EFFECTS OF YOGA ON LOW BACK STABILITY, STRENGTH AND ENDURANCE

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Thesis Submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
in

Industrial and Systems Engineering

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September 8, 2011
Blacksburg, Virginia

Keywords: Yoga exercise, Low Back Stability, Endurance, Strength, Postural Control, Wobble Chair

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ABSTRACT

AIMS: To investigate the effects of Yoga on improving low back stability (threshold of stability, and mean total velocity of center of pressure), trunk strength (isometric strength in extension and flexion), and back endurance (isometric endurance in extension, flexion, and side laterals).

METHODS: A pretest posttest control group experimental design was used. Sixteen participants, 10 females and 6 males, without a history of low back pain, and no prior experience of Yoga, were recruited. Yoga participants were recruited following registration in a yoga class; the control subjects were selected and recruited selectively in order to match the stature and body mass of the Yoga participant pool. Performance was measured prior to the beginning of Yoga exercises and 7 weeks later for both the groups.

RESULTS: Contrary to the control group, the Yoga group significantly improved in terms of low back stability (decrease in threshold of stability by ~19%) and sway parameters (decrease in mean total velocity of COP by ~17%).

CONCLUSIONS: The outcomes of this study illustrate the potential of Yoga as a low-impact exercise regime for improving low back stability via neuromuscular control and proprioception. There was no significant difference in trunk strength and endurance when comparing the two groups; therefore, the Yoga exercise was equally effective as the regular exercises.

Dedication

I dedicate this thesis to my Mom, Bharati, my Dad, Dilip, my most beloved Sister, Shreni and my uncle, Dhruva. This effort would not have been possible without the undying support and faith of this Mistry family.

ACKNOWLEDGEMENTS

I would like to thank my thesis committee, Dr. Michael Agnew, Dr. Maury Nussbaum and Dr. Thurmon Lockhart for their support and patience. Dr. Agnew, I owe my biggest lessons in Masters education to you. Thank you for your incredible patience and understanding.

I would also like to thank Ranjana Mehta for her lessons in writing. Shreni, Brad, Wade, and Nashita, thank you for aiding me in my thesis endeavors, listening, making me laugh, and providing unforgettable moments.

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Chapter 1: Introduction

1.1 Background and Significance

Low Back Pain (LBP) disables around 5 million Americans every year and results in about $100 billion in direct and indirect costs related to LBP treatments (National Health Interview Survey, 2007, Springen, 2008). After the first episode of low back pain, about 25% of patients have a recurrence within the next year (Stanton et al., 2008). In addition to their pain, these patients' health problems typically include reduced physical function and psychological distress (Bogduk et al., 2004). Despite the availability of a variety of treatments for low back injuries, such as exercise, medications, and spinal manipulation, most treatments have shown mixed evidence in terms of a significant reduction in pain symptoms and disability (Bogduk et al., 2004). In an effort to reduce work related injury, and promote health and wellness within the workforce, many of the nation's largest employers (i.e., workforce of 750+ employees) incorporate health promotion programs; about 65% of these employers have full or part-time employees that are responsible for such programs / activities within a company (Linnan et al., 2004). Considering the economic and social effects of low back pain, appropriate management is necessary. As such, there is not only a need to further investigate the existing treatments and pathology of low back pain but to also examine alternate LBP treatment modalities as some may act as a proactive step to help prevent LBP and the associated impact of its prevalence. Currently, about 17% of Americans who experience back pain have sought forms of complementary alternative medicine (CAM) within which Yoga is ranked as one of the top 10 CAM modalities (National Health Interview Survey, 2008). About 6.1% or 13 million adults in America practiced Yoga in 2007. While Yoga has been adopted by many as a form of CAM, and even adopted in some employer-based health promotion programs, empirical evidence is lacking in regards to its viability to reduce injury risk.

By definition, CAM practices are not considered to be conventional medicine because there is insufficient proof that they are safe and effective (National Center for Complementary and Alternative Medicine, 2005). CAM treatments such as Yoga, along with Tai Chi, Pilates, meditation, deep breathing exercises, and biofeedback, are considered as mind-body exercises. Out of these, Tai Chi and Pilates are examples of CAM treatments that particularly draw parallels to the characteristics of Yoga exercise. These low-impact exercises focus on body alignment, postures, and breathing techniques without the use of physiological overload (traditionally). These exercises have developed a few variations over generations of followers and enthusiasts within which, Yoga in particular, has many different forms of practices that focus on the mind, body and spirituality. The present study focuses on the most basic (beginner level) form of *Hatha* Yoga comprising of aforementioned characteristics of low-impact exercises, which do not rely on any environmental or ambience alterations.

Supporters of Yoga have claimed satisfactory improvement in general fitness of the mind and body; furthermore, some low back patients have reported a reduction of pain intensity and low back pain symptoms (Sherman et al., 2005). In addition, there is evidence that illustrates the efficacy of Yoga practice on bodily diseases and organ health; such as bronchial asthma (Vedanthan et al., 1998), pulmonary tuberculosis (Visweswaraiah et al., 2004), drug addiction (Shaffer et al., 1997), and hypertension (Murugesan et al., 2000). While somewhat minimal in scope, the existing evidence of the benefits of Yoga on skeletal and/or muscle health, such as osteoarthritis (Garfinkel et al., 1994), carpel tunnel syndrome (Garfinkel et al., 1998), multiple sclerosis (Oken et al., 2004), and even the lower back (Kimberly et al., 2005) do illustrate positive biomechanical effects. These effects were measured via psychophysical measures however; an improvement in terms of objective data has not been observed using a metric that quantifies biomechanical and/ or physical performance. Through a review of the literature, only one searchable paper demonstrated higher EMG activation of rectus abdominis during loading as a result of practicing Yoga that has implications relevant to objective measures of LBP like trunk co-activity and stability (Petrofsky et al., 2005a). Furthermore, another three peer-reviewed studies of effects of Yoga on chronic low back pain were found: one study lacked a control group (Vidyasagar et al., 1989) while the other was not powered to reach statistical significance (Galantino et al., 2004), and the third was a feasibility analysis of *Iyengar* Yoga presenting only baseline data and adherence rates to therapy (Jacobs et al., 2004).

The physical exercise version of Yoga, *Hatha* Yoga, focuses on the maintenance of specific postures known as *Asanas.* The purposes of the Asanas are to condition the body, and consequently increase strength, flexibility and endurance. Practice of these poses is also thought to improve concentration, focus and the awareness of body sensations (Satchidananda, 1990). More so, these Yoga postures are argued to stimulate body organs, promoting digestion, improving circulation and nervous system functioning (Iyengar, 2005). Asanas are performed standing, sitting, reclining or inverted and may involve forward bending, backward bending, and twisting of the trunk. It has been argued that holding these poses for a prolonged period of time (about 30 seconds or more for each pose) along with controlled breathing may be one of the most important aspects of Yoga exercise, since it impels the mind and body to focus on the active muscles responsible for stabilizing the body in the various poses (Weil, 2006). Several proposed mechanisms have been offered to explain the neuromuscular benefits of yoga. One idea is that the repetitive stretching and force resistance movements of yoga postures increase blood circulation to muscles and connective tissues, and also improves proprioception by stimulating intrafusal and golgi tendon organ feedback mechanisms (Riley, 2004). This has been supported through evidence of increased muscle size, strength and endurance (Brochu, 2002). Improved proprioception tone and perhaps, spinal stability, also result from the emphasis on proper skeletal alignment during performance of yoga poses that strengthen core abdominal and spinal stabilizer muscles. Finally, Yoga has also been shown to improve balance

(Gauchard, 1999; Bastille et al., 2004; Galantino et al., 2004) and lower extremity muscle strength (Brochu, 2002). These arguments have been further substantiated by efficacies of exercises that bear similarities with Yoga, such as Tai Chi, and passive stretching (Slade et al., 2007).

1.2 Comparisons Between Yoga and Other Low Impact Exercises

Yoga involves similar physical and mental demands associated with Tai Chi and Pilates. With respect to the physical demands, these techniques focus on the trunk core; which includes the abdominal, gluteal and paraspinal muscles. Each exercise follows a controlled range of motion of the upper and lower limbs, placing demand on the core musculature. These three modalities are low-impact exercises, meaning that there is no physiological overload while exercising. The goals of these exercises are to increase muscle strength and endurance, and to improve posture and balance. With regard to the mental (i.e., psychological) benefits, these exercises emphasize the practice of proper breathing and concentration during the performance of the respective postures.

Tai Chi exercises are generally performed while standing, and Pilates postures are typically performed in a seated or supine/prone posture. These postures are assumed through slow controlled movements of the limbs in order to maintain balance. Yoga exercise incorporates postures similar to those associated with Tai Chi and Pilates (i.e., standing, seated and supine/prone postures). Given the wide range of postures assumed during Yoga, there are similarities in the postures that are utilized in Tai Chi and Pilates separately. For example, the locust pose is shared by Yoga and Pilates alike, and the warrior pose is used in both Yoga and Tai Chi.

There are similarities between Yoga exercises and some rehabilitation exercises that are intended to correct faulty motor patterns (Aktuhota et al., 2004; McGill, 2007). For example, the movement and instructions for performing Yoga's *utkatasana, or fierce pose*, and the rehabilitation exercise, *rising from chair pose*, suggested by McGill (2007) are essentially the same. A few obvious similarities that are visible from looking at the postures are; maintaining a straight neutral back without losing lumbar lordosis, and extension of the spine with the ribcage rising and spine flexion solely occurring through the hips (Fig.1). Upon many repetitions, a motor pattern develops and the participant successfully makes conscious efforts to flex from the hip over the course of the exercise. Other examples of rehabilitation exercises similar in nature to Yoga Asanas are: the cat/camel exercise, intermediate bird dog, potty squat and single legged squat (Fig. 2, Fig. 3). Although similar in terms of posture, rehabilitation exercises require multiple repetitions to learn and develop a motor pattern, whereas in Yoga, a pose has to be achieved slowly and held for a longer duration. In essence, Yoga exercises (and Tai Chi) highlight the importance of performing the poses such that the mind achieves cognizance of activated muscles, resulting in a healthier motor pattern.

Rising from the chair

Chair Pose

Fig.1 Comparison of rehabilitation exercise (Rising from the Chair) and its corresponding Yoga exercise (Chair pose). Both forms of exercise stress on the lumbar lordosis of the low back ensuring that bending occurs at the hips instead of the back (Photo taken by the author)

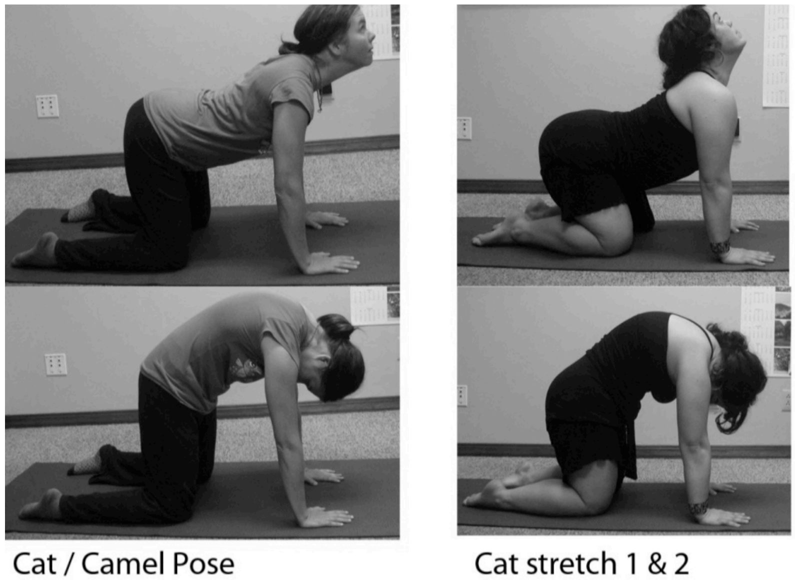


Fig. 2. Comparison of rehabilitation exercise (Cat/Camel Pose) and its corresponding Yoga exercise (Cat Stretch 1 & 2) (Photo taken by the author)

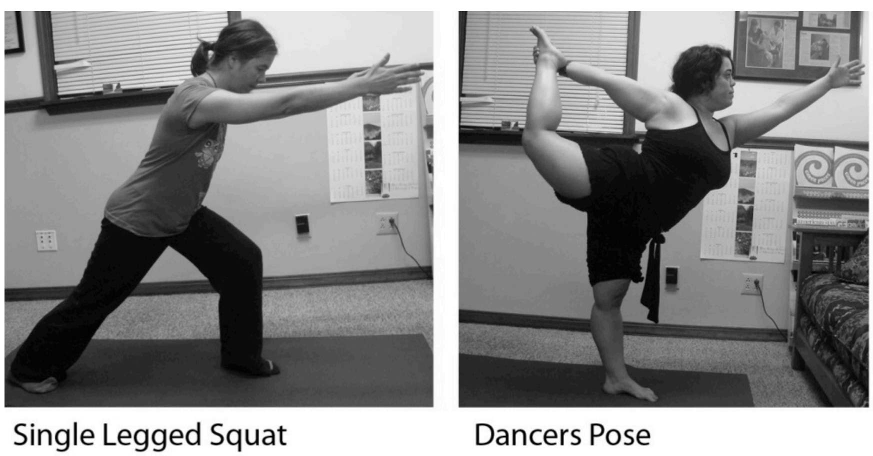


Fig. 3. Comparison of rehabilitation (Single Legged Squat) and its corresponding Yoga exercise (Dancer's Pose) (Photo taken by the author)

While the precise mechanism that underlies the prophylactic and therapeutic effect of Yoga remains unclear, the practice of Yoga could be argued to have a beneficial impact on physical and mental factors that are associated with LBP. Keeping in mind that the low back achieves stability through a control system that includes active, passive and neuromuscular subsystems; an exercise intervention that may improve stability should condition each of these interdependent subsystems. The active subsystem consists of local and global muscles. As described by Hodges et al., (1996), and Sharp et al., (2004), the local musculature has a direct attachment to the spine and controls segmental motion (e.g. the multifidi). They are intersegmental and produce only small amounts of force and seem to aid in proprioception and postural control, which could lead to better spinal stability if the local muscles are trained accordingly (Norris, 2000; McGill, 2009). Such training could be achieved through the use of stabilization exercises where the spine is held in static positions, such as in Yoga. However, it is reasonable to consider that contributions from both the local and global muscles may be needed for low back stabilization (Hodges et al., 1996) and training of local muscles alone may not be sufficient.

Additionally, for patients with LBP, Yoga appears to address imbalances in the musculoskeletal system affecting spinal alignment and posture. For example, Yoga targets many muscle groups with the aim of balancing strength and conditioning certain underutilized core muscles (Galantino et al., 2004; Williams et al., 2005). More so, proprioception, which is considered important for providing low back stability, is significantly impaired by muscular fatigue (Taimela et al., 1999). Previous research supports this argument, as a larger diffusion of center of pressure, used as postural sway parameter, has been observed to occur following the onset of localized fatigue in the lumbopelvic musculature (Granata et al., 2008). The underlying mechanism could be due to the fact that the neuromuscular control of the spine is inhibited by feedback delay (Franklin et al., 2006). This feedback delay, which could be both myoelectric and electromechanical delay, is generally an effect of fatigue (Hotobagyi et al. 1991, Hagbarth et al. 1995). Although fatigue may influence several control sub-systems, it is difficult to predict whether these effects are sufficient to affect overall stability. Furthermore low back endurance and strength show inconclusive evidence of any existing relationship with the occurrence of low back injuries (Hamberg-Ven-Reenen et al., 2007). However, there seems to be no counterargument suggesting that improving low back stability could be adversely affected by an improvement in endurance of the supporting musculature.

Thus, the aim of this study was to determine the efficacy of Yoga in improving low back stability, strength, and endurance that may lead to an effective proactive and reactive treatment modality for low back injuries.

1.3 Research Objectives and Hypothesis

The purpose of this study was to investigate the effectiveness of a 7-week program of Yoga exercise in a sample of people without low back pain. As such, the experiment addressed the following hypotheses:

Hypothesis 1: The practice of Yoga, over a 7-week period, will increase low back stability, measured via threshold of stability, more so than any changes observed within a control group.

Hypothesis 2: The practice of Yoga, over a 7-week period, will increase low back stability, measured via mean total velocity, more so than any changes observed within a control group.

Hypothesis 3: The practice of Yoga, over a 7-week period, will increase core endurance (back extensors, flexors, side laterals) more so than any changes observed within a control group.

Hypothesis 4: The practice of Yoga, over a 7-week period, will increase in isometric strength (back extensors and flexors), more so than any changes observed within a control group.

Chapter 2: Research Design and Methods

A pretest posttest control group experimental design was used to quantify the effects of practicing Yoga on lower back stability, endurance and strength. Yoga participants were recruited following registration in a Yoga class; the control subjects were selected from the Virginia Tech community and were recruited selectively in order to match the stature and body mass of the Yoga participant pool. Due to the recruitment pattern for the experiment, the study utilized a quasi-experimental design. Both cohorts were pre-tested before any practice of Yoga. Post testing was performed 7(*SD*=0.5) weeks after the pre-test on both the groups. Certified and professional instructors taught Yoga to the treatment cohort, approximately 15(*SD*=1.2) sessions were given between pre and post-test; sessions lasted 58.6(*SD*=2.3) minutes on average. The control group was instructed to continue performing exercises according to their regular exercise schedule, which primarily included cardiovascular activities (~30min/day), weight lifting exercises (~20 min/day), abdominal crunches (~8 min/day), and lower body exercises (~20min/day).

2.1 Participants

Sixteen adults (6 males, 10 females) from the university and surrounding area participated in the study. Mean (*SD*) age, body mass, and stature for the Yoga group were 21.5(*SD*=1.5) yrs, 69.7(*SD*=11.2) kgs & 173.2(*SD*=8.1) cm, compared to control group means of 22.1(*SD*=1.4) yrs, 68.2(*SD*=8.0) kgs & 173.4(*SD*=14.4) respectively. All participants were asymptomatic of lower back pain and injuries as found by the Oswestry Disability Questionnaire (Appendix A). Subjects were balanced with respect to gender between groups. Each participant was informed of the purpose, methods, and experimental procedures used in the study. An informed consent document, which was approved by the Virginia Polytechnic Institute IRB Committee, was read and signed by each participant (Appendix B) before testing. A coding scheme was employed to maintain anonymity.

2.2 Independent Variables

The introduction of a Yoga intervention was the only independent variable found within this study. The Yoga routines performed were under the guidance of Yoga instructors available on the college campus. Despite having two different sets of Yoga instructors over the spring and summer semesters, all the participants were taught *Hatha* Yoga at the same level of difficulty (i.e., a beginner level). The control group was instructed to carry out their regular exercise routine over the seven-week period. These exercises included cardiovascular exercises (running, walking, cycling, and sports), light to moderate strength training, and other activities such as horseback riding, swimming, and hiking. A seven-week time period was selected to measure the potential changes in stability, endurance and strength. This period was chosen based on the methodologies employed in previous investigations of exercise and neural and physiological adaptation (Staron et al. 1994; Behn et al. 2002; Ludmila et al., 2003).

2.3 Equipments

2.3.1 Wobble Chair

The wobble chair employed was an unstable seat, and was used for stability testing (Tanaka et al., 2009). It consisted of a seat supported by a ball joint and four circumferential steel springs (Fig. 4). The springs were located in the anterior-posterior and medial-lateral axes and oriented at 90° from each other in order to provide restorative moment for the unstable seat on top of the pivot.

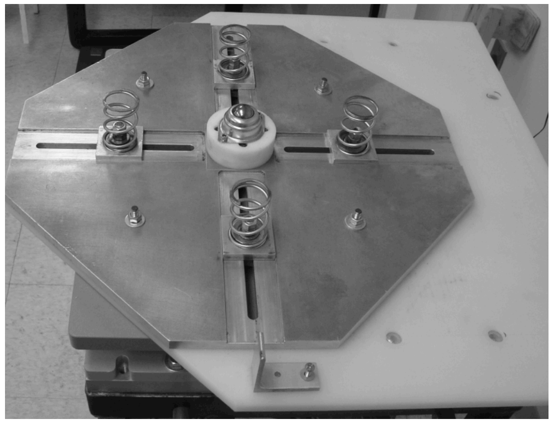


Fig. 4: Adjustable circumferential springs on the wobble seat (Photo taken by the author)

The restorative moment provided by the chair/spring system was adjusted by changing the distance of the springs to the central pivot. Adjusting the restorative moment, (i.e., the proportional gain provided by the springs), altered the level of task difficulty for the subject on the seat.

The adjustable features on the wobble chair allowed normalization of the rotational stability provided by the chair relative each participants body mass and distribution. The gravitational gradient (∇G) was computed as a measure of weight distribution of an individual on the seat. The restorative moment provided by the springs was directly proportional to the spring distance from the center pivot of the chair. As such, task difficulty was set by changing the distance of the springs from the central pivot, such that the restorative moment was equal to a proportion of the gravitational gradient (∇G). As such, the seat was inherently stable when the spring setting was set to 100% of ∇G or higher. Consequently, when the spring settings were set to less than 100% of ∇G, the system was subject to kinematic variability. All stability tests were performed below the 100% spring settings in the AP direction, which necessitated neuromuscular control (hence, kinematic variability) in order to maintain stability. As such, the wobble chair acted as a surrogate measure of low back stability.

For testing the low back stability of the subject, the seat was first adjusted to align the center of mass of the subject on central pivot of the wobble chair. The spring distances were then adjusted to determine the 100% proportional gain. The wobble chair can be simply demonstrated by a 2 segment under-actuated inverted pendulum (Fig. 5).

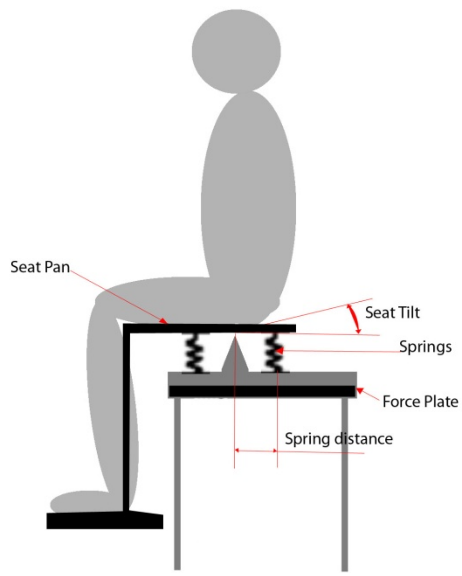


Fig. 5: Wobble Chair apparatus model

2.3.2 Isometric Strength Testing Apparatus

A custom apparatus (Fig. 6) was used to collect and quantify the strength of the lower back in isometric extension and flexion (Hendershot et al., 2011). The exertion forces were sampled at 1000Hz, using a load cell (Interface SM2000, Scottsdale, AZ, USA) that was connected to the harness on top of the participant's upper body via a rigid rod. The hardware were connected to a 16-bit DAQ card (National Instruments, Texas) and raw signals (Voltage) were collected, calibrated and written to file for post-processing.

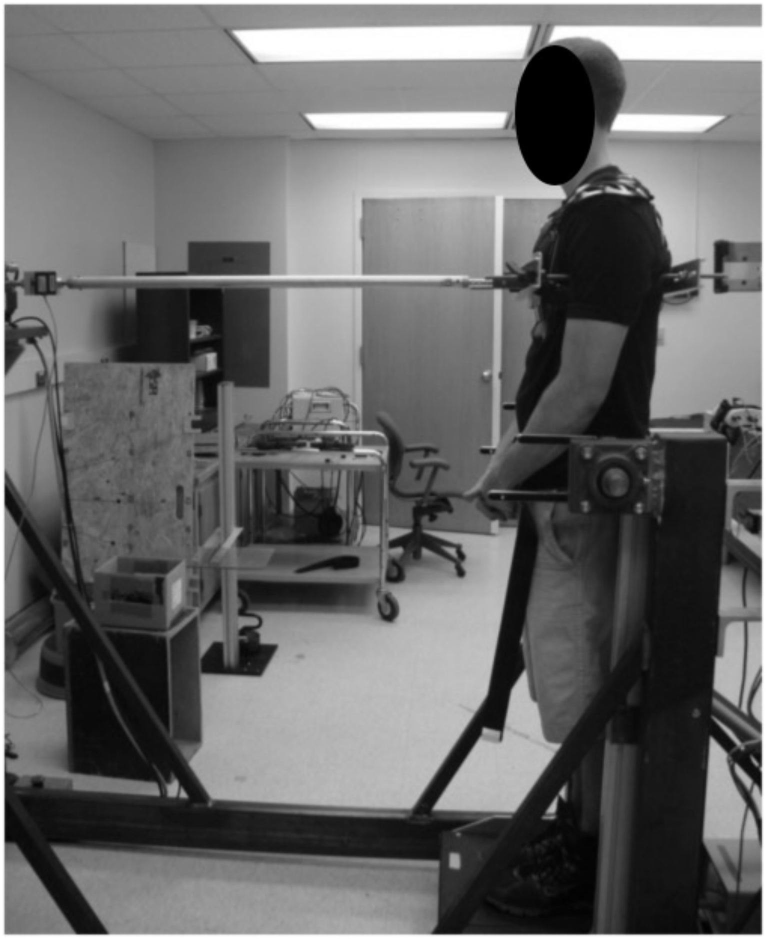


Fig 6: Custom apparatus with a load cell that is attached to the harness on top of the participants via a rigid rod (Photo taken by the author)

2.4 Procedure

An IRB approval to perform the experiment was procured before recruiting subjects for the study. All procedures were written down in detail during the pilot experiment and were made available with the experimenter for reference. As mentioned previously, all pre- and post-tests were performed within 7(*SD*=0.5) weeks of each other. Given that the physical performance of a subject varies significantly with circadian rhythm (Coldwell et al., 1994), subjects were tested at about the same time of the day during pre-test and post-test.

Upon arrival, each subject was asked to fill out the consent form and an Oswestry disability questionnaire. The subjects were then asked to perform three tasks in the following order for both the pretest and posttest:

- Stability test
- Isometric strength tests involving back flexion and extension,
- Isometric endurance tests involving back extension, flexion and lateral muscles

The isometric endurance test was performed last in order to avoid performance confounds due to fatigue.

2.4.1 Stability Test

Before the start of stability tests, the seat on the wobble chair was adjusted to align the center of mass of the subject to the pivot of the seat. Thereafter, the gravitational gradient (∇G) was obtained by methods described in Tanaka et al. (2009). The spring distance was adjusted based on ∇G.

The medial-lateral springs were kept at 100% throughout the test, forcing the system to only wobble in the anterior-posterior direction. Testing began at 80% of ∇G. The subject was given approximately 30 seconds of practice before every trial. The trials lasted for 60 seconds. The gradient ∇G was reduced by 20% (in other words, an increase in task difficulty by 20%) for every passing trial. A trial was considered a "pass" when the observed seat tilt remained within 4º of the seat center. For any other passing trial not meeting these kinematic criteria, ∇G was reduced by 10%. Conversely, every failed trial resulted in an increase of ∇G by 5% (in other words, decrease in task difficulty by 5%). A failed trial was classified as any task performance that caused the seat pan of the chair to make contact with the base. The seat tilt angle was measured using an Xsens intertial motion capture unit (MTx Technologies; Enschede, The Netherlands) aligned with the seat-pan; performance (i.e., seat pan sway) was visually monitored through use of a graphical display. The sample rate of the Xsens sensor was set to collect at 100 Hz. Utilizing this method, the TOS was quantified through determination of the lowest passing spring setting for each participant (Table 1). A rest period of 1 minute was given between each trial.

Table 1: Example of the methodology used to determine the Threshold of Stability. Here the subject successfully passes the 40% spring setting but fails at the 30%; passes the 35% and then fails at 25% and 30%. Thus the TOS is noted as 35% since that was the lowest passing spring setting.

Spring Settings (% ∇G)	25	30	35	40
Passed trial	0	0	1	1
Failed trial	1	1, 2	0	0
	✘	✘	✓	✓

Each participant was given the same set of instructions with regard to adjustment of posture on the wobble chair (Fig. 7): They were asked to shift back on the seat as much as possible, put on the seat belt, keep their arms across the chest and hands on opposite shoulders, keep a straight back as much as possible with the hips and knees at 90º each, do not apply pressure on foot rest for balancing, and visually focus on an object from the room at eye level. In addition, 20 seconds of practice was provided before the wobble seat tests in order to standardize the test and to obtain optimal performance. During a given practice trial the participants were also instructed to tilt the seat back and forth until the seat touched the base. This was done to help participants achieve a sense of kinesthetic awareness and experience the end range of allowable seat tilt. As a final form of standardization, participants were instructed to wear the same shoes and clothes in both the pre-test and post-test conditions.

Fig 7. Sitting posture on the wobble chair. The participant has a straight back with arms across the chest, knees at 90^{o}.and eyes focused on a fixed object (Photo taken by the author)

2.4.2 Postural Sway Test

Following the TOS tests, an additional test was conducted on the wobble chair to measure postural sway (i.e. mean total velocity of center of pressure) at a fixed, submaximal level of difficulty. For each participant, the wobble chair was configured to 60% of their respective TOS. The subjects were given only 1 trial on this spring setting. Center of pressure (COP) data over a period of 40 seconds were estimated through use of a Force plate, (AMTI force plate, OR6-7-1000, England) mounted beneath the wobble chair. The data were captured to a PC using a 16-bit DAQ card (National Instruments, Texas) and stored for post processing. During post processing, the Force plate data were calibrated based on the manufacturer's specifications and filtered using a Butterworth low-pass filter with a cutoff of 10 Hz.

The filtered data were manipulated to produce estimates of system center of pressure using the following equations (1) & (2), obtained from the manufacturer's specifications. These equations accounted for the plate thickness and consequently shifted the estimates COP position to the true center of the plate. All the manipulations were performed in MATLAB (The Mathworks, Natick, Massachusetts)

$$x = \{M_{xo} – F_y*(-0.039817) – F_z*(-0.000389)\}/ F_z \qquad …(1)$$

$$y = \{M_{yo} + F_x*(-0.039817) + F_z*(0.000526)\}/ F_z \qquad …(2)$$

where, (x, y) = coordinates of COP on the force plate plane

The estimates of COP calculated using (4) & (5) were obtained for 40 seconds of the submaximal stability test. Since there were no external sources of perturbation, the lower back muscles and hip muscles were solely responsible for the kinematic variability of the center of pressure.

2.4.3 Isometric Strength Tests

The subjects were asked to stand on a non-slip surface with their lower body fixed against the back support, such that the upper edge of the support was at the level of the iliac crest (Fig 8 a). Following, a custom harness was secured tightly on the shoulders of the participant. The lower body was strapped to the back support to avoid any movements and minimize force generation from the pelvis or lower body (Fig 8 b). The upper body was connected to the strain gauge dynamometer mounted in series with a rigid rod attached to the harness. The height of the back support, straps and strain gauge dynamometer was set as per individual anthropometry. Each trial lasted for 7 seconds during which the subjects were asked to gradually exert an effort on the rod attached to the dynamometer until maximum effort was reached. The subjects were instructed to build up maximum effort over a period of 2 sec and then retain the effort for another 3 sec. The participants performed two trials with 10 minutes of rest between each trial. Consistent verbal encouragement was provided to the participants while they performed the test.

Fig 8(a): Pulling on the rod gives the extensor strength and pushing on the rod gives the flexor strength
Fig 8(b): Straps to fix the lower to the back support (Photo taken by the author)

The data were recorded as voltage changes in the load cell due to force exerted through the connecting rod. The data were transferred to a PC via a LabVIEW program. During post processing, MVC values were identified using a moving 500 msec average. This time window was chosen in order to remove the possibility of identifying an MVC that may be the result of jerking on the rod as opposed to continuous push/pull.

Isometric strength of the trunk extensors was obtained by asking the participants to pull on the rod with backward extension. The isometric strength of trunk flexors was obtained by pushing on the rod.

2.4.4 Isometric Endurance Tests

Endurance was defined as the time to absolute exhaustion, as perceived by the participant for a given muscle group. Each muscle group was tested using assumed postures intended to isolate each particular group. The subject was instructed to terminate the test if excessive pain-like symptoms or excessive fatigue was experienced. The experimenter could also choose to terminate the test if the proper posture was deviated from, or not assumed. The posture was empirically monitored by attaching an inertial motion sensor to the lower back. Since isometric endurance was to be measured, the subjects were instructed to restrict postural deviations to less than 5º, real time feedback was provided by the experimenter. Verbal encouragement was also provided. Due to its difficult nature, subjects were required to perform each endurance test only once. A rest period of 10 to 15 minutes was provided between each endurance test.

For the isometric endurance of back extensors, the subjects were asked to lay prone on a table with the upper body hanging outside the table from the upper limit of the iliac crest. The lower body was strapped to the table at the ankles and buttocks to isolate the lower back and avoid any force generation from the limbs. The subject had to maintain an unsupported upper trunk in a neutral horizontal posture, with the arms across the chest, until absolute exhaustion (Fig. 9).

Fig. 9. Beiring-Sorenson (1984) test for extensor endurance (Photo taken by the author)

Endurance of the trunk flexors was established with the subject oriented in a sit-up position (Fig. 10). The subject was asked to rest against a jig angled at 60°, with their legs flexed at 90° at both the hips and knees. Subjects assumed this position with their arms across the chest and hands on their shoulders for the duration of the test. A lab assistant held down their feet during testing. The jig was moved back by a few inches to begin the test, and the subject was required to assume this posture until exhaustion.

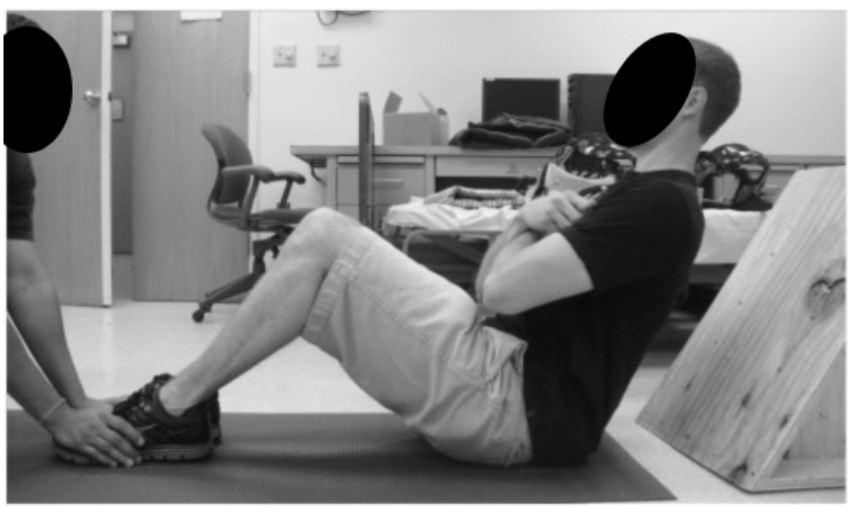


Figure 10. Sit-up position for the flexor endurance test (Photo taken by the author)

Endurance of left and right lateral musculature was tested by employing the side plank position (Fig. 11). The feet were placed one above the other, and the support elbow and shoulder had to be aligned in a straight line, with the elbow at 90º. The other hand could rest along the side of the body.

Fig. 11. Side plank position for Lateral Endurance test (Photo taken by the author)

2.5 Dependent Variables

To quantify changes due to the Yoga intervention, the following dependent variables were obtained:

- Threshold of Stability (TOS):

The Threshold of Stability was defined as the maximum level of task difficulty in which stability could be maintained. It was found by increasing task difficulty until observed kinematic variability was just within the boundary of the basin of stability; defined as a percentage of the gravitational gradient ∇G. The basin of stability remained constant for a given difficulty setting and was derived in terms of the angle of the seat in the medial-lateral plane. Unstable behavior was identified when the seat tilted enough to make contact with the base, or in other words, displacement of the center of pressure moved beyond the basin of stability. The subjects typically failed to display any stability or control of the seat once they went past the TOS.

- Mean Total Velocity of COP as sway data at a sub maximal level of task difficulty:

Performance was measured in terms of Mean Total Velocity of the center of pressure. It was measured at a submaximal setting in terms of task difficulty, specifically a setting of 60% TOS for each subject was used to normalize the test condition.

- Isometric strength of trunk extensors and flexors (N). Obtained through the protocol above
- Endurance of lower back extensors, back flexors and lateral musculature (time, sec). Obtained through the protocol above.

2.6 Statistical Analysis

A two-way analysis of variance (ANOVA, 2x2 mixed factor design) was conducted to determine the effects of Yoga exercise on the aforementioned dependent variables. The two factors considered in the ANOVA were treatment type (Yoga, Control) and time interval (Pre, Post). Post hoc comparisons were conducted using simple effects F-tests, whenever an interaction effect was encountered. A Shapiro-Wilk test was performed before statistical analysis to check the normality of the data. All statistical analysis was performed using JMP 9.0 (SAS Institute Inc. USA). The a priori level of significance for all the tests was set at α=0.05.

***Chapter 3*: Results**

The results have been divided into three main categories: Stability, Strength, and Endurance measures. These categories were subdivided into their respective test results. The differences between the pre-test and post-test presented addressed the training effect of the Yoga intervention on these measures.

3.1 Stability Measures

3.1.1 Threshold of Stability (TOS)

The two-way analysis of variance revealed a significant interaction effect of TREATMENT*INTERVAL, $F(1, 14)=11.72$, $p=0.0047$. The subsequent post hoc test of simple effects indicated that the Yoga group significantly improved in terms of the TOS test by 19% ($F(1,14)=36.63$, $p=0.0001$) from pre-test to post-test, whereas no appreciable improvement was observed in the control group. The TOS levels for the two groups were similar in the pre-test, however the Yoga group had a significantly lower ($F(1,14)=27.51$, $p<.0001$) TOS in the posttest than the control group (39.38(SD=9.82)% vs. 47.5(SD=5.39)%, respectively).

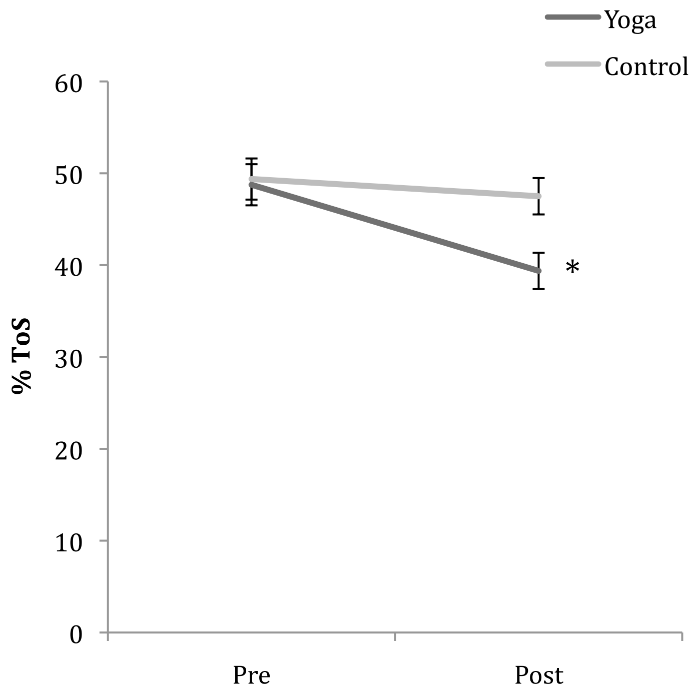


Fig. 12. TOS response of Yoga and Control groups in Pre-test and Post-test. A reduction in the level of TOS indicates an improvement in terms of the stability of the lower back. Error bars indicate the standard error in data; *Indicates a significant difference between the yoga and control group (p<.0001) in the posttest.

3.1.2 Mean Total Velocity of Center of Pressure (COP)

The two-way analysis of variance yielded a significant interaction effect of TREATMENT*INTERVAL at $F(1,14)=11.27$, $p=0.0047$. The subsequent post hoc test for simple effects indicated that the Yoga group, although similar to the control group in the pretest, had a 21% lower ($F(1,14)=8.82$, $p=0.0102$) COP mean total velocity than the control group after the Yoga intervention. The yoga group observed a 17% decrement ($F(1,14)=5.12$, $p=0.0401$) in the COP mean total velocity from pre-test to post-test. On the contrary, the control group observed a 22% increase ($F(1,14)=6.16$, $p=0.0264$) in the COP mean total velocity was observed in the control group.

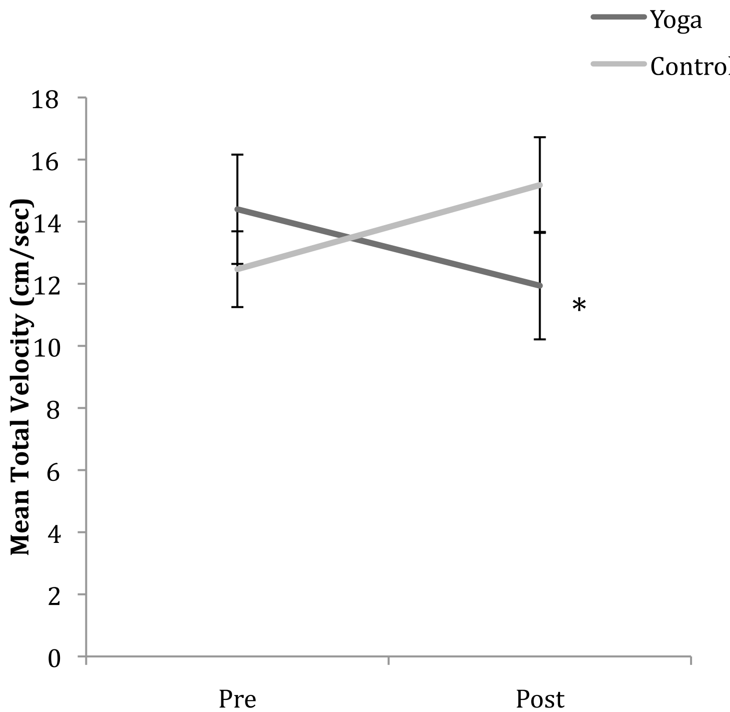
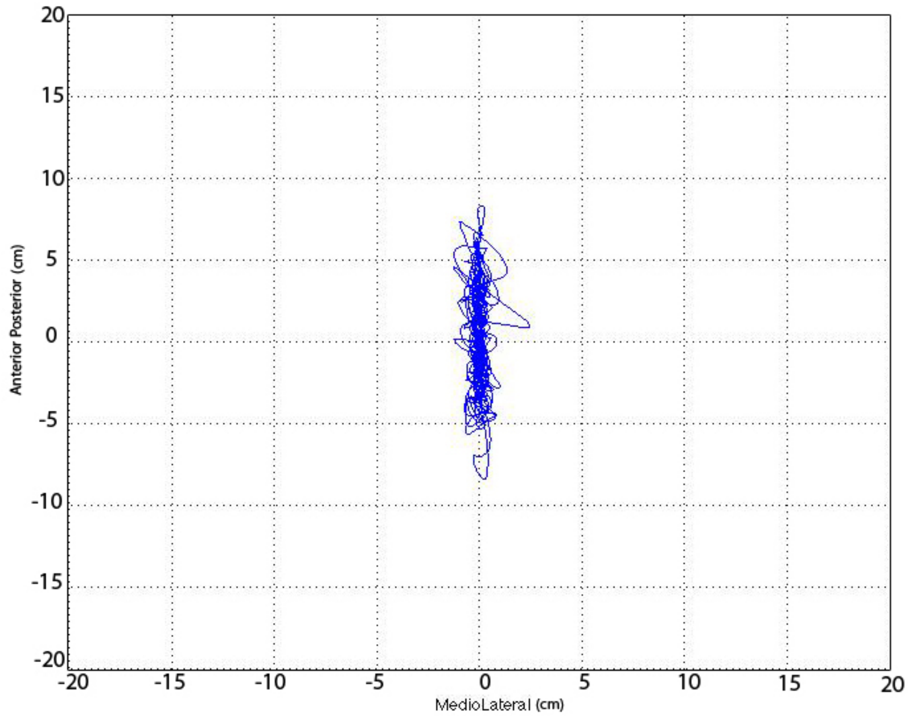
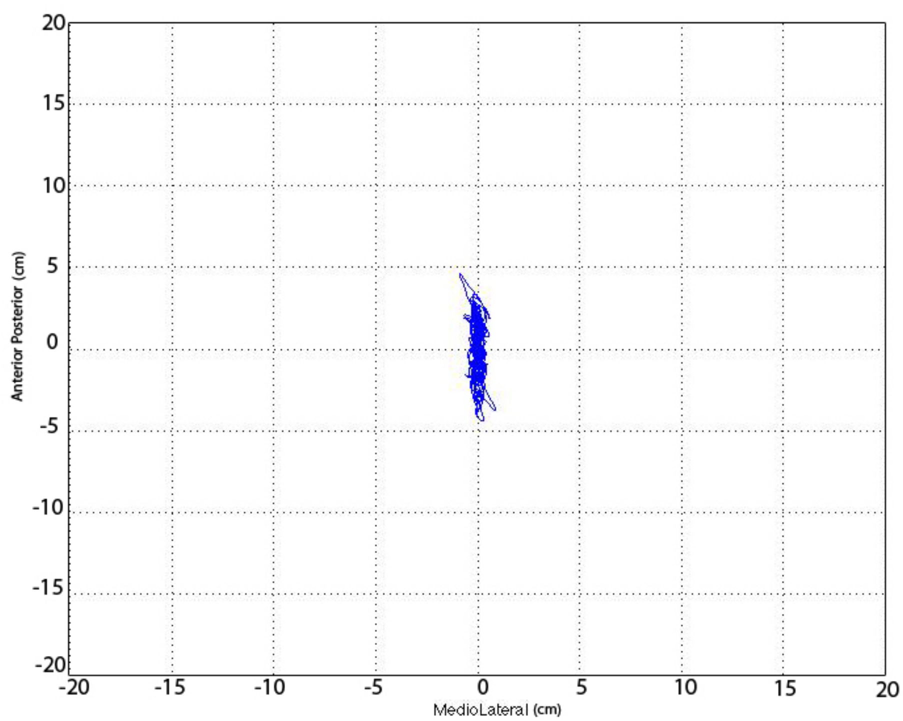


Fig 13: COP Mean Total Velocity response of Yoga and Control groups in Pre-test and Post-test. A reduction in the level of TOS indicates an improvement in terms of the stability of the lower back. Error bars indicate the standard error in data; *Indicates a significant difference between the yoga and control group (*p*=.0102) in the posttest.

Figures 14, 15, presented on the following page, are presented as means of illustrating COP path length effects due to the treatment of Yoga. Since the COP path length is easier to comprehend visually than the mean total velocity, it is offered here as an analog for mean total velocity. This is intuitive, as mean total velocity is calculated as total path length divided by time (Salvati et al., 2009). As can be seen within the figure(s) representing exemplar performance, the practice of Yoga decreased the COP path length plot by a considerable amount compared to the control subject, which did not indicate much change in terms of COP path length at all. Again, since mean total velocity is a derivative of COP path length, a reduction in the path length is indicative of a decrease in the mean total velocity. Thus the differences in mean total velocity can be visually observed by comparing the COP path length plots with one another.



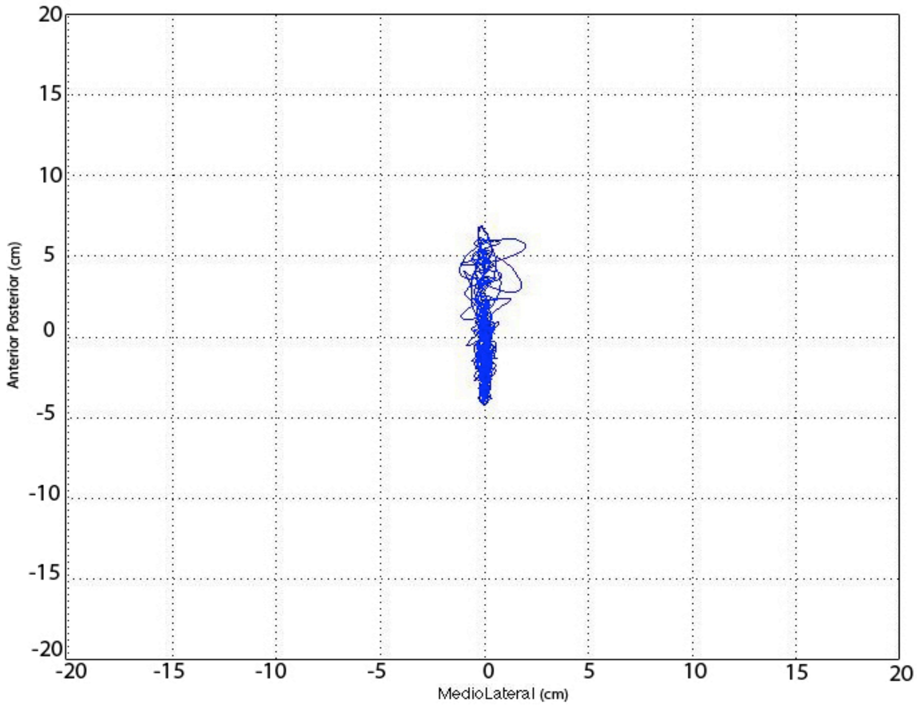
(a)



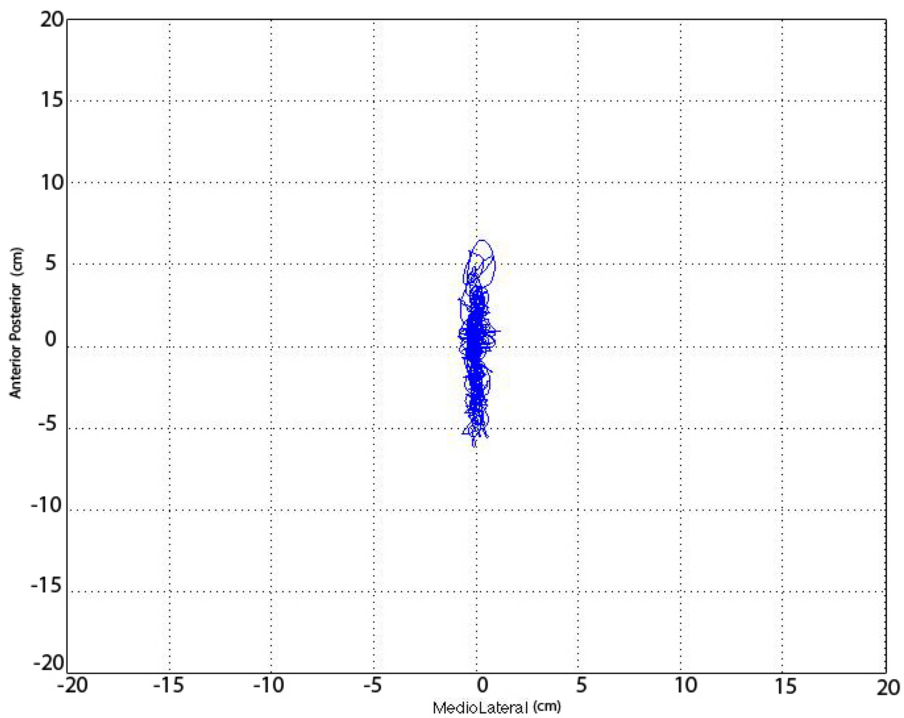
(b)

Fig 14. COP plots for a Yoga subject seated on the wobble chair for a period of 40 sec, during the pre-test (a), and the post-test (b). Mean Total Velocity is obtained from dividing the length of the COP path to the time.

The stability data for this participant was: 35% TOS & 3.72 m COP path length in pre-test and 25% TOS and 2.68 m COP path length in post-test.



(a)



(b)

Fig 15. COP plots for a Control subject seated on the wobble chair for a period of 40 sec, during the pre-test (a) and the post-test (b). Mean Total Velocity is obtained from dividing the length of the COP path to the time.

The stability data for this participant was: 40% TOS & 3.11 m COP path length in pre-test and 40% TOS and 3.44 m COP path length in post-test.

3.2 Isometric Trunk Strength Test Measures

The control group had 14% greater ($F(1,14)=6.59$, $p=.0024$) trunk extensor strength and 12% greater ($F(1,14)=6.78$, $p=0.0208$) trunk flexor strength than the Yoga group. The differences between the control and Yoga group were observed throughout the pre-test and post-tests, although a 12% ($F(1,14)=8.66$, $p<.0107$) increment in trunk extensor strength was observed for all the participants. The summary table (table 2) shows the response of the two groups in pre and post-test.

Table 2: Isometric trunk strength as maximum voluntary contractions measured in Newtons

Muscle Group	Pre-test		Post-test	
	Yoga (n=8)	Control (n=8)	Yoga (n=8)	Control (n=8)
Trunk Extensor	541.93 (140.36)	644.08 (210.70)	633.75 (173.24)	693.84 (213.41)
Trunk Flexor	488.44 (123.61)	586.13 (204.79)	565.36 (140.94)	598.23 (227.62)

3.3 Isometric Endurance Test Measures

The control group was found to have higher endurance levels for three out of four muscle groups in the lower back. The control group had longer endurance times for the back extensor by 56% ($F(1,14)=31.47$, $p<.0001$), back flexor by 59% ($F(1,14)=47.02$, $p<.0001$), left side lateral by 14% ($F(1.14)=9.21$, $p=0.0089$). Again, these differences were maintained throughout the pre and post-test although the participants showed an improvement in endurance of back extensor from pre-test to post-test by 21% ($F(1,14)=5.50$, $p=0.0342$), left side lateral by 23% ($F(1,14)=21.85$, $p=0.0004$) and right side lateral by 16% ($F(1,14)=5.23$, $p=0.0383$). The summary table (table 3) shows the response of the two groups in pre and post-test.

Table 3: Isometric back endurance time measured in Seconds

Muscle Group	Pre-test		Post-test	
	Yoga (n=8)	Control (n=8)	Yoga (n=8)	Control (n=8)
Back Extensor	87.50 (18.51)	150.41 (62.99)	117.05 (32.21)	168.80 (81.25)
Back Flexor	164.34 (94.48)	292.79 (370.49)	203.82 (87.68)	296.79 (367.49)
Left Side Lateral	54.11 (13.75)	66.85 (20.12)	71.84 (21.72)	77.54 (20.82)
Right Side Lateral	58.77 (15.30)	67.14 (15.35)	70.85 (14.42)	74.82 (21.32)

Chapter 4: **Discussion**

The purposes of this study were to compare the efficacy of a Yoga exercise regime on 1) low back stability; 2) low back endurance and 3) low back strength. An improvement in low back stability was indicated by a decrease in TOS and mean total velocity of COP. The results of the study suggest that Yoga may be an effective intervention in work-site wellness programs for enhancing low back stability. This is supported by the significant improvement in the TOS, and mean total velocity of COP for the Yoga group from the pre to post-test as compared to the control group.

4.1 Stability

The TOS of the participants in this study was found to be partly consistent with the results obtained by Tanaka et al. (2009). Their study used a sample population consisting of college students from in and around the university area with the average age of 27(5) years, as compared to 22(1.5) years for this study. The TOS levels reported in their findings was 36 (6.4) %, about 35% lower than all the subjects in the pre-test component of the current study. Apart from this, no other studies were found in the literature that quantified lower back stability in terms of TOS and hence no additional comparisons were made. The mean total velocity of the COP was measured at a fixed relative level of task difficulty for all the subjects. It was set at 60% of each participant's recorded TOS. This was done in order to achieve a standardized level of difficulty for every participant. An absolute level of difficulty was rejected due to fact that the level of task difficulty was different for each participant. For example, a level of 60% ∇G (of absolute) would be easier for a person who exhibits a TOS of 40% ∇G as compared to someone who exhibits 55% ∇G.

In the postural sway tests, the yoga group had 21% lower mean total velocity of COP compared to the control, post intervention. This improvement was significantly correlated to the changes in

TOS. Smaller displacements of COP sway data have been indicators of performance that are associated with those that are asymptomatic of low back injuries (Radebold et al., 2001). Alternate stability methodologies, such as stability diffusion analysis (Collins and De Luca, 1993), Lyapunov stability analysis (Granata et al., 2006), also suggest that smaller diffusions of COP sway data are indicative of a system with higher (i.e., more robust) stability. Mean total velocity of COP was also used as a sway parameter; its use has shown strong correlation with additional methodologies, and has shown high to very high reliability (Salvati et al., 2008). However, this sway parameter is a ratio of the average displacement over a time period and hence does not consider the large short-term diffusion of COP that may have occurred. Although, even in the presence of low velocity of COP, large short-term diffusion of COP suggests loss of balance (Van Dieën et al., 2010) and thus requires multivariate analysis of the COP trajectories. However, loss of balance on the current wobble chair apparatus was clearly indicated by contact of seat to the base while testing and thus such an analysis was not considered.

It could be argued that any exercise aimed at improving low back stability by training the neuromuscular system must challenge both motor learning and training principles. Firstly, it challenges the similarity and specificity principle in motor learning. For example, a baseball player will not be able to apply his motor skills in a game of basketball. Based on this principle, the motor control skills will be most utilized when the low back has to be stabilized in the postures that are specific to the various exercises and cannot be transferred to other activities (Schmidt et al., 2005). However, the study measured low back stability on wobble chair. The task difficulty on the wobble chair was set such that reflexive and voluntary muscle activation was needed to stabilize the seat on the pivot. The actions performed on the wobble chair are very different than the ones performed during exercising, such as performing Yoga or other exercises such as cardiovascular training, and exercises involving physiological overloading.

Contrary to the established motor learning principles, the Yoga exercise group showed higher postural control ability on the wobble chair than the control group. This is consistent with the conclusions of Tsao et al., (2008). They showed that motor control changes are persistent following training and may lead to motor learning of automatic postural control strategies. Thus, it is highly possible that Yoga exercises, unlike traditional exercises, improve neuromuscular control and proprioception, which may leads to higher low back stability.

The study showed significant results in the tests characterized by maximum control, i.e. TOS and mean total velocity tests. The subjects were asked to explain the reasons of failure after every failed trail on the wobble seat. The answers included one of the following. Firstly, they reported altered breathing techniques due to the heightened concentration on stabilizing the seat. After a few seconds of holding their breath, an event of deep breathing, resulted in a failed trial on the wobble seat. The Yoga participants reported controlled and effective breathing during the stability tests, and subsequent endurance tests, in the post-test, which could be a result of the breath training (*pranayama*) in Yoga exercises. In turn, this may have aided in performing better on the wobble seat. The improved breathing could be a result of the *pranayama* exercise taught for 5-10 minutes at the end of every Yoga class. During the Yoga sessions, the participants were instructed to become aware of how core muscles feel during breathing exercises, relaxation. The breathing techniques of Yoga may be responsible in activating and training core abdominal muscles involved in spinal support and stabilization (Michels et al., 2006). These breathing techniques were not only taught as a different exercise, but also during the practice of Asanas. The breathing patterns taught in Yoga may also improve the mental focus and concentration (Satchidananda, 1990) along with activating parasympathetic nervous system such that the participant was able to modulate the sympathetic nervous system over an activity (Benson, 2000).

The other reason that the participants provided for failure was the inability to control the seat tilt near the failure limits. All participants, except the Yoga group during post-test, failed to activate low back muscles such that they could bring the seat tilt back to central position. It can be argued that this is a direct result of neuromuscular control. The higher control on the movement of the wobble seat on the central pivot as suggested by the above explanation can be verified by the mean total velocity of COP response in both the groups. The Yoga group displayed lower mean total velocity of the COP after the 7 weeks of yoga treatment; this improvement was not present within the control group.

4.2 Strength and Endurance

The isometric strength test results for the current sample population were consistent with previous studies (Essendrop et al., 2001). Isometric trunk strength has shown inter-session reliability and is considered to have clinically acceptable-to-good reliability (Graves et al., 1990; Essendrop et al., 2001; Gruther et al., 2009). The strength test results revealed that even though the control group was significantly stronger than the Yoga group in both pre and post-test, the improvement in isometric trunk strength of Yoga group was more than the control group. However, the Yoga group was not expected to show an appreciable improvement in the strength tests after the Yoga intervention since the Yoga exercise is relatively low-impact and by nature it does not include the use of physiological overload in its regime.

Yoga is considered a low-impact exercise that does not rely on physiological overloading to condition the core muscles. A recent study has demonstrated that contractions at levels as much as 70% MVC are needed to promote strength gains within the abdominal muscles (Stevens et al., 2008). It is unlikely that during core stability exercises, such as those practiced here, would activate the abdominal muscles at this force level (Stevens et al., 2007). The core stability exercises that were tested by Stevens et al. (2007) mostly included postures that may be considered a part of Yoga exercise regime, for example the bridge exercise to the neutral spine alignment position, quadruped arm and lower extremity lift with the trunk in neutral spine alignment. Other researchers have also shown that during core stability exercises, the MVC of the core muscles is well below the level required for muscle hypertrophy and is therefore unlikely to provide strength gains (Vezina et al., 2000; Souza et al., 2001).

The current study findings provide conflicting evidence to the argument presented above. Even without physiological overload the back extensors and flexors were subjected to loads depending on the Yoga posture, for example, *seated boat pose* loads the back flexor and table *balancing pose* and *locust pose* load the back extensors. The improvement in strength could be explained as the early stages of muscular response to adjust to higher spinal loads. It may have led to the 17% increase in back extensor strength and a 16% increase in the back flexor strength. However, it may be necessary to find the levels of muscle activation during Yoga exercises to provide conclusive evidence of the efficacy of yoga exercises in improving isometric trunk strength.

The outcomes of the endurance measures in this study are supported by the previous reviews of Lederman (2003), and Kava et al., (2010) who reported that trunk endurance exercise directed at increasing endurance was effective. It has been reported that trunk muscle endurance and lumbopelvic control are necessary for trunk stabilization, which allows for more efficient management of upper extremity workloads (Leetun et al., 2004). This is especially important in an occupational work setting where workers are subjected to low level fatigue induced due to sedentary work, light weight lifting and high level fatigue which is induced by heavy lifting and constant loading in most cases. Both Yoga and control groups in the current research study displayed small levels of improvement in lower back endurance. This was consistent with the study results of Kava et al., (2010), where the *Pilates* and *endurance exercise* group showed a significant difference between the pre-test and post-test, but not between group differences. Another study performed by Carter et al., (2006), showed that the participants who performed endurance training exercises on a stability ball also had higher endurance times post exercises. Both the aforementioned studies measured endurance times using the same testing postures as the current study. It further supports the behavior of endurance times recorded in this study, suggesting that most forms of exercise will increase endurance of the core muscles.

The endurance times recorded in this study had high variability. A possible explanation could be that the effort put forth by the participants in the endurance test was not consistent within and between the cohort groups. Some participants reported a much higher level of perceived exertion than others. The participants seemingly had nothing to gain, apart from fatigue, out of providing their utmost effort. Some participants also reported pain and discomfort in certain muscle groups, other than the ones being tested. It suggests that the endurance ratings were also confounded by the presence of effort from other muscle groups in assuming the desired testing posture. Thus it is possible that the subjects may have voluntarily ended the test prior to absolute exhaustion in the muscle targeted.

It could be argued that strength and endurance of the lower back muscles is not important in maintaining low back stability. Cholewicki et al., (1997) demonstrated that sufficient levels of stability of the lumbar spine can be achieved with very modest levels of co-activation of the paraspinal and abdominal muscles. During standing and walking the trunk muscles are minimally activated (Andersson et al., 1996), for example rectus abdominis has an average activity of 2% MVC and external oblique is 5% MVC (White et al., 2002). The improvement in endurance may be sufficient to provide the activation needed throughout these daily activities, including sitting which may reduce risk of injuries in the future.

4.3 Limitations and Future Directions

This was study was a quasi-experimental design. Since the participants may have had a pre-disposed inclination towards Yoga or regular exercises. Hence, it could be argued that the groups were not similar, perhaps due to the lack of random assignment in the treatment variables. This was observed specially with respect to the endurance and strength outcomes. Hence a few points must be considered with regard to generalizing the results of this study.

Firstly, the stability tests were conducted with only 1 directional set of active springs on the wobble chair. Varying the anterior-posterior springs along with the medial-lateral springs could reveal balancing strategies, effects of side lateral musculature. Additionally, the endurance and strength tests were not as controlled as the stability tests. More precise measurements such as EMG, spectral shift in the median frequency of the power spectrum, could have yielded more accurate results. Finally, the control group subjects were free to practice exercises of their choice as long as they continued performing regular exercises without introducing any new exercise regimes. The results in the presence of random assignment to exercise groups and placebo Yoga exercises could be generalized to a larger population.

The actual definition and underlying mechanism of low back stability are unclear. The proposed mechanisms and findings presented by previous authors and this study are speculations and no consensus has been made on any one metric for the measurement of stability. Furthermore, low back stability, strength, and endurance, have not presented sufficient viability to reduce risk of future injuries. In this study, the outcomes could be attributed to a variety of reasons ranging from control of the experiment, to the basic characteristics of the concept of stability exercises and also the characteristics of Yoga as a low-impact exercise.

Future research could be conducted on specific muscles in the lower back while performing

Yoga exercises. It would also be highly important to incorporate maximum control in the study to avoid the threats to internal validity. Furthermore, a longitudinal study with a cohort of greater size would be advised to accurately suggest the risk reduction efficacy of Yoga exercises.

4.4 Conclusion

The results of the study demonstrate the positive effects of a 7 week Yoga intervention on stability of the lower back, measured in terms of TOS and mean total velocity of center of pressure. The study also found that the improvement in low back stability does not require higher endurance and strength and thus suggests that a Yoga intervention improves the neuromuscular control and proprioception of the lower back to bring about an improvement in the stability. Based on the current study results, Yoga appears to be a beneficial proactive and/or rehabilitative modality. It is a low cost intervention that could be easily implemented within a fitness program in occupational settings, helping employees improve lower back health and assisting in the prevention of occupationally related injuries. However, it is warranted that future research be focused on measuring neuromuscular differences after a Yoga intervention, over a greater exposure period, using a larger sample, to quantify its prophylactic and therapeutic value, if possible.

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Appendix A: Oswestry Disability Questionnaire

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking **one box in each section** for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement **which most clearly describes your problem.**

Section 1: Pain Intensity

☐ I have no pain at the moment
☐ The pain is very mild at the moment
☐ The pain is moderate at the moment
☐ The pain is fairly severe at the moment
☐ The pain is very severe at the moment
☐ The pain is the worst imaginable at the moment

Section 2: Personal Care (eg. washing, dressing)

☐ I can look after myself normally without causing extra pain
☐ I can look after myself normally but it causes extra pain
☐ It is painful to look after myself and I am slow and careful
☐ I need some help but can manage most of my personal care
☐ I need help every day in most aspects of self-care
☐ I do not get dressed, wash with difficulty and stay in bed

Section 3: Lifting

☐ I can lift heavy weights without extra pain
☐ I can lift heavy weights but it gives me extra pain
☐ Pain prevents me lifting heavy weights off the floor but I can manage if they are conveniently placed eg. on a table
☐ Pain prevents me lifting heavy weights but I can manage light to medium weights if they are conveniently positioned
☐ I can only lift very light-weights
☐ I cannot lift or carry anything

Section 4: Walking*

☐ Pain does not prevent me walking any distance
☐ Pain prevents me from walking more than 2 kilometres
☐ Pain prevents me from walking more than 1 kilometre
☐ Pain prevents me from walking more than 500 metres
☐ I can only walk using a stick or crutches
☐ I am in bed most of the time

Section 5: Sitting

☐ I can sit in any chair as long as I like
☐ I can only sit in my favourite chair as long as I like
☐ Pain prevents me sitting more than one hour
☐ Pain prevents me from sitting more than 30 minutes
☐ Pain prevents me from sitting more than 10 minutes
☐ Pain prevents me from sitting at all

Section 6: Standing

☐ I can stand as long as I want without extra pain
☐ I can stand as long as I want but it gives me extra pain
☐ Pain prevents me from standing for more than 1 hour
☐ Pain prevents me from standing for more than 30 minutes
☐ Pain prevents me from standing for more than 10 minutes
☐ Pain prevents me from standing at all

Section 7: Sleeping

☐ My sleep is never disturbed by pain
☐ My sleep is occasionally disturbed by pain
☐ Because of pain I have less than 6 hours sleep
☐ Because of pain I have less than 4 hours sleep
☐ Because of pain I have less than 2 hours sleep
☐ Pain prevents me from sleeping at all

Section 8: Sex Life (if applicable)

☐ My sex life is normal and causes no extra pain
☐ My sex life is normal but causes some extra pain
☐ My sex life is nearly normal but is very painful
☐ My sex life is severely restricted by pain
☐ My sex life is nearly absent because of pain
☐ Pain prevents any sex life at all

Section 9: Social Life

☐ My social life is normal and gives me no extra pain
☐ My social life is normal but increases the degree of pain
☐ Pain has no significant effect on my social life apart from limiting my more energetic interests e.g. sport
☐ Pain has restricted my social life and I do not go out as often
☐ Pain has restricted my social life to my home
☐ I have no social life because of pain

Section 10: Travelling

☐ I can travel anywhere without pain
☐ I can travel anywhere but it gives me extra pain
☐ Pain is bad but I manage journeys over two hours
☐ Pain restricts me to journeys of less than one hour
☐ Pain restricts me to short necessary journeys under 30 minutes
☐ Pain prevents me from travelling except to receive treatment

Appendix B: Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants

Project Title: The Effect of Yoga in Improving Low Back Stability, Endurance and Strength

Investigators: Dr. Michael J. Agnew
Anuj D. Mistry

I. Purpose of this Research/Project

The purpose of this study is to detect changes in stability and performance of the lower back, induced in asymptomatic subjects, due to physical therapy such as Yoga. The study requires 32 subjects asymptomatic of lower back disorders, between the age ranges of 18 to 35 yrs. They will be equally divided between two groups of 16 each. One group voluntarily attends Yoga classes held by Yoga professionals while the other does not practice any physical therapy. The study will provide insight into understanding the effect of core specific exercises in terms of muscle balance and control.

II. Procedures

You have to perform three tests.

1. Biering-Sorensen Endurance Test: You will get three trials with a rest period of at least 15 minutes between each.
    a. Endurance of back extensors will be established by the lying prone on a table with an unsupported upper body. You will be asked to hold their upper body in a horizontal, neutral position for as long as possible. The test is terminated when you start feeling extreme fatigue or discomfort due to exertion.
    b. Endurance of back flexors will be established in a sit-up position. You will be asked to rest against a jig angled at 55°, with their legs flexed at 90° at the hips and knees. Thereafter, the jig will be pulled back by 10 cm and you have to hold the sit-up position for as long as possible. Subjects will have to place their arms folded across the chest and toes will be secured under a toe strap. Failure eventuates when any part of your back touches the jig.
    c. The side-bridge position will be employed to test endurance of lateral musculature. You will be required to lie on their sides with extended legs, and the top foot placed in front of the lower foot. The upper body has to be supported by one elbow. You will then have to lift their hips off the floor such that it creates a straight line over the body length. The other arm has to be placed across the chest resting on the shoulder. Failure eventuates when you cannot hold the straight line any further.

2. Isometric Strength test
    a. Isometric strength will be measured by using a Biodex strain gauge dynamometer. You will be asked to stand on a non-slip surface with your lower body supported against a supporting board such that the upper edge of the

support is at the level of iliac crest. You will be instructed to build up maximal effort while pulling a chain attached to the dynamometer over a period of 5 s and retain the pressure for another 2 s. For each strength measure, three MVCs will be obtained with a rest period of 30 s between each. Consistent verbal encouragement will be provided to extract maximum voluntary efforts without inducing pain or discomfort.

b. The test will be performed for back extensors and flexors.

3. Wobble Chair Stability Test

You will be asked to sit on the wobble chair with crossed arms, for 60 seconds. You will be given 5 trials with a rest period of 1 minute to avoid any mental or physical fatigue. The spring settings underneath the unstable seat will be changed based on the performance of the subjects. This will be carried out until maintaining stability is no more possible. The unstable seat presents no danger of falling off the chair, as the tilt in the seat is small enough that the subjects on top will not slide off the seat nor need external support if they fail in achieving stability.

III. Risks

The tests present minimal risk to the subjects. Risks primarily involved are that of fatigue. Fatigue is similar to that experienced while performing daily activities and tasks in the household.

IV. Benefits

By participating in this study, you will assist the investigators in acquiring knowledge of the effectiveness and possible positive results of performing Yoga on a routine basis; however, you are encouraged to discontinue Yoga exercises if you experience discomfort or do not perceive any improvement in physical health.

The study does not promise or guarantee benefits. This highly depends on your sincerity in performing routine yoga exercises.

V. Extent of Anonymity and Confidentiality

You will not be asked to provide any personal information. The investigators will take anthropometric measures and demographic information (age, gender, physical activity levels) only which will be identified by subject number only. At no time will the researchers release the results of the study to anyone other than individuals working on the project without your written consent.

It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

You will be compensated at a rate of $10 per hour for your participation.

VII. Freedom to Withdraw
You are free to withdraw from the study at any time without penalty. If you choose to withdraw, you will be compensated for the portion of the time of the study. You are free not to answer any questions or respond to experimental situations that you choose without penalty.

VIII. Subject's Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities:

1. To read and understand all instructions
2. To follow instructions provided by the investigator to the best of my abilities.
3. To inform the investigator of any discomforts I experience immediately
4. Be aware that I am free to ask questions at any point.

IX. Subject's Permission

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________
Subject signature

____ Date __________
Witness (Optional except for certain classes of subjects)

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

_______________________________________ _________________________
Investigator(s) Telephone/e-mail

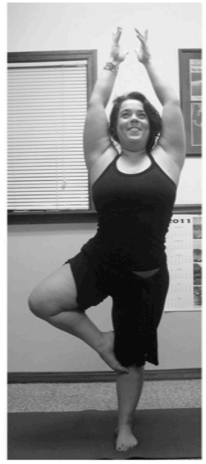
____ _________________________ Departmental
Reviewer/Department Head Telephone/e-mail

David M. Moore 540-231-4991/moored@vt.edu
Chair, Virginia Tech Institutional Review Telephone/e-mail
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Appendix C: *Hatha* Yoga Illustrations (Photographs taken by the author)
(*Photographed at the Blue Ridge School of Yoga and Massage, Blacksburg, VA)


Crescent Moon


Chair


Tree


Side Angle


Triangle


Dancer 1


Dancer 2


Standing head-to-knee


Eagle


Standing wide angle forward bend


Pyramid


Side angle twist

Warrior 1

Warrior 2

Table balancing

Cat stretch 1

Cat stretch 2

Half locust

Eight point

Downward facing dog

Cobra

Full locust

Bow

Thunderbolt

Cow face

Seated half spinal twist

Staff

Head to knee

Seated forward bend

Child

Seated boat

Bridge

Fish

Inclined plane

Camel

Reclining hero