (Wahl & Behm, 2008).

Muscle	Stable	Dyna Disc	BOSU up	BOSU down	Wobble board	Swiss ball
LSES	0.76 ± 0.90	0.52 ± 0.34	0.46 ± 0.25	0.68 ± 0.82	0.80 ± 0.82	0.42 ± 0.22
Lower abdominals	0.11 ± 0.08	0.08 ± 0.09	0.07 ± 0.06	0.09 ± 0.07	0.18 ± 0.15*	0.18 ± 0.14*
Rectus femoris	0.48 ± 0.31	0.55 ± 0.50	0.51 ± 0.50	0.49 ± 0.44	0.42 ± 0.30	0.50 ± 0.32
Biceps femoris	0.05 ± 0.02	0.06 ± 0.07	0.07 ± 0.05	0.08 ± 0.05	0.10 ± 0.08	0.07 ± 0.03
Soleus	0.13 ± 0.08	0.23 ± 0.14	0.17 ± 0.11	0.21 ± 0.13	0.41 ± 0.30*	0.28 ± 0.19*

iEMG = integrated electromyography; LSES = lumbosacral erector spinae.
*Significant difference from other unmarked values in the row.

Table 1: Mean values for EMG (mVs) for the squatting posture.

Another device known to significantly increase lower body neuromuscular activation is the whole-body vibration platform. The addition of whole-body vibration (WBV) to a squat amplifies the magnitude of muscular contractions as seen in Table 2 (Ronnestad, 2004; Jacobs & Burns, 2009).

	WBV		CYL	
	Pre	Post	Pre	Post
Knee extension: peak (N·m)	151.3 ± 39.6	162.9 ± 44.4	152.4 ± 39.6	151.3 ± 40.3*
Knee extension: average (N·m)	91.8 ± 24.3	100.6 ± 27.4	93.3 ± 23.7	90.8 ± 22.4*
Knee flexion: peak (N·m)	83.3 ± 22.1	87.5 ± 23.3	83.8 ± 21.9	83.8 ± 22.6
Knee flexion: average (N·m)	61.9 ± 17.5	66.7 ± 18.6	63.7 ± 17.0	62.8 ± 17.0*

Data are displayed as means ± standard deviations.
*Statistically significant difference ($p < 0.05$) between the change in torque after WBV compared with CYL.

Table 2: Peak and average torque of knee extensors and flexors before and after whole-body vibration (WBV) and bicycle ergometry.

The increase in muscle activity as seen in these studies is due to cocontraction of muscles on either side of the joint to maintain support and balance (Gantchev & Dimitrova, 1996).

Not all studies have found an increase in neuromuscular activation during unstable conditions. Behm, Anderson, and Curnew (2002) found that instability resulted in a significant decrease in activity of the agonist muscles and no significant change in antagonist or synergist muscles. Therefore, the noted benefit of increased muscle activation with instability seems to be unfounded as well (Behm et al., 2002). In another study by Anderson and Behm (2004a), maintenance of EMG activity and force output were measured between stable and unstable movement conditions for a chest press. There was no significant evidence of changes in the extent of muscle activation as measured by EMG within the same muscle between the stable and unstable maximum voluntary contractions (Anderson & Behm, 2004a). These findings may be explained by the experimental design used in these studies. Behm et al. (2002) had subjects perform unilateral knee extension and plantar flexion contractions while seated. As only one leg was tested, the unilateral limb forces would generate disruptive moments or torques on the stability of the body (Behm et al., 2002). Thus, to maintain balance, the activation and force output of the lower limb would need to decrease (Behm et al., 2002). In other words, a percentage of force was diverted to joint stabilization. The subjects were also experienced weight lifters who incorporated some form of stability training into their routines on a regular basis. These subjects would be able to perform a balance task with less effort than a sedentary person.

Biomechanics & EMG of a Squat

The Indo Board is a close replication of a surfboard and is often used for sport-specific training. It simulates many types of surfing movements: A) the barrel stance or ripping through the barrel of a wave, B) floaters or sliding along the lip of the wave, and C) hanging ten or surfing on the nose of the board.

A) 

B) 

C) 

Most novice Indo Board users cannot perform these difficult movements, so the most common board position (the squat stance) will be the main focus of this research. The dynamic squat seems to be the primary exercise that biomechanic researchers have used to observe and analyze stability training devices because it is a fundamental human movement (Abercromby et al., 2007; Augustsson & Thomee, 2000; Boling et al., 2006; Marshall & Murphy, 2006; Rittweger et al., 2003; Roelants et al., 2006; Wahl & Behm, 2008). This closed kinetic chain movement can be performed with varying degrees of knee flexion, such as the full squat or half squat. A dynamic squat is done in a continuous, smooth motion. The individual begins in an upright standing position with knees and hips fully extended (Escamilla, 2001a). The individual then squats down in a continuous motion until the desired squat depth is obtained and immediately ascends back to the upright position (Figure 10) (Escamilla, 2001a).

Figure 10: The dynamic squat.

It is crucial to set a controlled depth for the squat for all participants because muscle activation differs at different joint angles. One study reported the effect of hip angle on quadriceps and hamstring recruitment and found increasing hamstring activity with corresponding increases in hip flexion angle (Isear, Erickson, & Worrell, 1997). Another study reported the effect of knee angle on quadriceps and hamstring recruitment, noting significant quadriceps activity but only minimal hamstring activity throughout all phases of the squat (Gryzlo, Patek, Pink, & Perry, 1994). Stance width does not need to be controlled during studies examining the dynamic squat movement. Anderson, Courtney, and Carmeli (1998) found no significant differences when comparing the respective ranges of the narrow-stance squat with the wide-stance squat (Paoli, Marcolin, & Petrone, 2009). Performing with proper mechanics is important because it aids in injury prevention and maintaining proper strengthening mechanics.

Many of the kinematics of the dynamic squat exercise can be controlled; however, all subjects will have slight differences in their movement. No one is structurally made the same. Joint tracking, muscle imbalances, limb length differences, and even experience level can cause these movement differences. Studies have shown that expert squatters, such as experienced power lifters, perform better and have more favorable kinematics (more erect trunk, less horizontal hip displacement, and less vertical bar velocity during the descent) and kinetics (less trunk torques and greater extensor dominant thigh torques) compared with novice squatters (McLaughlin, Dillman, & Lardner, 1977; Miletello, Beam, & Cooper, 2009). Experienced or advanced people will have a learned effect from more repetitive neuromuscular training, which results in preactivated muscle tension in anticipation of expected joint load (Rozzi, Lephart, Gear, & Fu, 1999). The mechanics of these individuals are more fluid and technically sound compared to a novice person. Despite the slight differences between individuals, the symmetrical nature of a dynamic squat allows for unilateral measurements to represent bilateral events within the same subject. This was supported in a study by Escamilla (2001b), linear and angular displacements and velocities, as well as joint moments and moment arms, were averaged from the left and right sides of the body. There were no significant differences between bilateral measurements, which demonstrate the symmetrical nature of the squat exercise (Escamilla, 2001b). This implies that during the squat analysis, only one side of the body may be adequate in calculating joint and segment angles, joint moments, and joint moment arms (Escamilla, 2001b; Shields et al., 2005).

The primary knee muscles utilized during the squat are the quadriceps (vastus lateralis, rectus femoris, and vastus medialis), hamstrings (biceps femoris), and gastrocnemius. Co-contractions among these muscles are believed to enhance knee stability (Escamilla, 2001a). Because the quadriceps cross the knee anteriorly and the hamstrings and gastrocnemius cross the knee posteriorly, co-contractions from these muscle groups are very important in enhancing anteroposterior knee stability (Escamilla et al., 2001a). To monitor this muscle activity occurring in the lower body during a squat, electromyography (EMG) may be used (Abercromby et al., 2007; Anderson, Courtney, & Carmeli, 1998; Boling et al., 2006; Gullett et al., 2009; Isreatel et al., 2010).

One element that has been observed during the dynamic squat movement is which part of the movement peak neuromuscular activation occurs in each muscle. Escamilla (2001a) quantified quadriceps, hamstring, and gastrocnemius activity experienced in a squat on a stable surface. Quadriceps activity progressively increased as the knees flexed and decreased as the knees extended, with peak activity occurring at approximately 80–90° knee flexion (Escamilla, 2001a). Hamstring activity was highest during the squat ascent, with the lateral hamstrings showing greater overall activity than the medial hamstrings (Escamilla, 2001a). Peak hamstring activity was reported between approximately 30 and 80% of a MVIC, occurring near 50–70° knee flexion (Escamilla, 2001a). This study also showed moderate gastrocnemius activity during the squat, which progressively increased as the knees flexed and decreased as the knees extended (Escamilla, 2001a). Peak gastrocnemius activity was reported between 60 and 90° knee flexion (Escamilla, 2001a). Escamilla's study can be used as a reliable guideline for where peak muscle contractions occur during squats on a flat surface; however, it may be different during squats on an unstable surface.

EMG Reliability

An acceptable way to assess physiological events within a muscle is to use surface electromyography (EMG) to monitor changes in the spectral and amplitude characteristics. This method is non-invasive and convenient (Cifrek, Medved, Tonkovic, & Ostojic, 2009; Kallenberg & Hermens, 2007; Paoli et al., 2009). Surface EMG is influenced by a number of physiological properties such as motor unit discharge rates and muscle fiber membrane characteristics, as well as non-physiological properties such as electrode size, shape and placement (Farina, Merletti, &

Enoka, 2004). The surface electrodes must be placed on the same part of the muscle and in the same direction (parallel to the muscle fibers) for each subject (Wong & Ng, 2006). Otherwise there could be discrepancies in the results. Despite correct placement of the EMG electrode, there could be interference caused by the extent of body fat at the site of the placement. An individual with a large amount of body fat at the surface electrode site would have a weaker EMG signal than an individual with relatively low body fat at the same location (Petrofsky, 2008). To compare EMG values of individuals with varying body fat percentages, intramuscular EMG electrodes would be more reliable because the electrical signal is coming straight from the muscle fiber. Most of the previous research on balance trainers in which muscle contractions are measured surface EMG has been used due to its convenience. In a study on the acute effects of whole-body vibration (WBV) on muscle activity, the exact location of the electrode was marked following the first testing session to ensure consistent placement in subsequent tests. EMG of the vastus lateralis, vastus medialis, and biceps femoris muscles was collected at 1,000 Hz using a telemetry transmitter (Cormie, Deane, Triplett, & McBride, 2006). This method found that there were no statistically significant changes in EMG amplitude during WBV (Cormie et al., 2006). Another study that used surface EMG electrodes measured WBV-induced increase in leg muscle activity during different squat exercises. The surface EMG signals from the rectus femoris, vastus lateralis, vastus medialis, and gastrocnemius (medial) muscle of the dominant leg were recorded by disposable 20-mm bipolar disc electrodes (Roelants, Verschueren, Delecluse, Levin, & Stijnen, 2006). The electrodes were fixed lengthwise over the middle of the muscle belly with an interelectrode distance of 25-mm (Roelants et al., 2006). Results showed that EMG root-mean-square increased significantly ($p < 0.05$) during WBV at 35 Hz in all muscles and all exercises compared with the non-vibrating, stable condition (between +39.9 ± 17.5% and

+360.6 ± 57.5%) (Roelants et al., 2006). Leg muscle activity varied between 12.6 and 82.4% of MVIC values (Roelants et al., 2006). EMG surface electrodes are widely used as a reliable and valid measure of lower body muscle activity. EMG has also been used on the lower body during single-leg and two-leg squats. McCurdy, O'Kelley, Kutz, Langford, Ernest, and Torres (2010) placed EMG surface electrodes 2cm apart and parallel to the fiber direction of the gluteus medius, rectus femoris, and biceps femoris on the dominant leg for the two-leg and single-leg squats. The raw signal was smoothed using the root mean square and then a linear envelope calculated the mean EMG activity for each muscle (McCurdy et al., 2010). The data had to pass assumptions of normality before statistical analysis could occur. The gluteus medius and hamstring EMG mean ($P < 0.01$) and mean peak activity ($P < 0.05$) were significantly higher during single-leg squats than two-leg squats (McCurdy et al., 2010). These results supported earlier findings that highly unstable squats stimulate an increase in hamstring activity (McCurdy et al., 2010). By reducing the point of contact with the floor (two legs to one leg), instability was increased, which induced an increase in lower body muscular activation. In this current study, the Indo Board roller and IndoFlo® Cushion have the only contact point with the ground in 2 out of 3 of the squat conditions. Like McCurdy's study (2010), this study has increasing levels of instability. The flat, stable ground squat has two points of contact with the ground (both of the subject's feet). The Indo Board with the roller has one point of contact with the ground and one plane of instability. The Indo Board with the IndoFlo® Cushion also has one point of contact with the ground but has instability in all planes of motion.

Summary

There have been many studies investigating neuromuscular activation during stability training on different balance training devices (Abercromby et al., 2007; Behm, Anderson, & Curnew, 2002; Roelants et al., 2006; Ronnestad, 2004; Wahl & Behm, 2008). Most of them have used the functional movement of a dynamic squat to assess balance and muscle activity. However, there are no studies investigating electromyographical activity on the Indo Board. This study will add to the knowledge of previous products with similar balance training concepts, as well as, add insight to new training regimens. It has been shown that most balance training devices increase muscle activation compared to exercise on a stable platform (Bogaerts et al., 2007; Carter et al., 2006; Gantchev & Dimitrova, 1996; Roelants et al., 2006). The greater instability of the Swiss ball and wobble board did result in greater muscle activation than found on a stable surface and generally greater muscle activation than Dyna Discs and BOSU balls (Wahl & Behm, 2004). Due to the well researched procedures of using a dynamic squat movement with EMG, the procedures of this study can be considered a valid method for analyzing neuromuscular activation. In order to determine differences between neuromuscular activation between devices, the following hypotheses will be investigated: (1) mean neuromuscular activation will be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats; (2) mean neuromuscular activation will be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface.

CHAPTER 3

METHODS

Purpose Statement

The purpose of this study was to compare differences in mean peak EMG activity in the quadriceps, hamstrings, and gastrocnemius of individuals during dynamic squats on and off an Indo Board with a roller (B+R) or an IndoFlo® Balance Cushion (B+C).

Subjects

Seven healthy male and 7 healthy female adults (aged 18-38 years) were recruited from Miami-Dade and Broward County to participate in this study. Subject recruitment was via flyers in surf shops, athletic facilities (gyms, sport fields, and universities), and the beach (Appendix A). Word of mouth from the subjects also helped recruit more subjects. Subject applicants filled out a questionnaire regarding past and present health issues, demographics, and Indo Board and squatting experience (Appendix C). All subjects were clear of any health problems that may compromise balance including but not limited to: infections (viral or bacterial), head injury within the past six weeks, disorders affecting the inner ear or brain, and taking of certain medications (aminoglycosides, diuretics, vasodilators, phenothiazines, tranquilizers, antidepressants, anticonvulsants, hypnotics, analgesics, alcohol, caffeine, and/or tobacco products). The fourteen subjects (7 male and 7 female) were beginner Indo Board users (never to at least once every 3 months of Indo Board use throughout the year). After a review of the experimental and safety protocol, the subjects signed an informed consent document, which was approved by the Barry University Institutional Review Board (Appendix B). Subjects were informed they may drop out of the study at any time if they had any insecurity regarding the balance testing. Subjects were also instructed to refrain from alcohol and drug use the day before and the day of the Indo Board training and testing.

Instrumentation

A 30" x 18" natural-colored Indo Original Board® was used for two of the three squat conditions. The first condition was a baseline (B) dynamic squat on the flat, stable ground. The second condition (B+R) was a dynamic squat performed on an Indo Board with a 6.5" diameter roller underneath the board (Figure 11).

Figure 11: Indo Board with roller (Joslin, 2009).

The third condition (B+C) was a dynamic squat performed on an Indo Board with a 14" diameter polyvinyl IndoFlo® Balance Cushion inflated to a height of 4" underneath the board (Figure 12 and 13).

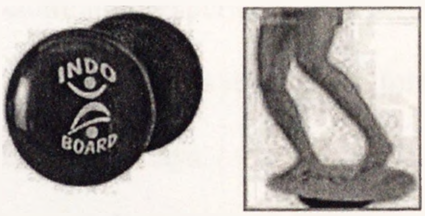

Figure 12 and 13: IndoFlo® Balance Cushion and subject positioning (Joslin, 2009).

A Delsys electromyography (EMG) system was used to measure peak muscle contractions created by the quadriceps (vastus lateralis, vastus medialis, and rectus femoris), biceps femoris, and medial gastrocnemius. The amplified 5-channel EMG signals were band pass filtered near the electrodes and transmitted to a receiver (Butterworth filter, 10-200 Hz band pass). The EMG signal was collected over 30 seconds and sampled at 1000 Hz. All kinematic data was collected and processed with Vicon Nexus (Centennial, CO) software and presented with Vicon Polygon (Centennial, CO) software.

Procedures

The subjects were instructed prior to their arrival to wear athletic clothing (shorts and a t-shirt) during the training and testing. The training and testing were performed barefoot. Indo Board training and data collection occurred on 2 separate days and required about 15 minutes of the subject's time on the first day and 45 minutes of the subject's time on the second day. The procedure consisted of Indo Board and safety training, EMG preparation, and randomized data collection of the 3 maximum isometric voluntary contractions (MVICs) and the 3 squat conditions (B + R, B + C, and B).

Training and Safety Protocol

The day prior to the data collection day all the subjects met at Barry University's biomechanics lab for Indo Board training. The purpose of this session was to familiarize the subjects with the Indo Board and explain the safety protocol. The researcher has five years of continuous experience in supervising and instructing individuals on unstable balance training devices and was responsible for hands on supervision through the entire training and data collection days.

The Indo Board was placed in the middle of the room away from any objects and had padded mats surrounding it on all sides. The researcher demonstrated how to get on and off the Indo Board with the roller and the IndoFlo® Cushion. The subject had the option wear protective gear consisting of a helmet and elbow pads during training and testing. The researcher acted as a spotter in front of the subject and a research assistant was the spotter behind the subject. To get on and off the Indo Board with the roller or the IndoFlo® Cushion, the subject held hands with the researcher and the research assistant placed their hands on the subject's waist to help stabilize. The subject placed one foot on the Indo Board causing one side of the board to be in contact with the floor. The researchers continued to assist in stabilization until the second foot was placed on the board and the subject could stabilize on their own. The spotters slowly removed their hands from the subject but kept them close by to assist in stabilization if the subject needed help. The subject practiced the dynamic squat as many times as needed to feel comfortable on the Indo Board with the roller and IndoFlo® cushion.

EMG Preparation

Upon arrival at Barry University's biomechanics lab on the day of data collection, the subject was prepped. Electrode placement sites on each subject were abraded and scrubbed with alcohol pads. Any excess body hair was also shaved in order to create a good connection. The bipolar surface electrodes were placed parallel to the muscle fibers of the right rectus femoris (RF, channel 1) halfway between the right anterior superior iliac spine (ASIS) and the superior part of the patella; right vastus medialis (VMO, channel 2) 80% of the way between the right ASIS and the joint space in front of the anterior border of the medial ligament; right vastus lateralis (VL, channel 3) 2/3 of the way between the right ASIS and the lateral side of the patella; right biceps femoris (BF, channel 4) halfway between the right ischial tuberoscity and the lateral epichondyle of the tibia; and right medial gastrocnemius (Gastroc, channel 5) on the most prominent bulge of the muscle (Bosmajian & Blumenstein, 1989). The ground electrode was placed on the right tibial tuberosity. The EMG unit was attached to the posterior belt loop of the subject's shorts with the wires bundled securely along the waistline. If the subject's shorts were too long, black elastic straps were used to fold and hold their shorts at mid-thigh. This method was sufficient to keep the clothing and EMG unit from interfering with the balance activity. To reduce as much EMG noise as possible, the EMG amplifier was placed away from all other electronics.

EMG Measurements

In order to quantitatively analyze the peak EMG signals, maximum isometric voluntary contractions (MVIC) were measured. During MVIC in healthy young subjects, the greatest part of the recruitable force is reliably elicited (Allen, Gandevia, & McKenzie, 1995). One benefit MVIC normalized data provides is the estimation of neuromuscular effort needed for a given exercise; therefore, giving an understanding at what capacity the muscles did work (Konrad, 2005). To normalize the data, the raw EMG signal was first rectified. Then the root mean square (RMS) was taken of the rectified EMG signal. The RMS of the EMG signal at the peaks of every measured squat was averaged and then divided by the MVIC recording. The final EMG reading is represented as a percentage of the MVIC, which is a more realistic representation of the increase or decrease in muscle activity. This method has become a valid and reliable measure for assessing mean peak neuromuscular activation (Anderson et al., 1998; Gullet et al., 2008; Marshall & Murphy, 2006; Rittweger, Mutschelknauss, & Felsenberg, 2003; Roelants et al., 2006; Schaub & Worrell, 1995; Shields et al., 2009; Stensdotter et al., 2003).

The maximum voluntary isometric contractions (MVICs) were measured randomly with the 3 dynamic squat conditions. EMG signal recordings were taken during the MVICs. The subject was asked to sit on the end of a table with an erect posture and knees and hips at 90° while the MVICs were collected (Anderson et al., 1998; Gullet et al., 2008; Marshal & Murphy, 2006). This was the starting position for two of the MVICs. The manual resistance was applied by the same researcher for all the subjects. Verbal encouragement was given to ensure the subject performs at their maximum ability during each MVIC. Encouragement phrases included: "Go, go, go! Keep pushing! You're almost there!" For the quadriceps MVIC, the subject performed a manually resisted knee extension. Resistance was applied by hand at the anterior side of the dominant ankle just above the malleoli. The hamstring MVIC was measured by manually resisting knee flexion. Resistance was applied by hand at the posterior side of the dominant ankle slightly above the malleoli. The gastrocnemius MVIC was measured by manually resisting plantar flexion. The subject laid prone on a table with their foot over the edge of the table. The foot started at 45° dorsiflexion. Resistance was applied by hand to the posterior surface of the rearfoot. When the instructor said "go," the subject forcefully pushed against the provided resistance. The subject continued the isometric contraction until the instructor said "stop." Three successful trials (approximately 10 seconds of recorded data per MVIC measurement) were collected with 1 minute of rest between trials.

For the dynamic squats, the Indo board was placed in the center of the room away from any objects and with padding on all sides. The safety protocol from the training day was used again for the data collection day. All subjects were instructed to stand barefoot with their feet hip width apart while performing the dynamic squat. Dynamic squats were practiced the day before and the day of data collection until the balance point was found and a performance at a constant pace was achieved. The dynamic squat was performed as followed: starting from an upright posture with approximately 5° knee flexion and outstretched arms with palms facing down, the subject slowly squatted until 60° of knee flexion was achieved. The subject then slowly returned to the starting posture. A metronome was used at 40 bpm to keep the tempo of the squats (4 seconds total for knee flexion and extension with a 2 second pause between squats until 3 consecutive squats were achieved). The subjects were also instructed to stand with their head and eyes forward and equal weight on each foot. For the B squat condition, the subjects performed the dynamic squat on a stable, hard surfaced floor. During the data collection, at least three successful trials (consisting of 3 consecutive squats) were collected for each subject during each condition. If the Indo Board touched the ground or the subject did not perform a full squat the trial was not considered a successful trial. Immediately after a trial was completed, the subject was allowed to rest for one minute. During and after the testing protocol, the subjects were instructed to report any discomfort or problems to the test operators.

Design and Analysis

A factorial study design was used in which peak EMG activity (averaged over 3 trials) in 5 lower body muscles (biceps femoris, vastus lateralis, rectus femoris, vastus medialis, and medial gastrocnemius) were the dependent variables. The independent variable was squat condition (Indo Board on a roller (B+R), Indo Board on an IndoFlo® Cushion (B+C), or baseline (B)). Data was entered into IBM SPSS Statistics (Version 18.0; 2010; SPSS Inc, Chicago, IL) and screened for normality. A MANOVA was calculated using SPSS with a significant alpha level of 0.05. The power analysis for a sample size of 14 subjects ($n_1 = 7$, $n_2 = 7$) was 0.3389.

CHAPTER 4

RESULTS

The purpose of this study was to compare differences in mean peak EMG activity in five lower-body muscles during dynamic squats on and off an Indo Board (B) with a roller (R) or an IndoFlo® Balance Cushion (C). Another variable (gender) collected was for purpose of discussion and may have an effect on any variance in the results. The dependent variables were peak EMG values of the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, and medial gastrocnemius. The first hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats. The second hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface.

Participants were recruited from Miami-Dade County and Broward County. Seven male and 7 female subjects (age: 31 ± 7 years) volunteered to participate in this study. All subjects had less than once a month or no Indo Board experience. The results are presented as follows: (a) normality and descriptive analysis and b) multivariate analysis.

Normality and Descriptive Analysis

The raw EMG peak values were transformed into useable data by calculating the linear envelope and then averaging the peak values of the 3 trials for each squat condition. The 3 trials for each maximum voluntary isometric contraction (MVIC) were averaged as well. The averaged peak muscle contraction values were divided by the averaged MVIC values to create a value that better represents the actual amount of effort the muscles were producing. Table 3 shows the descriptive statistics for the 5 dependent variables (peak neuromuscular contractions of the biceps femoris, medial gastrocnemius, vastus lateralis, rectus femoris, and vastus medialis).

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
bicepsB	14	.417	1.856	.99607	.087221	.326352
bicepsC	14	.455	3.119	1.45164	.187660	.702159
bicepsR	14	.644	6.186	1.91707	.484396	1.812444
Vastus lateralisB	14	2.270	9.844	4.11357	.526529	1.970092
Vastus lateralisC	14	1.654	5.874	3.59214	.329793	1.233974
Vastus lateralisR	14	.662	5.276	3.02664	.322965	1.208424
gastrocB	14	.379	3.072	1.33621	.180144	.674037
gastrocC	14	.586	3.314	1.78371	.203641	.761955
gastrocR	14	.414	5.068	1.80429	.327304	1.224658
rectusB	14	1.025	8.442	3.30829	.501430	1.876180
rectusC	14	1.475	8.929	3.61457	.509212	1.905297
rectusR	14	1.682	6.466	2.89836	.324961	1.215893
Vastus medialisB	14	2.481	10.530	4.50500	.513767	1.922340
Vastus medialisC	14	2.029	8.625	4.29786	.500246	1.871751
Vastus medialisR	14	1.797	7.175	3.73086	.370305	1.385554
Valid N (listwise)	14					

Table 3: Mean and standard deviation of the variables (as measured by percent (%) MVIC) for each condition (B = baseline, C = cushion, R = roller).

The initial values were not normally distributed, so a square root transformation was performed. Four out of 5 variables (gastrocnemius, vastus lateralis, vastus medialis, and rectus femoris) became normally distributed while the last variable (biceps femoris) had to undergo a $\log_{10}$ transformation to reach normality.

Multivariate Analysis

A multivariate of analysis of variance (MANOVA) was calculated to examine the five dependent variables at all levels of the independent variable. Table 4 shows the results of the multivariate test. A one-way MANOVA was calculated examining the effect of squat (flat, IndoFlo® Cushion, and Indo Board roller) on peak muscle contractions of the biceps femoris, gastrocnemius, vastus lateralis, rectus femoris, and vastus medialis. No significant effect was found (Lambda(10,70) = .736, p = .333). None of the muscles examined were significantly affected by the squat condition ($p > .01$).

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.970	227.080[a]	5.000	35.000	.000
	Wilks' Lambda	.030	227.080[a]	5.000	35.000	.000
	Hotelling's Trace	32.440	227.080[a]	5.000	35.000	.000
	Roy's Largest Root	32.440	227.080[a]	5.000	35.000	.000
Squat	Pillai's Trace	.272	1.136	10.000	72.000	.349
	Wilks' Lambda	**.736**	1.159[a]	10.000	70.000	**.333**
	Hotelling's Trace	.347	1.180	10.000	68.000	.320
	Roy's Largest Root	.310	2.228[b]	5.000	36.000	.073

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + Squat

Table 4: Results of the MANOVA test through all levels of the independent variable.

Another MANOVA was calculated to examine differences between genders in peak neuromuscular activation during each squat condition. Table 5 shows the results of this multivariate test. No significant differences were found (Lambda(11,2) = .167, p = .634). Gender had no significant effect on peak neuromuscular activation of the five lower body muscles during all squat conditions (p > .01).

Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.997	61.854[a]	11.000	2.000	.016
	Wilks' Lambda	.003	61.854[a]	11.000	2.000	.016
	Hotelling's Trace	340.198	61.854[a]	11.000	2.000	.016
	Roy's Largest Root	340.198	61.854[a]	11.000	2.000	.016
Gender	Pillai's Trace	.833	.905[a]	11.000	2.000	.634
	Wilks' Lambda	**.167**	.905[a]	11.000	2.000	**.634**
	Hotelling's Trace	4.980	.905[a]	11.000	2.000	.634
	Roy's Largest Root	4.980	.905[a]	11.000	2.000	.634

a. Exact statistic

b. Design: Intercept + Gender

Table 5: Results of the MANOVA test to examine differences between genders

Total neuromuscular activation from all five muscles was also calculated using the three averaged peak values of each squat trial (flat, cushion, and roller) (Table 6). The mean peak value for each muscle (before finding percent MVIC) was added under each squat condition to show total neuromuscular activation for each condition. This allows for an overall view of the neuromuscular activation in the lower body besides the individual muscle activation values.

Subject	Flat	Cushion	Roller
1	0.743	0.664	0.606
2	1.057	0.688	0.658
3	0.700	0.692	0.498
4	0.886	1.175	1.119
5	0.693	0.687	0.547
6	0.516	0.546	0.520
7	1.336	1.095	0.941
8	1.489	1.506	1.423
9	0.597	0.651	0.765
10	0.664	0.792	0.874
11	1.063	1.907	1.633
12	1.101	1.089	0.996
13	1.138	1.064	1.103
14	0.821	0.905	0.680

Table 6: Total lower body neuromuscular activation (in mVs) for each squat condition before calculating %MVIC.

CHAPTER 5

DISCUSSION

The purpose of this study was to examine differences between mean peak muscle contractions of the lower body during squats on an unstable training device. The dependent variables were peak EMG activity of the biceps femoris, gastrocnemius, vastus lateralis, rectus femoris, and vastus medialis. The two hypotheses researched were that peak neuromuscular activation would be greater during squats on both training devices compared to the flat stable ground squats and peak EMG measures would be greater during squats on the IndoFlo® Cushion compared to the Indo Board roller and flat ground. Any relationships between variables, unexpected findings, and importance of results will be discussed in more detail.

The first hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats. The statistics show there were no significant differences and no clear trends between peak muscle contractions during the three squat conditions. When looking at the overall sum of peak EMG activity from all five muscles (before transformation) during each squat condition, 50% of the subjects had higher peak EMG activity during the flat squat condition compared to the unstable conditions (Table 6). This means that half of the subjects recruited more muscle fibers in their lower body while squatting on the flat, stable surface compared to the Indo Board. Fatigue could not have been a factor in these results due to the randomized selection of squat condition order and manual voluntary isometric contraction (MVIC) order. Half of the subjects were randomly selected to perform the MVIC's first while the other half performed them after the squat conditions. Even the order in which the three MVIC's and the three squat conditions were performed was randomized. Behm, Anderson, and Curnew (2002) examined isometric contractions of the quadriceps and plantar flexors and reported significant decreases in force and muscle activation with the unstable platforms. In studies that found no significant increase in neuromuscular activation during movements on an unstable surface compared to a stable surface, researchers have concluded that a percentage of force had been diverted to joint stabilization (Anderson & Behm, 2004a; Carter et al., 2006; Korneki & Zschorlich, 1994; McBride, Cormie, & Deane, 2006). Under unstable conditions with the feet placed on a moderately unstable BOSU ball, the plantar flexors were not able to exert similar forces as under stable conditions (Behm, Anderson, & Curnew, 2002). In addition, unstable isometric squatting does not result in a significant increase in the muscle activity of agonist, antagonist, or synergist muscles (McBride, Cormie, & Deane, 2006). Contradictorily, there were a couple studies that did find increases in EMG activity of muscles controlling joints while unstable or perturbed (Gantchev & Dimitrova, 1996; Ivanenko et al., 1997). This discrepancy may be attributed to the muscles examined. These 2 studies evaluated stabilizer muscles while the current study evaluated prime movers. Their response to instability may differ from primarily stabilizing muscles (Anderson & Behm, 2004a). Stabilizer muscles are usually not directly involved in a movement but work to keep you steady so the primary movers can do their job. An example of lower body stabilizer muscles could include: the gluteus medius, anterior tibialis, abdominals, and erector spinae. Another possibility for discrepancy could be the difference in experience level. The past studies had subjects with experience on that particular balance training device, whereas, the current study had all beginner Indo Board users. This meant that stability assistance was needed to successfully perform a full squat without the Indo Board touching the ground or the subject falling off. Maybe the subjects were provided with too much stability help and did not have true muscle activation during the squat. Some subjects needed more stability assistance than others, so there should have been a way to quantify or differentiate between balance abilities among subjects. Unlike measurements of muscle activity, balance assessment values result from input originating from not only the peripheral somatosensory system but also from both the visual and vestibular systems (Guskiewicz & Perrin, 1996; Irrgang, Whitney, & Cox, 1994; Rozzi et al., 1999).

The second hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface. Statistical results have shown there were no significant differences in mean neuromuscular activation between the Indo Board with the IndoFlo® Cushion and the Indo Board with the roller; however, trends in the total mean neuromuscular activation of all five muscles move toward squats on the Indo Board with the IndoFlo® Cushion being greater than squats with the roller (Table 6). Although, squats on the flat, stable ground had higher neuromuscular activation than both the IndoFlo® Cushion and the roller (Table 6). With the IndoFlo® Cushion, there is instability in all planes of motion where as the Indo Board roller only has one (lateral) plane of motion; therefore, neuromuscular activation must increase to stabilize the body on this training device. If greater balance skills are sought, then devices with greater instability (i.e., smaller point of contact with the body or base, greater distances of the body from the base of support, or greater malleability of the device) should be used (Wahl & Behm, 2008). It has been shown that the use of moderately unstable training devices such as Dyna Discs and BOSU balls are not as effective as extremely unstable training devices such as Swiss balls and wobble boards in increasing activation in the lower body (Wahl & Behm, 2008). During squatting, there was more EMG activity in the soleus on the wobble board than in the stable, Dyna Disc, BOSU up, and BOSU down conditions (Wahl & Behm, 2008). However, the studies that have reported increased muscle EMG activity when an exercise was performed on an unstable rather than stable surface have had subjects with at least a year of experience using stability training devices (Anderson & Behm, 2004b; Behm et al, 2002; De Luca & Mambrito, 1987; Wahl & Behm, 2008). The subjects in the current study were beginners on the Indo Board with less than once every 3 months to no experience using this device; therefore, these subjects should not be expected to have the same results as those more experienced on the Indo Board or other balance training device.

Conclusions

According to the results of this study, performing squats on an Indo Board has no greater effect on lower body neuromuscular activation than doing squats on a flat, stable surface. There was a noticeable fear factor contributing to the subjects' insecurities on the Indo Board, which means the subjects were more concerned about not falling off the Indo Board than actually performing a fluid dynamic squat. Since the subjects were unable to perform on the Indo Board independently, researchers and trainers should not expect to see increase muscle activity because the muscles are not recruiting fully on their own to control balance. With the lack of muscle recruitment caused by using spotters for stability assistance, there would be no proprioception benefits. Through examining the results of this study, researchers can conclude that beginner Indo Board users can use this training device for balance practice under close supervision but should not expect to see increase muscle activity or proprioception benefits until the Indo Board can be used independently.

Practical Application and Use of Knowledge

Results of the current study show that the Indo Board does not have a significant difference on peak neuromuscular activity in the lower body during dynamic squats, but that does not mean it is not a good training device. The Indo Board can provide variety in an exercise routine with the added benefits of proprioception training once stability is achieved on their own. According to previous studies, static and dynamic proprioceptive training through the use of a wobble board and other balance training devices can significantly reduce sports-related injuries among healthy adolescents (DiStefano et al, 2009; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; McGuine & Keene, 2006; McLeod, Armstrong, Miller, & Sauers, 2009). The inclusion of balance training in a program is thought to improve co-activation of the muscles surrounding joints, increasing joint stiffness and active joint stability, and may also alter biomechanical injury risk factors (Hewett, Myer, & Ford, 2005; Lloyd, 2001; Hewett, Paterno, & Myer, 2002; Myer, Ford, McClean, & Hewett, 2006). Furthermore, the need for greater stabilizing responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sport (Anderson & Behm, 2004a). In order to gain the benefits of proprioception and increased muscle activity from performing exercise on a balance training device, expertise is needed. Balance training devices are only useful after an individual can perform on them independently without any form of stability assistance. Effects of a 6-week strength and proprioception training program on clinical measures of balance were examined (Mattacola & Lloyd, 1997). A single-plane balance board was used during the training program, which occurred three times a week for 10 minutes per session (Mattacola & Lloyd, 1997). Results showed a slight change in mean scores from baseline to intervention phase, which means the strength and proprioception training program positively influenced all subjects' ability to balance dynamically on a single-plane balance board (Mattacola & Lloyd, 1997). The Indo Board with the roller is an example of a single-plane balance board. Most beginners on balance training devices can benefit from closely supervised practice on the balance training device. It is known that training under unstable conditions provides a greater stress to the overall musculature compared to training under stable conditions (Anderson & Behm, 2004a). Stress, according to Selye's adaptation curve, is essential in forcing the body to adapt to new stimuli (Anderson & Behm, 2004a). Emery et al. (2005) demonstrated that healthy adolescents who complete a balance training program using tilt boards can effectively increase their balance time on an unstable surface. At 6 weeks, improvements in static and dynamic balance were observed in the intervention group but not in the control group (Emery et al., 2005). Another similar study made weekly progressions in the difficulty of the exercises and increased the number of repetitions, which may have aided in improving neuromuscular control (McLeod et al., 2009). A balance training program with timely progressions according to balance skill adaptations would be beneficial in learning to master the Indo Board.

Limitations

A major limitation to this study was the subject population due to the small turn out of volunteers. All subjects had little (less than once every 3 months) or no Indo Board experience, so the researcher could not examine if experience level was related to peak muscle activation on the training device. All subjects were healthy at the time of the study, so results may not be the same for people using the device for rehabilitation purposes. The results were also limited to muscle activation of only the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, and medial gastrocnemius.

Future Recommended Research

There are many opportunities for further research surrounding the findings of this study including but not limited to:

1) A study similar to the current study but including the core muscles.

2) A study examining neuromuscular differences between experienced and amateur Indo Board users.
3) Examine neuromuscular differences and training effects of multiple training devices (such as the BOSU, wobble board, and Indo Board).
4) Investigate neuromuscular differences of various exercises on the Indo Board (not just a squat).
5) Analyze neuromuscular activation during different phases of the squat on an Indo Board.
6) A training study to see how much practice time is needed for beginner Indo Board users to be able to use the Indo Board independently.

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APPENDIX

APPENDIX A

Please Help...

Barry University Grad Student in need of research subjects.

Requirements:

- Miami-Dade or Broward County resident
- Ages 18 to 39
- Healthy (no injuries or balance issues)
- Indo Board experience or
- No Indo Board experience
- Participate at least 1 hr on 2 separate days

If you meet these requirements and would like to participate, please contact Melissa at maweirich@gmail.com for more info.

Your help is greatly appreciated!

Melissa
Barry University Biomechanics Masters Program
11300 NE 2nd Ave • Miami Shores, FL 33161
Email: maweirich@gmail.com

Free Food • Help enhance balance training technology • Fun, friendly environment

APPENDIX B

Barry University
Consent Form

Your participation in a research project is requested. The title of the study is lower body neuromuscular activation during dynamic squats on an Indo Board. The research is being conducted by Melissa Weirich, a student in the human performance and leisure science department at Barry University, and is seeking information that will be useful in the field of biomechanics. The aims of the research are to investigate the differences in neuromuscular activation while performing squats on two balance training devices and a flat, stable surface. In accordance with these aims, the following procedures will be used: the participant will be briefed on the research instructions while filling out a short survey, each participant will be partake in a safety training day prior to the data collection day, and the randomized data collection will consist of three successful trials of dynamic squats on each balance training device (Indo Board + Roller, Indo Board + IndoFlo® Cushion, and flat ground) and 3 maximum voluntary isometric contraction (MVIC) measurements. We anticipate the number of participants to be thirty-two.

If you decide to participate in this research, you will be asked to do the following: arrive to your scheduled appointment on time; wear the proper attire (t-shirt and shorts); only use the research equipment when instructed; allow the researchers to obtain personal demographics (age, sex, and Indo Board and squatting experience) and lower body measurements; place & remove EMG electrodes on your lower body; perform dynamic squats on an Indo Board; perform a MVIC on your gastrocnemius, hamstrings, and quadriceps; and remain in the laboratory until the procedures are done (approx 60 minutes).

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects on your status within the community.

The risks of involvement in this study are minimal and include falling off the platform or muscular fatigue. The following procedures will be used to minimize these risks: thorough instructions on Indo Board usage will be given during the training day and data collection, clear communication about how the subject is feeling, no objects (besides the research equipment) will be within a ten foot radius of the participant, proper screening of each participant will rule out any health problems that could cause balance issues, and constant supervision. Although there are no direct benefits to you, your participation in this study may help our understanding of new training technologies.

As a research participant, information you provide will be kept anonymous, that is, no names or other identifiers will be collected on any of the instruments used. Data will be kept in a locked file in the researcher's office. By completing and returning this survey you have shown your agreement to participate in the study.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Melissa, at (808)446-4569, my supervisor, Dr. Egret, at (256) 226-1064, or the Institutional Review Board point of contact, Barbara Cook, at (305) 899-3020.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Melissa Weirich and that I have read and understand the information presented above. I give my voluntary consent to participate in this experiment.

_______________ _______________
Signature of Participant *Date*

_______________ _______________ _______________ _______________
Researcher *Date* *Witness* *Date*

(Witness signature is required only if research involves pregnant women, children, other vulnerable populations, or if more than minimal risk is present.)

APPENDIX C

Demographic & Experience Questionnaire

Name______________________________________

Age__________ Sex__________

Email address: ____

Describe any previous experience with an Indo Board (frequency of use, etc):__________

____

____

____

Describe any previous experience with squatting (recreational exercise, professional lifting, etc):

____

Do you have inner ear problems (Yes or No)? ______________________________________

Do you have any current injuries (Yes or No)? _____________________________________

Have you had a head injury within the past 6 weeks (Yes or No)? ____________________

Are you medically cleared to participate in exercise (Yes or No)?____________________

Are you taking any medications or supplements? ________________________________

If so, what? ____

APPENDIX D

JOURNAL MANUSCRIPT

Abstract

Despite the wide use of balance training devices in exercise or rehabilitation programs, there is no published research on the Indo Board. Results from this study could help determine a plan of action for strength training and injury prevention through use of this stability training device. The purpose of this study is to compare differences in mean peak EMG activity in the quadriceps, hamstrings, and gastrocnemius during dynamic squats on and off an Indo Board (B) with a roller (R) or an IndoFlo® Balance Cushion (C). Ten healthy male and female adults (aged 18-38 years) were recruited from Miami-Dade and Broward County to participate in this study. Electromyography (EMG) was used to measure peak neuromuscular activity in the lower body during the squat conditions. A multivariate of analysis of variance (MANOVA) was calculated to examine the five dependent variables at all levels of the independent variable with a significance level of $p < .05$. No significant effect was found (Lambda(10,70) = .736, $p = .333$). These findings suggest that despite the increased instability, squats on an Indo Board will produce similar neuromuscular results to normal flat surfaced squats in beginner Indo Board users. Beginner Indo Board users should not expect to see increased muscle activity and proprioception benefits until the Indo Board can be used independently from all stability assistance. Further investigation is needed to determine if experience level or a different form of exercise will affect lower body neuromuscular activity on an Indo Board.

Introduction

With the rapid growth of health and fitness technology comes the development of a variety of exercise devices that claim to have the solution to all the fitness needs. Some are well worth the time and money spent, while others do not hold true to their end of the bargain. According to the American College of Sports Medicine's annual survey, core training, stability ball workouts, and balance training are some of the most popular fitness trends of 2009 [26]. These concepts are all inter-related. Stability ball routines focus on core muscles and require a great deal of balance to perform [17]. The biggest benefit of core training is to develop functional fitness - that is, fitness that is essential to both daily living and regular activities [23]. Using the concept of functional kinetics (which is observing, analyzing, and teaching human movement), the stability ball was incorporated into programs to treat adults with orthopedic problems. A stability, or Swiss, ball is an air-filled ball constructed of elastic, soft PVC with a diameter of 35 to 85cm. Other devices that stress core muscles and challenge balance through neuromuscular activation include the BOSU ball, wobble board, Dyna Disc, whole-body vibration (WBV) platform, and the Indo Board. The BOSU ball, which stands for "both sides utilized," was created by David Weck. It focuses on the human fundamental concept of alternating bilateral coordination of both sides of the body [29]. The wobble board is similar to the BOSU ball. It has a round, flat, hard surface on one side and a rounded surface on the opposite side. The rounded surface of the wobble board is smaller and made of solid plastic. The biggest difference between these two devices is the wobble board can only be used on one side (round surface down). A Dyna Disc can be used on both sides like a BOSU but does not have a hard surface on one side. It has a bumpy surface on one side to help with traction and a smooth flat surface on the other. It can be used by itself or with another Dyna Disc, such as a squat with one foot on each disc. Compared to the other training devices, the Dyna Disc and BOSU ball do not provide sufficient challenges to the neuromuscular system of highly resistance-trained athletes [28]. A balance training device that is different from all the others is the whole-body vibration (WBV) platform. Whole-body vibration is a form of exercise that uses a mechanical platform device to elicit a rapid series of muscle contractions by the involuntary muscle stretch reflex (IMSR). The platform vibrates rapidly side-to-side like a teeter-totter motion. Previous research has shown that a single bout of WBV improves muscle performance of the lower body and balance in young healthy adults by increasing neuromuscular activation [1, 24, 27]. The root mean square of the soleus and gastrocnemius EMG activity increased significantly on average 21.6% and 35.2% respectively with the use of an unstable platform [27]. Whole-body vibration was used as a pilot study for this research. Use of surface EMG electrodes on 4 lower body muscles during dynamic squats on and off a WBV platform was sufficient to measure neuromuscular activation during the activity; so similar methods can be used during dynamic squats on an Indo Board. The balance training device used in this study (an Indo Board) will not be vibrating; however, it is still an unstable object on which the dynamic squats will be performed. There are two devices that the Indo Board deck can balance on: the IndoFlo® Cushion and the roller [14]. When the deck is placed on an IndoFlo® Cushion, there is instability in all directions; whereas with the roller, there is instability only in one plane. The Indo Board, whether it is on the IndoFlo® Cushion or the roller, requires a high level of skill to successfully use it. Balance training devices similar to the Indo Board stress the neuromuscular system to stabilize the body but to what extent?

There is still plenty of research to be done on the effects of Indo Board balance training for specific sports and how it can be used as an alternative to traditional resistance training. The purpose of this study is to compare differences in mean peak EMG activity in the quadriceps, hamstrings, and gastrocnemius during dynamic squats on and off an Indo Board (B) with a roller (R) or an IndoFlo® Balance Cushion (C). The other variable being collected, gender, is for purpose of discussion and may have an effect on any variance in the results. In order to determine differences between neuromuscular activation between devices, the following hypotheses will be investigated: (1) mean neuromuscular activation will be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats and (2) mean neuromuscular activation will be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface.

Methods

Seven healthy male and 7 healthy female adults (aged 18-38 years) were recruited from Miami-Dade and Broward County to participate in this study. All subjects were healthy and medically cleared to perform physical activity. After a review of the experimental and safety protocol, the subjects signed an informed consent document approved by the Barry University Institutional Review Board, filled out a short experience questionnaire and demographic survey, and completed a practice session on the different Indo Board devices. Participants were made aware they may drop out of the study at any time without penalty.

Instrumentation

A 30" x 18" natural-colored Indo Original Board® was used for two of the three squat conditions. The first condition was a baseline (B) dynamic squat on the flat, stable ground. The second condition (B+R) was a dynamic squat performed on an Indo Board with a 6.5" diameter roller underneath the board. The third condition (B+C) was a dynamic squat performed on an Indo Board with a 14" diameter polyvinyl IndoFlo® Balance Cushion inflated to a height of 4" underneath the board. A Delsys electromyography (EMG) system was used to measure peak muscle contractions created by the quadriceps (vastus lateralis, vastus medialis, and rectus femoris), biceps femoris, and medial gastrocnemius. The amplified 5-channel EMG signals were band pass filtered near the electrodes and transmitted to a receiver (Butterworth filter, 10-200 Hz band pass). The EMG signal was collected over 30 seconds and sampled at 1000 Hz. All EMG data was collected and processed with Vicon Nexus (Centennial, CO) software and presented with Vicon Polygon (Centennial, CO) software.

Procedures

The subjects were instructed prior to their arrival to wear athletic clothing (shorts and a t-shirt) during the training and testing. The training and testing were performed barefoot. Indo Board training and data collection occurred on 2 separate days and required about 15 minutes of the subject's time on the first day and 45 minutes of the subject's time on the second day. The procedure consisted of Indo Board and safety training, EMG preparation, and randomized data collection of the 3 maximum isometric voluntary contractions (MVICs) and the 3 squat conditions (B + R, B + C, and B). Upon arrival at Barry University's biomechanics lab on the day of data collection, the subject was prepped by scrubbing their skin with alcohol pads and shaving excess body hair, if needed, at the site of the five electrode placements. The ground electrode was placed on the right tibial tuberosity. The EMG unit was attached to the posterior belt loop of the subject's shorts with the wires bundled securely along the waistline.

In order to quantitatively analyze the peak EMG signals, maximum isometric voluntary contractions (MVIC) were measured. The MVIC's were measured randomly with the 3 dynamic squat conditions. The quadriceps MVIC was measured by a manually resisted knee extension. The biceps femoris MVIC was measured by a manually resisted knee flexion. A manually resisted plantar flexion from the prone position measured the gastrocnemius MVIC. Three successful trials (approximately 10 seconds of recorded data per MVIC measurement) were collected with 1 minute of rest between trials.

For the dynamic squats, the Indo board was placed in the center of the room away from any objects and with padding on all sides. All subjects were instructed to stand barefoot with their feet hip width apart while performing the dynamic squat. Research assistants acted as spotters in front of and behind the subject to help with stabilization if needed. The spotters held the hands of the subject while getting on and dismounting from the Indo Board with the roller (B+R) and IndoFlo® Cushion (B+C). For the B squat condition, the subjects performed the dynamic squat on a stable, hard surfaced floor. During the data collection, at least three successful trials (consisting of 3 consecutive squats) were collected for each subject during each condition. If the Indo Board touched the floor or the subject did not complete a full squat, the trial was considered unsuccessful and not included in the data collection. Immediately after a trial was completed, the subject was allowed to rest for one minute. During and after the testing protocol, the subjects were instructed to report any discomfort or problems to the test operators.

Design and Analysis

A factorial study design was used in which peak EMG activity (averaged over 3 trials) in 5 lower body muscles were the dependent variables. The independent variable was squat condition (Indo Board on a roller (B+R), Indo Board on an IndoFlo® Cushion (B+C), or baseline (B)). Data was entered into IBM SPSS Statistics (Version 18.0; 2010; SPSS Inc, Chicago, IL) and screened for normality. A MANOVA was calculated using SPSS with a significant alpha level of 0.05. The power analysis for a sample size of 14 subjects ($n_1 = 7$, $n_2 = 7$) was 0.3389.

Results

Normality and Descriptive Analysis

The raw EMG peak values were transformed into useable data by calculating the linear envelope and then averaging the peak values of the 3 trials for each squat condition. The 3 trials for each maximum voluntary isometric contraction (MVIC) were averaged as well. The averaged peak muscle contraction values were divided by the averaged MVIC values to create a value that better represents the actual amount of effort the muscles were producing. The initial values were not normally distributed, so a square root transformation was performed. Four out of 5 variables (gastrocnemius, vastus lateralis, vastus medialis, and rectus femoris) became normally distributed while the last variable (biceps femoris) had to undergo a $\log_{10}$ transformation to reach normality.

Multivariate Analysis

A multivariate of analysis of variance (MANOVA) was calculated to examine the five dependent variables at all levels of the independent variable. Table 1 shows the results of the multivariate test. A one-way MANOVA was calculated examining the effect of squat (flat, IndoFlo® Cushion, and Indo Board roller) on peak muscle contractions of the biceps femoris, gastrocnemius, vastus lateralis, rectus femoris, and vastus medialis. No significant effect was found (Lambda(10,70) = .736, p = .333). None of the muscles examined were significantly affected by the squat condition (p > .01).

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.970	227.080[a]	5.000	35.000	.000
	Wilks' Lambda	.030	227.080[a]	5.000	35.000	.000
	Hotelling's Trace	32.440	227.080[a]	5.000	35.000	.000
	Roy's Largest Root	32.440	227.080[a]	5.000	35.000	.000
Squat	Pillai's Trace	.272	1.136	10.000	72.000	.349
	Wilks' Lambda	**.736**	1.159[a]	10.000	70.000	**.333**
	Hotelling's Trace	.347	1.180	10.000	68.000	.320
	Roy's Largest Root	.310	2.228[b]	5.000	36.000	.073

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + Squat

Table 1: Results of the MANOVA test through all levels of the independent variable.

Another MANOVA was calculated to examine differences between genders in peak neuromuscular activation during each squat condition. Table 2 shows the results of this multivariate test. No significant differences were found (Lambda(11,2) = .167, p = .634). Gender had no significant effect on peak neuromuscular activation of the five lower body muscles during all squat conditions (p > .01).

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.997	61.854[a]	11.000	2.000	.016
	Wilks' Lambda	.003	61.854[a]	11.000	2.000	.016
	Hotelling's Trace	340.198	61.854[a]	11.000	2.000	.016
	Roy's Largest Root	340.198	61.854[a]	11.000	2.000	.016
Gender	Pillai's Trace	.833	.905[a]	11.000	2.000	.634
	Wilks' Lambda	**.167**	.905[a]	11.000	2.000	**.634**
	Hotelling's Trace	4.980	.905[a]	11.000	2.000	.634
	Roy's Largest Root	4.980	.905[a]	11.000	2.000	.634

a. Exact statistic

b. Design: Intercept + Gender

Table 2: Results of the MANOVA test to examine differences between genders.

Total neuromuscular activation from all five muscles was also calculated using the three averaged peak values of each squat trial (flat, cushion, and roller) (Table 3). The mean peak value for each muscle (before finding percent MVIC) was added under each squat condition to show total neuromuscular activation for each condition. This allows for an overall view of the neuromuscular activation in the lower body besides the individual muscle activation values.

Subject	**Flat**	**Cushion**	**Roller**
1	0.743	0.664	0.606
2	1.057	0.688	0.658
3	0.700	0.692	0.498
4	0.886	1.175	1.119
5	0.693	0.687	0.547
6	0.516	0.546	0.520
7	1.336	1.095	0.941
8	1.489	1.506	1.423
9	0.597	0.651	0.765
10	0.664	0.792	0.874
11	1.063	1.907	1.633
12	1.101	1.089	0.996
13	1.138	1.064	1.103
14	0.821	0.905	0.680

Table 3: Total lower body neuromuscular activation (in mVs) for each squat condition before calculating %MVIC.

Discussion

The first hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on both balance training devices compared to the flat, stable surface squats. The statistics show there were no significant differences and no clear trends between peak muscle contractions during the three squat conditions. When looking at the overall sum of peak EMG activity from all five muscles (before transformation) during each squat condition, 50% of the subjects had higher peak EMG activity during the flat squat condition compared to the unstable conditions (Table 3). This means that half of the subjects recruited more muscle fibers in their lower body while squatting on the flat, stable surface compared to the Indo Board. Fatigue could not have been a factor in these results due to the randomized selection of squat condition order and manual voluntary isometric contraction (MVIC) order. Half of the subjects were randomly selected to perform the MVIC's first while the other half performed them after the squat conditions. Even the order in which the three MVIC's and the three squat conditions were performed was randomized. A previous study examined isometric contractions of the quadriceps and plantar flexors and reported significant decreases in force and muscle activation with the unstable platforms [2]. In studies that found no significant increase in neuromuscular activation during movements on an unstable surface compared to a stable surface, researchers have concluded that a percentage of force had been diverted to joint stabilization [2, 6, 23, 28]. Under unstable conditions with the feet placed on a moderately unstable BOSU ball, the plantar flexors were not able to exert similar forces as under stable conditions [3]. In addition, unstable isometric squatting does not result in a significant increase in the muscle activity of agonist, antagonist, or synergist muscles [19]. Contradictorily, there were a couple studies that did find increases in EMG activity of muscles controlling joints while unstable or perturbed [8, 13]. This discrepancy may be attributed to the muscles examined. These 2 studies evaluated stabilizer muscles while the current study evaluated prime movers. Their response to instability may differ from primarily stabilizing muscles [2].

The second hypothesis stated that mean neuromuscular activation would be greater during dynamic squats on the Indo Board with the IndoFlo® Balance Cushion compared to the Indo Board with the roller and the flat surface. Statistical results have shown there were no significant differences in mean neuromuscular activation between the Indo Board with the IndoFlo® Cushion and the Indo Board with the roller; however, trends in the total mean neuromuscular activation of all five muscles move toward squats on the Indo Board with the IndoFlo® Cushion being greater than squats with the roller (Table 3). Although, squats on the flat, stable ground had higher neuromuscular activation than both the IndoFlo® Cushion and the roller (Table 3). With the IndoFlo® Cushion, there is instability in all planes of motion where as the Indo Board roller only has one (lateral) plane of motion; therefore, neuromuscular activation must increase to stabilize the body on this training device. If greater balance skills are sought, then devices with greater instability (i.e., smaller point of contact with the body or base, greater distances of the body from the base of support, or greater malleability of the device) should be used [28]. It has been shown that the use of moderately unstable training devices such as Dyna Discs and BOSU balls are not as effective as extremely unstable training devices such as Swiss balls and wobble boards in increasing activation in the lower body [28]. During squatting, there was more EMG activity in the soleus on the wobble board than in the stable, Dyna Disc, BOSU up, and BOSU down conditions [26]. However, the studies that have reported increased muscle EMG activity when an exercise was performed on an unstable rather than stable surface have had subjects with at least a year of experience using stability training devices [2, 3, 28]. The subjects in the current study were beginners on the Indo Board with less than once every 3 months to no experience using this device; therefore, these subjects should not be expected to have the same results as those more experienced on the Indo Board or other balance training device.

Conclusions

According to the results of this study, performing squats on an Indo Board has no greater effect on lower body neuromuscular activation than doing squats on a flat, stable surface. All subjects were beginner Indo Board users and could not use the Indo Board independently. Stability assistance was needed to successfully perform a full squat without the Indo Board touching the ground or the subject falling off. Maybe the subjects were provided with too much stability help and did not have true muscle activation during the squat. Some subjects needed more stability assistance than others, so there should have been a way to quantify or differentiate between balance abilities among subjects. Unlike measurements of muscle activity, balance assessment values result from input originating from not only the peripheral somatosensory system but also from both the visual and vestibular systems [9, 12, 25].

There was a noticeable fear factor contributing to the subjects' insecurities on the Indo Board. Since the subjects were unable to perform on the Indo Board independently, researchers and trainers should not expect to see increase muscle activity because the muscles are not recruiting fully on their own to control balance. With the lack of muscle recruitment caused by using spotters for stability assistance, there would be no proprioception benefits. Through examining the results of this study, researchers can conclude that beginner Indo Board users can use this training device for balance practice under close supervision but should not expect to see increase muscle activity or proprioception benefits until the Indo Board can be used independently.

Practical Application and Use of Knowledge

Results of the current study show that the Indo Board does not have a significant difference on peak neuromuscular activity in the lower body during dynamic squats, but that does not mean it is not a good training device. The Indo Board can provide variety in an exercise routine with the added benefits of proprioception training once stability is achieved on their own. According to previous studies, static and dynamic proprioceptive training through the use of a wobble board and other balance training devices can significantly reduce sports-related injuries among healthy adolescents [6, 7, 20, 21]. The inclusion of balance training in a program is thought to improve co-activation of the muscles surrounding joints, increasing joint stiffness and active joint stability, and may also alter biomechanical injury risk factors [10, 16, 11, 22]. Furthermore, the need for greater stabilizing responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sport [2]. In order to gain the benefits of proprioception and increased muscle activity from performing exercise on a balance training device, expertise is needed. Balance training devices are only useful after an individual can perform on them independently without any form of stability assistance. The effect of a 6-week strength and proprioception training program on clinical measures of balance was examined in 1997 [18]. A single-plane balance board was used during the training program, which occurred three times a week for 10 minutes per session [18]. Results showed a slight change in mean scores from baseline to intervention phase, which means the strength and proprioception training program positively influenced all subjects' ability to balance dynamically on a single-plane balance board [18]. The Indo Board with the roller is an example of a single-plane balance board. Most beginners on balance training devices can benefit from closely supervised practice on the balance training device. It is known that training under unstable conditions provides a greater stress to the overall musculature compared to training under stable conditions [2]. Stress, according to Selye's adaptation curve, is essential in forcing the body to adapt to new stimuli [2]. Healthy adolescents who complete a balance training program using tilt boards can effectively increase their balance time on an unstable surface [7]. At 6 weeks, improvements in static and dynamic balance were observed in the intervention group but not in the control group [7]. Another similar study made weekly progressions in the difficulty of the exercises and increased the number of repetitions, which may have aided in improving neuromuscular control [21]. A balance training program with timely progressions according to balance skill adaptations would be beneficial in learning to master the Indo Board.

Limitations

A major limitation to this study was the subject population due to the small turn out of volunteers. All subjects had little (less than once every 3 months) or no Indo Board experience, so the researcher could not examine if experience level was related to peak muscle activation on the training device. All subjects were healthy at the time of the study, so results may not be the same for people using the device for rehabilitation purposes. The results were also limited to muscle activation of only the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, and medial gastrocnemius.

Future Recommended Research

There are many opportunities for further research surrounding the findings of this study including but not limited to:

1) A study similar to the current study but including the core muscles.
2) A study examining neuromuscular differences between experienced and amateur Indo Board users.
3) Examine neuromuscular differences and training effects of multiple training devices (such as the BOSU, wobble board, and Indo Board).
4) Investigate neuromuscular differences of various exercises on the Indo Board (not just a squat).
5) Analyze neuromuscular activation during different phases of the squat on an Indo Board.
6) A training study to see how much practice time is needed for beginner Indo Board users to be able to use the Indo Board independently.

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