EFFECTS OF SWISS BALL TRAINING ON KNEE JOINT REPOSITION SENSE, CORE STRENGTH AND DYNAMIC BALANCE IN SEDENTARY COLLEGIATE STUDENTS

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Approval of the Graduate School of Social Sciences

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Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

____

Prof. Dr. M. Settar Koçak
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

____

Prof. Dr. Feza Korkusuz
Supervisor

Examining Committee Members

Prof. Dr. Feza Korkusuz	(METU, PES)	____________________
Prof. Dr. M. Settar Koçak	(METU, PES)	____________________
Assoc. Prof. Dr. Özgül Yılmaz Tüzün	(METU, ESE)	____________________
Assoc. Prof. Dr.Ayşe Kin İşler	(BU, SBB)	____________________
Assist. Prof. Dr. Aynur OTAĞ	(CU, BESYO)	____________________

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Name, Last name: MUTLU CUĞ

Signature:

ABSTRACT

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Cuğ, Mutlu

Ph.D., Department of Physical Education & Sports

Supervisor: Prof. Dr. Feza Korkusuz

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The purpose of this study was to investigate the effects of Swiss ball training on (1) knee joint reposition sense (knee proprioception), (2) core muscle strength and (3) dynamic balance in sedentary collegiate students. In this thesis, two different participant groups and two different training methods were used. In order to evaluate the effect of Swiss ball training on knee proprioception and core strength, 3 days per week training was conducted throughout 10 weeks (Study 1). In order to evaluate the effect of Swiss ball training on dynamic balance, 2 days per week training was conducted throughout 10 weeks (Study 2). 60 sedentary university students participated in Study 1. 47 sedentary university students participated in Study 2. The results of the study indicated that Swiss ball training has significant effect on knee proprioception and core muscle strength. For dynamic balance, at the end of the 10-week Swiss ball training, in both groups (Swiss ball and control), dynamic balance scores were improved significantly. Therefore, effect of the Swiss ball training on dynamic balance could not be determined. As a conclusion, an instability training program using Swiss balls with body weight as resistance can provide prolonged improvements in joint proprioception and core strength which would contribute to general health and performance.

Keywords : Swiss ball, unstable surface, knee proprioception, core strength, dynamic balance.

ÖZ

SPOR YAPMAYAN ÜNİVERSİTE ÖĞRENCİLERİNDE İSVİÇRE TOPU ANTRENMANININ DİZ EKLEMİ YENİDEN POZİSYONLANMA ALGISI, KARIN&BEL KASI KUVVETİ VE DİNAMİK DENGE ÜZERİNE ETKİSİ

Cuğ, Mutlu

Doktora, Beden Eğitimi ve Spor Bölümü
Tez Yöneticisi: Prof. Dr. Feza Korkusuz
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Bu çalışmanın amacı, spor yapmayan üniversite öğrencilerinde İsviçre topuyla yapılan egzersizlerin (1) diz eklemi yeniden pozisyonlanma algısı (diz propriosepsiyonu), (2) karın & bel kası kuvveti, (3) dinamik dengeye olan etkisini araştırmaktı. Bu tezde, iki farklı katılımcı grubu ve iki farklı antrenman metodu kullanılmıştır. İsviçre topu egzersizlerinin dizin propriosepsiyonu ve karın bel kası kuvvetine olan etkisini araştırmak amacıyla, 10 hafta süresince haftada 3 günlük bir antrenman programı uygulanmıştır (Çalışma 1). İsviçre topu egzersizlerinin dinamik denge üzerine olan etkisini araştırmak amacıyla, 10 hafta süresince haftada 2 günlük bir antrenman programı uygulanmıştır (Çalışma 2). Birinci çalışmaya, spor yapmayan toplam 60 üniversite öğrencisi katılmıştır. İkinci çalışmaya ise spor yapmayan 47 üniversite öğrencisi katılmıştır. Bu çalışmanın sonuçlarına gore, İsviçre topu egzersizleri dizin propriosepsiyonu ve karın-bel kası kuvveti üzerinde anlamlı etkiye sahiptir. Dinamik denge için, 10 haftalık İsviçre topu egzersizleri sonunda, her iki grubunda (İsviçre topu ve kontrol) dinamik denge skorları gelişmiştir. Bu yüzden İsviçre topu egzersizlerinin dinamik denge üzerine etkisi olup olmadığı anlaşılamamıştır. Sonuçta, vücut ağırlığını direnç olarak kullanarak, İsviçre topu ile yapılan dengesizlik antrenmanları, genel sağlık ve performans için gerekli olan propriosepsiyon ve karın-bel kası kuvveti üzerinde etkiye sahiptir.

Anahtar kelimeler: İsviçre topu, sabit olmayan zemin, diz propriosepsiyonu, karın & bel kası kuvveti, dinamik denge.

To My Family

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Definition of Terms

Afferent system : Afferent nerves transmit the neural impulses from peripheral part of the body to central nerve system such as pain, temperature. Direction of the afferent impulses is from peripheral to central.

Agonist antagonist Ratio: The value of peak torque of the agonist muscles generated from the maximum isokinetic contraction divided by peak torque of the antagonist muscles generated from the maximum isokinetic contraction.

Ankle instability: Ankle instability is a situation that identified by a repeated "giving way" of the inversion position of the ankle.

Anterior – posterior stability index (APSI) scores; Medial-lateral stability index scores (MLSI; Overall stability index (OSI): These indexes are standard deviations assessing oscillations around the zero point. The MLSI and the APSI assess the oscillations from horizontal along the AP and ML axes of the Biodex Stability System; the OSI is a compound of the MLSI and APSI.

Core body: The core of the body can be simulated as a box. Abdominal muscles locate in front of this box, diaphragm as the ceiling, paraspinal and gluteal muscles locate in the rear, pelvic floor and hip girdle muscles constitute the floor and finally rotator muscles place side parts of the box.

Core stability: Stabilization, control and movement capability of center of the body during motion.

Dynamic balance: is the ability to maintain equilibrium while in motion, such as walking or running.

Efferent system: Efferent nerves transmit the neural impulses from central nerve system to effector organ such as muscles. Direction of the efferent impulses is from central to peripheral.

Feed-back loop: Signal transfer between afferent and efferent system to prepare the body to next motion; in other words, rapid connection between central nerve system and the receptor organs.

Kinetic chain: Transferring of the momentum from ground and lower body to upper body. Tennis serve is an example of kinetic chain movement.

Knee Joint Proprioception: The kinesthetic awareness and sensitiveness of the knee joint responsible to detect and response to a movement with regard to localization, position, reaction.

Knee instability: Also called as patellar subluxation. Knee joint holds by ligaments. When these ligaments injured, this situation can lead to instability of knee joint.

Low back pain: LBP is a very general musculoskeletal problem. According to estimates, nearly 70% of the people will have experienced at some period of their lives.

Peak torque: PT is an isokinetic assessment parameter which indicates maximum muscular force output at any moment during the test.

Peak torque / Body weight: PT/BW is an isokinetic assessment parameter which gives comparison opportunity of the people with different sizes. It gives comparable individual peak score.

Posture: Posture is a consequence of a state of muscular and skeletal balance within the body and this creates stability by an orientation of the constituent parts of the body in space at any moment time.

Somatosensory system: Somatosensory system is a part of sensory system comprised of the proceeding centers and receptors to generate the sensorial signals such as proprioception, pain, temperature.

Static balance: is used to maintain a static posture while without moving.

Swiss ball: Swiss balls are big, inflatable balls with a diameter of 45-75 cm. Smaller sizes generally use for medical purpose, especially for bedridden patients. Bigger sizes are suggested for exercises. Swiss ball is also known as the physio-ball, stability ball, Pilates-ball, exercise balls, wellness ball, fit-ball, and gym-ball.

Total work: Total work is the area under the torque curve.

Vestibular cochlear: The vestibulocochlear system, in simple terms, one of the systems responsible for balance consists of processing in the inner ear and brain.

Wobble board (tilt board- ankle disc): These boards are rectangular or circular shape. The upper side, on which the person stands, is straight and the bottom side, which touches the base, has a hemisphere in the center. Wobble boards capable of moving 360 degrees with 10 to 20 degrees of axial tilt.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

1.1.1 Unstable surface training

The rationale behind of unstable surface training is to procure a mixed and effective training stimulus (Behm & Anderson, 2006). Instability training aims to improve neuromuscular adaptations, decrease in the risk of injury, increase in coordination increase in balance, stability and proprioceptive capabilities rather than to gain explicit strength (Behm & Anderson, 2006). The main purpose of instability training is to reduce contact area of with the ground and compose an unstable condition. By improving dynamic postural control and balance, and producing more coordinated and consistent movement patterns during movement, injuries may be prevented (Verhagen, Tulder, Beek, Bouter, & Mechelen, 2005).

1.1.2 Core muscle strength

The core of the body can be simulated as a box. Abdominal muscles locate in front of this box, diaphragm as the ceiling, paraspinal and gluteal muscles locate in the rear, pelvic floor and hip girdle muscles constitute the floor and finally rotator muscles place side parts of the box. The core region consists of 29 pairs of muscles that are responsible for supporting the lumbo-pelvic-hip system so as to stabilize the spine and kinetic chain during motion (Faries & Greenwood, 2007). Core muscles have significant importance for daily life activities, athletic performance, and the treatment/rehabilitation of low back pain (LBP). Training the core muscles of the body is crucial to maintain musculoskeletal health, especially to prevent low back pain (Behm & Anderson, 2006). Core muscle training can be used in the treatment and rehabilitation phase of trunk-related musculoskeletal problems after injury (McGill, 1998). Training the core muscles is not only an essential parameter for prevention from injury, but also increases performance. Trained core muscles provide a solid foundation to the limbs to generate torque (Behm & Anderson, 2006). Nearly all movements begin in the core region. The core muscles are activated to act as a stabilizer in order to keep the body in an upright position even before movement in the limbs are initiated (Hodges & Richardson, 1997). The abdominal region is also a bridge between the upper and the lower extremities. Movements are continuously being transferred up and down during activity. Greater neuromuscular control and stabilization can provide efficient posture during kinetic chain movements. Efficient core muscles control allows for acceleration, deceleration and stabilization (Ebenbichler, Oddsson, Kollmitzer, & Erim, 2001).

Most strength and conditioning programs include exercises to enhance the strength of the core muscles, yet many of these exercises are unable to differentiate between the recruitment of the stabilizing muscles and the global mobilizing muscles. Instructions for abdominal exercises may over facilitate the development of the mobilizing of the muscles, and neglecting the recruitment of the stabilizing muscles (O'Sullivan, Twomey, & Allison, 1998) The core stabilizer muscles are activated more by unstable than by stable exercise. Therefore, the exercise program should involve a destabilizing component for strengthening or enhancing the endurance of the core stabilizer muscles (Behm & Anderson, 2006).

The spine is inherently unstable. The body wants to maximize spine stability for functional demands (Faries & Greenwood, 2007), and to maintain spinal stability, Swiss ball exercise is suggested for the core region. As for the reasons for this suggestion; core stabilizer muscles are activated more on unstable rather than stable surfaces. Core muscles can be classified into two categories: global and local. The global muscles including the erector spinae, external oblique, rectus abdominis and quadratus lumborum have long levers and large moment arms responsible for producing a torque output, generating movement in a larger range of motions (Cholewicki & VanVliet, 2002). The local muscles including the transverse abdominis, internal oblique, multifidus, lumbar transversospinalis, diaphragm, and the pelvic floor muscles have shorter muscles lengths, connect directly to the vertebrae, and act in order to directly stabilize the individual spinal segments which are the targeted muscles during core muscles strengthening programs (Briggs, 2004). (Table 1.1) (Figure 1.1,1.2,1.3,1.4).

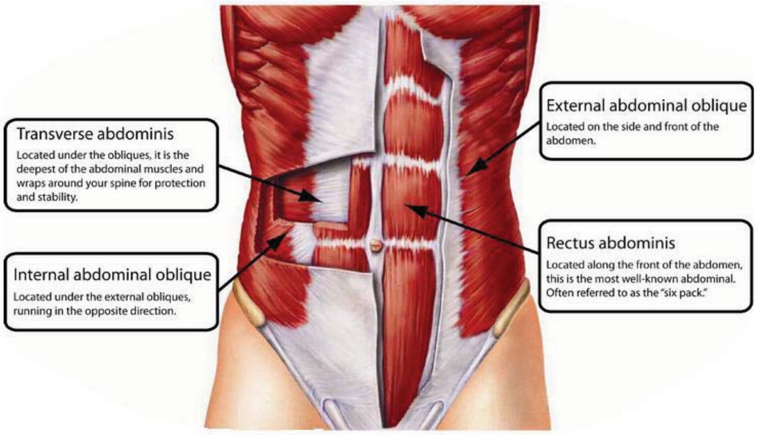

Figure 1.1 Local and global muscles (Transversus Abdominis, Internal Oblique, External Oblique, Rectus Abdominis) (Retrieved from http://www.muscle-fitness-tips.net/abdominal-muscles.html)

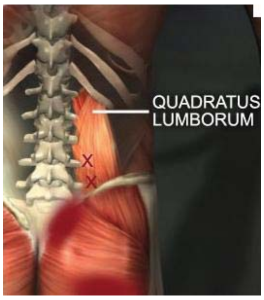

Figure 1.2 Quadratus Lumborum (Retrieved from http://www.deeptissue.com/learn/torso)

Figure 1.3 Erector Spinae (Retrieved from http://dynorock.wordpress.com/erector-spinae/)

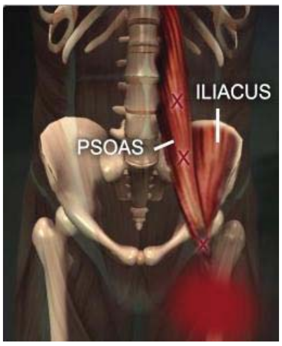

Figure 1.4 Psoas Major and Iliocostalis (Iliacus) (Retrieved from http://taylorednutrition.tripod.com/improvinghipflexors.html

Table 1.1 Global and Local Muscles

Local muscles (stabilization system) Primer system	Seconder System	Global muscles (movement system)
Transversus abdominis	Diaphragm	Rectus abdominis
Multifidus	Internal oblique	Erector spinae
	Quadratus lumborum	Ilıocostalis
	Pelvic floor muscles	Psoas major

Traditional floor exercises such as sit-up, focuses on improving the potential of global but not local muscles. At that point, it should be noted that while performing exercises (for example sit-up), both groups, in theory, work in harmony (Cholewicki & VanVliet, 2002). One surpassing characteristic of the Swiss ball training is that core stabilizer muscles are activated more on unstable rather than stable surfaces. Another advantage of the Swiss ball sit-up exercise is the preventing of extra compressive force to spine that is generated in traditional sit-ups. Maintaining of the neutral spine has beneficial effects to avoid low back pain. Swiss ball sit-up exercise can minimize the load on the spine (McGill, 1998). Therefore, there is a consensus on core muscles strengthening or endurance development program that should involve destabilizing equipment.

1.1.3. Proprioception

Joint sensation or proprioception and kinesthesia are defined in the literature. Most updated definition of proprioception is afferent message originating from peripheral region of the body that provides to postural equilibrium, joint stability, and other conscious perceptions (Riemann & Lephart, 2002). Proprioception refers to the innate kinesthetic awareness of body posture including motion, tension, and changes in balance (Baltaci & Kohl, 2003; Lephart, Pincivero, Giraldo, & Fu, 1997). Proprioceptive organs are found in the skin, muscles, tendons, ligaments and this process provides input to central nerve system about heat, pain, tension, pressure, balance, and body position. Joint position sense (active or passive) and kinesthesia are components of proprioception and they are often used to assess proprioception. Kinesthesia is an ability to detect movement; in other words, threshold for perception of slow passive movement ($< 1°/s$). Joint position sense is assessed by determining the error between the instructed angle and participant's decision. In active repositioning of the joint angle, participants play an active role where they try to find the instructed angle by themselves. In passive repositioning of the joint angle, the machine moves the participant's limbs, and the participant cannot exert any effort to move his or her limbs. In this test, the participant again tries to find the instructed angle but for this test participant is passive whereas the machine is active (Bernier & Perrin, 1998).

There are no standard ways, methods or equipment to assess proprioception in both types of proprioception measurement. To evaluate proprioception, lots of devices are still being used ranging from the most basic goniometer to the most contemporary isokinetic dynamometers equipped with their own internal electro goniometers, such as the Biodex, Kin-Com, Cybex, Chattex. Passive joint position sense is significantly better than active joint position sense because passive method have less calculated error (Lephart,Pincivero & Rozzi, 1998). The reasons for this differences discrimination are theoretically explained by the phenomenon that while performing active repositioning test, both muscle and joint receptors are involved. During the test, the receptors of the joint responsible for sensing actual joint position and muscle receptors are found to be more reliant for detecting joint movement because extra input to the afferent-efferent system can make sensing joint position more challenging.

Knee and ankle injuries are among the most common injuries in daily and sports activities. Knee joint proprioception is essential for adequate joint movement and stability in daily life or sports area. When people move the joint or act with force while walking, running, jumping, proprioception can adjust the posture or enforce the accurate movements automatically (Baltaci & Kohl, 2003). Any type of joint injury can harm joint position sense. Damaged joint position sense can be a primary risk element for repetitive injuries. On the other hand, improved joint position sense may play a preservative role against injuries. Individuals with the history of knee injury are more susceptible to recurrent sprains, chronic instabilities or re-injury of the same character and localization (Murphy, Connolly, & Beynnon, 2003). Previous injury experiences may also lead to fear of re-injury that could induce the person to use different muscle recruitment patterns (Murphy, Connolly, & Beynnon, 2003). In the long term, this can cause asymmetry between body parts. Proprioceptive and balance training are presumed to enhance protection from injury, to provide more accurate movement pattern and also to be beneficial for optimal recovery after injury or operation (Baltaci & Kohl, 2003).

1.1.4. Dynamic balance

Balance can be defined as the ability to maintain the body's center of gravity over its base of support with smallest sway or maximum firmness. Maintaining balance is the basis of the complex interaction among the vestibular somatosensory, visual functions and coordination of movements with muscle activity (Emery, 2003; Horak, 1987).

There are mainly two types of balance: static and dynamic. Static balance refers to maintaining static position while stationary situations such as sitting or standing. Dynamic balance is the ability to maintain balance while moving. The optimal balance control is a fundamental necessity for sport, daily activities and protection from injury (Anderson & Behm, 2005) There are some balance strategies described in the literature to sustain balance in different conditions (Lephart, Pincivero, & Rozzi, 1998). The first strategy is ankle strategy. It is generally used in condition of small perturbation and the stable surface because ankle joint have only a small torque producing capability (Nashner, 1977). When ankle joint cannot able to produce enough torque due to unstable surface or larger perturbation requirement to maintain balance, knee and the hip joints are involved (Emery, 2003; Horak & Nashner, 1986).

The spherical shape of Swiss balls may help to stimulate more motor units of the stabilizing muscles than traditional floor exercises as a possible consequence of enhancing overall balance (Anderson & Behm, 2005) and core muscles stability (Behm, Drinkwater, Willardson, & Cowley, 2010b; Carter, Beam, McMahan, Barr, & Brown, 2006; Stanton, Reaburn, & Humphries, 2004). In addition to activation of more motor units, Swiss balls have been demonstrated to activate some regions of the brain stem, vestibular system and cerebellum which leads body control, balance, and posture (Carrière, 1998).

1.2 Rationale of the study

Swiss balls were previously used for physiotherapy, they are increasingly being used for workouts as well. Although its effectiveness has not been proven scientifically, Swiss ball exercises has become increasingly popular especially in the last decade. However, it is well documented that performing exercises on an unstable surface, when compared a stable surface, arouses a greater influence on muscular activity and unstable surface training can be very effective for injury prevention and treatment. Conversely, it has been clearly proven that Swiss ball exercises decrease force output when compared a stable surface. But, in some respects, effectiveness of unstable surface training needs to be investigated deeply. Authors have underlined this missing point in the literature. Stanton, Reaburn and Humphries (2004) stated that while an abundance of anecdotal proof supports the use of Swiss ball training to improve physical performance, this has not been proven by valid scientific research. Pettitt and Bryson (2002) specify that Swiss ball training in theory will enhance afferent and efferent sensorimotor control, with feedback from the somatosensory system, the vestibular cochlear system, the cerebellum, and visual inputs. Additionally and very recently, Behm and Sparks (2010) indicated that more investigation is needed to conclude if the use of instability training to enhance balance and stability. Faries and Greenwood (2007) stated that "most of the research addressed the application of the trunk muscle has concentrated to evaluate activation only. Quantification of the core muscles appear can be a convenient area of further investigation for the strength and conditioning or fitness professional.

Therefore, it is important to investigate the effects of Swiss ball exercises on proprioception, dynamic balance and core muscles strength.

1.3 Research questions

The research question of this thesis is whether 10-week Swiss ball exercise affects (a) knee proprioception, (b) dynamic balance and (c) core muscles strength in sedentary collegiate students.

1.4 Purpose of the study

The purpose of this study was to investigate the effects of Swiss ball training on (a) knee proprioception, (b) dynamic balance (c) core muscles strength in sedentary collegiate students, using Biodex isokinetic dynamometer for core muscles strength and knee proprioception and Biodex Stability System for dynamic balance assessments.

1.5 Research hypothesis

- Swiss ball exercises will improve knee proprioception scores.
- Swiss ball exercises will improve the core muscles (abdominal and low back) strength parameters.
- Swiss ball exercises will improve dynamic balance (overall, anterior-posterior and medial-lateral) scores

1.6 Limitations

- The participant's population consisted of 18-27 years old sedentary collegiate students.
- Daily activities of the participants were not controlled.
- Tests were conducted in laboratory settings.
- Lacking of stable surface (ground based) group.
- Small sample size of control group (Study 1).
- Gender comparison was not conducted.
- Communication between experimental and control group were not controlled.

1.7 Assumptions

- Control group did not participate in any sporting activity.
- Participants presented their best performance during tests.
- Participants in the experiment group did not perform any extra exercises.
- Rest intervals between trials were sufficient so fatique was not an internal threat.
- The participants did not rotate their trunk during the isokinetic assessments.

CHAPTER 2

REVIEW OF LITERATURE

This chapter gives detailed information about the subject related studies which is background information needed to understand the (1) unstable surface training, (2) core body (3) balance & proprioception and injury prevention.

Some studies in core section are not only related with core but also related with balance. So, these studies were explained in the core section and they were not discussed again in balance section.

2.1 History of the Swiss balls

The Swiss balls were firstly manufactured as a toy by an Italian plastics engineer (also owner of Toy Company) Aquilino Cosani in 1963. Physical therapist, Mary Quinton, in Switzerland used these balls for therapy of neurologically impaired children. Other therapists Dr. Susanne Klein-Vogelbach and Maria Kucera used these balls for posture training and back pain rehabilitation (Carrière, 1998). After that, these balls were only purchased in Switzerland. Hence these balls are called “Swiss balls”. In 1986, a famous football player, Joe Montana, underwent back surgery. He returned back to his profession only after six weeks of rehabilitation. His rehabilitation program received considerable attention that included Swiss ball exercises. After this, other therapists began to use the Swiss balls more widely in orthopedic rehabilitation. During the 1990s therapists, athletic trainers, and classroom teachers from other nations went to Switzerland to learn the effective usage of Swiss ball. Thus, Swiss ball exercise has begun to spread to the whole world afterwards (Carrière, 1998).

2.2 Childbirth and Swiss ball

Swiss balls are being used in lots of different areas such as, strength training, balance training, orthopedic rehabilitation, physical fitness, flexibility training, physical education classes, special education, and especially childbirth. Watkins (2001) proposed the usage of the Swiss ball during pregnancy which is a period in which certain anatomical changes occur (changes in center of gravity, weight gaining, postural problems...). Dynamic nature of the Swiss ball exercises can improve posture, balance, coordination, body awareness, flexibility and strength. Increase in strength (abdominal and back) is the goal of prenatal exercise program. Improving flexibility in specific muscle groups, such as abductor muscles, is more aptly achieved by these balls. Lots of pregnant women found these exercises "FUN". Using the ball is a way to relieve stress and tension. Many pregnant women report that "Swiss ball" is more comfortable to sit on and is much easier to handle than a stable chair. Perez (2000) stated that using the Swiss ball during pregnancy stimulates postural reflexes and keeps deep supportive (local) muscles, so protects the back and also enhances pelvic mobility and encourages rhythmic movement which may promote optimal positioning and reduce the pain of contractions.

2.3 Unstable surface & Core muscle researches

Instability resistance training has currently grown in acceptance in strength and conditioning. Although little research has examined how UST affects performance, many companies, strength coaches, personal and athletic trainers have profited from this trend by encouraging instability training products as helpful for enhancing performance (Cressey, West, Tiberio, Kraemer, & Maresh, 2007).

The trunk connects motions of the lower extremities to the upper extremities and vice versa. The kinetic chain involves the whole body and it allows for person to transfer momentum from lower body to core region and upper body. The core region is responsible for generating various movements of the trunk in sagittal, frontal and horizontal planes of motion (Jakubek, 2007). Core muscle exercises aim to improve the muscles' capability to stabilize spine, especially lumbar part, instead of enhance the stability of the musculature. During functional activities, core muscle is responsible for stabilize the spine because the body needs to maximal stabilization. The primary task of Swiss balls in resistance training is to build up a stable and neuromuscular efficient core. The core region is a multipart portion of the body, which is inclined to increased requests for balance control; for that reason, core muscles should be trained for strength, endurance, and neuromuscular control. In this manner, unstable surface training may be an appropriate way to train core region (Jakubek, 2007).

Schibek (2001) examined the effects of 6 weeks Swiss ball core muscle stabilization training on swim performance (100 yards swim times); core muscle stability, vertical jump, forward and backwards medicine ball throw and hamstring flexibility. At the end of 6 weeks Swiss ball core muscle stabilization training, only forward medicine ball throw and core muscle stability improved. Although core muscle stability improved, this gain could not be transferred to swim performance. Author concluded that Swiss ball exercises might not be particular to the core muscle stability necessity of swimming.

Similarly, Stanton, Reaburn and Humphries (2004) dwelled on the effects of 6 weeks Swiss ball core muscle stabilization training on core muscle stability, VO2 max, running economy and postural position during running the frequency of which was twice per week. Totally 12 exercises sessions were conducted by participants. Eighteen young male athletes (mean age = 15.5 years, $VO_{2\ max}$ = 55.3 ± 5.7 $ml.kg^{-1}.min^{-1}$) participated in the study. 10 participants were assigned to control group, remaining 8 participants were assigned to experimental group. By the end of 6 weeks, Swiss ball training positively affected the core muscle stability on the other hand physical performance parameter (running economy, postural position during running, $VO_{2\ max}$) did not change significantly. Authors concluded that training program (2 days per week, number of sets, repetitions) may not be enough stimulation to elicit significant training effect on the ability to stabilize spine during running.

General concerning use of Swiss ball in exercises is that it has some benefits (core muscle stability, muscle activation...). However, this improvement may not be transferred to specific sports area. At that point researchers go into a division. Opponents of Swiss ball exercises propose that “if this improvement cannot transfer into sports area you do not need to perform these exercises”. On the other hand, proponents of the Swiss ball defend the idea that “even if this improvement cannot be transferred to sports, another gain can be achieved such as improved coordination of agonist, antagonists, synergists, and stabilizers muscles.

Carter and colleagues (2006) conducted a study to understand the effect of Swiss ball training on spinal stability in sedentary individuals. Twenty sedentary individuals were randomly and equally assigned to groups (experimental, control). Exercise period was 10 weeks (2 days per week). Spinal stability was measured by static back endurance and side bridge tests. The objective of the test was to maintain a position. Duration of the tests (second) were recorded and analyzed. Post test scores (duration) were increased in both test, significantly. Authors stated that Swiss ball may provide improvements in spinal stability and these exercises can be used during early phases of back pain prevention programs. Interestingly, the control group's static back endurance scores decreased significantly from pre to posttest. Authors explain this situation as lots of the participant's having back ache after the pre assessments and in the post test leading them not to exert themselves. Also side bridge test of the control group slightly increased. Authors interpret this increment as a "learning effect" .

In a study, conducted by Cosio-Lima and colleagues (2003) was compared the effects of 5 weeks Swiss ball exercises and traditional floor exercises on muscle activity, torso balance, isokinetic strength (trunk and knee) and heart rate. Totally 30 female participants participated in the study. Participants were equally assigned to experiment or control group. Participants in the experiment group performed sit up and back extension exercises with Swiss ball, and participants in control group performed the same exercises on the floor. Exercise program was quite intensive, 5 days per week. From first week to fifth week repetition and set number increased. In the first week, participants performed 3*15 curl- up, 3*15 back extension; in the fifth week these numbers increased up to 4*25 for both exercises. Rest intervals between repetitions were not allowed. Unfortunately, there was no supervision throughout 5 weeks. At the beginning of the study, a session was conducted to instruct the participants on how they should execute exercises in a proper form. Each woman planned her individual program according to her own free time. Unfortunately, researchers compared only changes from pre to posttest scores of experiment and control group. They did not investigate whether these changes were significant or not from baseline (pre) to posttest individually. According to their study results, there were no significant differences between the changes of experiment and control group pre to post scores by means of isokinetic strength parameters and heart rate. On the other hand, experimental group achieved greater balance and EMG (trunk flexion/extension) activity. Critically, it is not possible to say whether strength gains in both groups were significant or not when pre and posttest scores were compared. Also, while evaluating isokinetic strength researchers used best (peak, maximum) repetition scores (ft/lb). In terms of comparability with the other studies, peak score can be used; however peak score indicates maximum effort. Exercises such as Sit-up or back extension (without additional load) does not actually aim to increase maximum strength, this kind of exercises aimed at improving endurance capacity.

Moreover, their training log aimed at increasing endurance capacity because it included high repetitions. Thus, using total work score to evaluate endurance capacity will be more applicable in that kind of exercises.

In the literature, general tendency is to investigate on and off Swiss ball studies, it means Swiss ball vs. stable surface. Despite some opposite findings, general agreement in that kind of research is that Swiss ball exercises elicit greater muscular activity. Although many researchers were conducted in that area, in this literature review only some of this research will be discussed.

In a study conducted by Marshall and Murphy (2006), the EMG activity of rectus abdominus, transversus abdominus/internal obliques, anterior deltoid, triceps brachialis, biceps brachialis, pectoralis major muscles during Swiss ball bench press and stable surface bench press were compared. Authors reported greater activity concerning only deltoid and rectus abdominis in Swiss ball group.

In another on and off Swiss ball study researchers compared EMG activity of erector spinae muscles, internal oblique, external oblique, and rectus abdominis on and off Swiss ball when performing overhead triceps extension, lateral raise supine chest press, shoulder press, biceps curl. Although researchers found great changes between different surfaces, these changes were not statistically significant. Only 7 male participants participated in the study. Small sampling size may have an effect in finding significant differences (Lehman, Gordon, Langley, Pemrose, Tregaskis, 2005).

Vera-Garcia, Grenier and McGill (2000) compared EMG activity of rectus abdominis, internal and external oblique muscles on stable and 3 different unstable surfaces during curl up exercises. Three unstable surfaces were: (1) curl-up with the upper extremity on a Swiss ball and with feet flat on the ground (2) curl-up with the upper extremity on a Swiss ball with feet on a bench (3) curl-up with the upper extremity supported by a wobble board. Simplified results showed that unstable (labile) surface increased muscle activity more than stable surface. As regards to results of different unstable surface, there was no superior method to increase muscle activity. Different unstable surfaces affect muscle groups in different portions.

As stated previously, some benefits of Swiss ball exercises are well-documented (core muscle stability, muscle activation); on the other hand, other possible benefits need to be investigated deeply.

Carpes (2008) implemented a study to show the effect of Swiss ball trunk (core) strength training on body balance. 6 female participants were recruited to study. Participant executed totally 20 exercise sessions lasting 50 minutes. Body balance was evaluated by 3-D force plate and center of pressure displacements (COP) were recorded. In the post test participants COP scores improved significantly. Authors concluded that enhanced balance may be associated with superior neuromuscular control, which happens due to an development in postural control.

Sekendiz, Cuğ and Korkusuz (2010) investigated the effects of 12 weeks Swiss ball core muscle strength training on abdominal strength, abdominal endurance, low back strength, low back endurance, lower limb (quadriceps, hamstring) strength, flexibility, and dynamic balance in sedentary women. Strength parameters were measured by isokinetic dynamometer. Trunk and limb strength were evaluated 60 and $90s^{-1}$, 60 and $240s^{-1}$ respectively. Curl-up test for abdominal endurance, modified Sorensen test for back endurance test, sit and reach for flexibility, functional reach test for dynamic balance were used. One of the limitations of this study was lacking of stable surface exercise group and control group. Authors stated that Swiss ball can be useful equipment to develop foregoing parameters in sedentary women. Researchers also concluded that Swiss ball exercises can be used as a preventative training against falls and following injuries in the sedentary women that is associated with low balance, lower extremity and core muscle strength.

Liggett and Randolph (1999) conducted a pilot study to compare the strength gain in abdominal muscles throughout conventional sit-up exercises with that achieved through exercising on a physioball. Their primary findings showed that greater strength gain was achieved in the participants who trained on the physioball; however, these strength gains were not significantly greater than those achieved through training in traditional sit-up type exercises.

A weakly developed core region may also contribute to weak posture (Faries & Greenwood, 2007). The most efficient way of transferring the force from lower body to upper body is to use the shortest distance, a straight line. Weakly developed core region can lead to less efficient movements and decrease force output (Brittenham, 1997). Researchers have shown that a weakly developed core muscle may be correlated with low back pain. Some studies suggest that high endurance capacity of the core region muscles can alleviate the risk of low back problems (Biering-Sorensen, 1983). In a study conducted by Biering-Sorenson (1983), participants were tested for trunk muscle endurance and strength. After 1-year period, results showed that isometric endurance capacity of the low back muscle was an important predictor in reducing low back trouble in men. Decreased muscular endurance of the low back musculature is strongly associated with low back pain (McGill, 1998; Nourbakhsh & Arab, 2002) Therefore, training methods for the core muscle might be structured differently, based on the health status and training goals of athletes and non-athletes (Behm, Drinkwater, Willardson, & Cowley, 2010b).

In summary, most of the research which addressed the effect of instability on core muscle has focused on muscle activation only. The primary consequence with the core muscle and its practical implementation to the strength and conditioning areas is that research is scarce. Quantification of the core muscle appears can be a convenient area of further investigation for the strength and conditioning or fitness professional (Faries & Greenwood, 2007).

2.4 Unstable surface & Balance Researches

The optimal balance control is a fundamental necessity for sport, daily activities and protection from injury (Anderson & Behm, 2005). Maintaining postural control is a principal element of implementing almost all physical movement (Ruiz & Richardson, 2005).

Although it is well known that balance training can improve balance, decrease injury rate, mechanisms of the balance is not fully resolved. Anderson and Behm (2005) stated that much is known about static balance, but little is known about how muscles maintain dynamic balance. Maintaining balance is the basis of the complicated interaction among the vestibular somatosensory, visual functions and coordination of movements with muscle activity (Horak, 1987).

There are various balance assessment techniques (Functional Reach Test, Berg Balance Scale, Star Excursion Balance Test...) and devices (Force Platforms, 3-D kinematic Analysis...). One of the most frequently used devices to assess dynamic balance is Biodex Stability System. Biodex Stability System SD (Biodex, Inc., Shirley, NY, USA), which comprises of a movable balance platform provide up to 20^0 of surface tilt in a 360^0 range of motion. A new version of BSS has 12 dynamic stability levels. Level 12 is the most rigid (easiest) and level 1 the most fluctuating (most difficult) level. The measure of postural stability includes the overall (OASI), the anteroposterior (APSI) and the mediolateral (MLSI) stability index scores. These scores are calculated from the amount of platform tilt (in degrees) from the preset centering of the participant. These measures are the average amount of tilt from baseline that occurred overall, in the sagittal plane, and in the frontal plane.

Although some research that criticize validity and reliability of laboratory measurement techniques closely (Emery, 2003; Emery, Cassidy, Klassen, Rosychuk, Rowe, 2005), other researches found these devices reliable ((Baltaci & Kohl, 2003; Lephart, Pincivero, Giraldo, & Fu, 1997; Schmitz & Arnold, 1998). There are contradictory findings in the literature about the laboratory balance measurement devices. In literature, it has been stressed that laboratory measurement techniques for balance are expensive, unmovable, and quite technical. Besides, these techniques are often not convenient for manage in a clinical setting or for research in a large field based clinical trial. Furthermore, these clinical tools are not suitable for use in the healthy active population and also these devices need to be improved and measured for reliability and validity (Emery, 2003). On the other hand, other research found Biodex Stability System reliable (Table 2.1).

Table 2.1. Studies related with reliability of Biodex Stability System

	Age range	Mean age	Sample size	BMI (kg/m^2)or weight	Visual situation	Stability level	Shoes (yes/no)	Test duration	Test position	ICC
Study 1 (cited in Hinman's study)	18-65	32.9 ± 11.5 years	50 (31 women, 19 men)		Eyes open, looking straight	Level 3 Level 6		30 seconds		*Level 3* *R* = .89 Level 6 *R* = .87
Study 2 (cited in Hinman's study)	21-52	28.1 ± 8.1 years	50 (37 women, 13 men)	17,7 to 31,4 (kg/m^2) (mean = 22,5 ± 2,9) (kg/m^2)	1-eyes open, looking straight ahead; 2- eyes open, receiving visual feedback; 3- eyes closed	Level 6		30 seconds		*Eyes open with feedback* *R* = .50 Eyes closed *R* = .83
Study 3 (cited in Hinman's study)	65-92	71,4 ± 5.4 years	79 older adults (47 women and 32 men)	39.9-117,9 kg Mean :74,4 ± 15,3 kg	eyes open, receiving visual feedback	Level 7	Hard soled shoes Soft soled shoes	30 seconds		*Soft soled* *R* = .79 Hard soled *R* = .82
Study 4 (cited in Hinman's study)	21-50	26 ± 6 years	44 participants (37 women and 7 men)	18.2-28.1 (kg/m^2) mean : 21,7± 2.3 (kg/m^2)	twice with visual feedback and twice with vision impaired by semitransparent goggles	Level 6		30 seconds		
Cachupe	23-34	27	20 participants (10 men 10 women)			Level 2	Low-top athletic shoes	20 seconds	Dom	Overall stability index *R* = .94
Schmitz and Arnold		24.4 ± 4.2	19 (8 male, 11 female)	70.5 ± 20.0 kg	Eyes open, look straight ahead	Gradually decreased (from 8 to 1)	Without footwear	30 seconds	Dom	Overall stability index *R* = .82
Pincivero			20			Level 2 Level 8		20 seconds	Dom & Non Dom Limb	For Dom Level8 ICC: .95 Level 2 ICC:.60

Balance is not only an inborn ability, yet it is also a learned and gained skill. Instability equipment (e.g., wobble boards, Swiss balls or physioballs) may provide postural challenging or instability, as postural sway may project the center of gravity point beyond the device's base of support area (Emery, 2003).

In unpublished master thesis, Corbett (2004) investigated the effects of 6 weeks Swiss ball training on balance tests (BERG balance scale, Functional Reach Test, Postural sway, timed one leg standing) in people over 65 years old. 15 volunteer participants were assigned randomly as either experiment or control group. Participants performed 10 Swiss ball exercises during 6 weeks for which there was no supervision. A photocopy of the exercises was given to participants whom they will perform. Participants were called by phone to make sure they were doing the exercises correctly and to answer any questions or problems. At the end of the study, all balance test scores were improved, however none of them were significant. Author concluded that Swiss ball exercises in supine, prone and seated positions may improve balance and Swiss ball could be an important tool to reduce falling.

In another comprehensive study, researchers compared the effects of balance and plyometric training on landing force, balance, and power in female athletes. 19 female participants participated to the study. 8 of them were assigned to plyometric group and remaining 11 were assigned to balance group. Exercises maintained 3 times per week for 7 weeks. The plyometric exercise group did not receive any dynamic balance exercises, whereas, the balance group did not receive any maximum effort jumps. Balance was evaluated by standard deviation of center of pressure during single leg hop and hold. Balance training equipment include Bosu balls (both side up), foam pads and Swiss balls. Bosu ball consists of an inflated rubber hemisphere attached to a rigid and flat platform, also referred to as "half ball" because it looks like a Swiss ball cut in half. At the end of 7 weeks both balance and plyometric training groups reduced their standard deviation of center of pressure scores. Authors concluded that both balance and plyometric training are efficient on neuromuscular control and can be used as a preventive tool in preseason training of female athletes (Myer, Ford, Brent, & Hewett, 2006).

Heitkamp and colleagues (2001) compared the effects of strength and balance training on strength and muscular balance. Strength and balance training were implemented by 15 persons each for 6-week consisting of 12 training. Swiss balls, mini trampoline, and rolling board were used as unstable surface training devices. Balance was assessed by stabilometer and self-constructed apparatus by researchers. Results indicated that balance training can be efficient for strength gain alone, and also balance training had superior effect for muscular imbalances.

Kahle (2009) investigated the effects of 6 weeks core muscle stability training on dynamic balance. 30 healthy participants were participated the study and were randomly assigned to experimental or control group. Core muscle stability movements were performed on both stable and unstable surface (Swiss ball) where balance was assessed with Star Excursion Balance Test (SEBT). This test requires individuals to maintain balance on a single limb. Participants try to reach maximum excursion on 8 unilateral tests; (1) medial, (2) lateral, (3) anterior, (4) posterior, (5) anteromedial, (6) anterolateral, (7) posteromedial, (8) posterolateral. Maximum excursion distances were recorded for statistical analysis for each test. In that study, researcher preferred to use anteromedial, medial, posteromedial directions. They reported this method to be more practical because when 8 directions used in the test redundancy of the scores can be observed. There is a significant correlation between reach directions. After 6-week period, maximal reach distances enhanced for the exercise group, compared with the control group. Authors concluded that core muscle stability training can improve dynamic postural control and can be used for treatment and rehabilitation of athletic injury.

In unpublished master thesis, Piegaro (2003) compared the effects of 4 weeks core muscle stabilization and balance training program on balance. 39 participants (27 men 12 women) were assigned to one of the four groups randomly :(1- Core muscle stabilization training group 2-Balance training group 3- Combined core muscle stabilization/balance training group 4- Control group). Biodex stability system and Star excursion balance test (SEBT) were used to assess balance. According to SEBT results, combined core muscle stabilization and training group improved their balance scores. On the other hand, none of the Biodex stability system scores were found significant in all groups. Critically, although researchers designed a very comprehensive experimental design, stability level 6 in BSS (closer to most stable level 8) may not be challenging enough to determine balance because participants were free from any medical disturbances and young persons (age = 21.87 ± 2.26 years).

Again in unpublished master thesis, McCaskey (2011) investigated the effect of 4 weeks core muscle stability training on global muscular endurance and dynamic balance in female college students. 30 participants were equally assigned to control or core muscle stability training group. Core muscle stability group performed their exercises on stable and unstable surface (Swiss ball). Balance was evaluated by Star excursion Balance Tests. Similar to Kahle's study, out of 8 directions only three reach distances (anterior, posteriolateral and posteriomedial) were evaluated. Global core muscle appraised by left-right bridge test (second) and flexor and extensor endurance test (second). At the end of the study, core muscle stability training group improved their posteriolateral reach direction, the posteriomedial reach direction, the right side bridge and the left side bridge durations. Author concluded that core muscle stability training program can be used to increase dynamic stability and core muscle endurance. Related to non-significant anterior reach author stated that ability to control the spine is highly related with posteriolateral and posteriomedial, but may not be related with anterior reach because of body position during test.

Hoffman and Payne (1995) implemented unstable surface training (ankle disc training) to see the effects of proprioceptive training on postural sway in healthy participants. 28 participants were randomly assigned to control and experiment group. Training group participants trained their dominant leg three times per week for 10 weeks. Postural sway was appraised by force platform. After 10- week training, postural sway in the directions of medial-lateral and anterior-posterior were significantly decreased.

In a study conducted by Yaggie and Campbell (2006), the effects of 4 weeks Bosu ball training on postural sway and displacement, vertical jump, time on ball and shuttle run were analyzed. Participants were assessed 3 times; pretest (Tl), a posttest (T2), and 2 weeks post-training (T3). 36 participants were randomly assigned to experiment (n=17) or control (n=19) groups. At the end of 4 weeks training, significant differences were found in postural displacement, shuttle run, total sway, time on the ball between pre and posttest. Follow up assessments showed that time on the ball and total sway remained the same but no other was retained. Authors concluded that balance training may improve specific sport-related movements and postural stability parameters.

In a case study, conducted by Mattacola and Lloyd (1997), the effects of ankle board and strength training on dynamic balance were assessed. Only 3 participants who experienced with first-degree lateral ankle sprains participated to the study. Participants attained both balance and strength training. Participant 1 attained 20 sessions, participant 2; 15 sessions and participant 3 attained 16 training sessions during 6 weeks. While evaluating balance, a "touch" number was recorded when the board touch the ground as observed either audibly or visually. Although it could not be shown statistically, improvement was observed concerning the "number of touches". Authors concluded that proprioception and strength training were effective to maintain balance as measured by Single Plane Balance Board.

2.5 Unstable Surface & Proprioception Researches

Proprioception refers to the innate kinesthetic awareness of body posture including motion, tension, and changes in balance (Lephart, Pincivero, Giraldo, & Fu, 1997) Proprioceptive organs are found in the skin, muscles, tendons, ligaments and this receptors provides input to central nerve system about heat, pain, tension, pressure, balance, and body position. (Michelson & Hutchins, 1995) Joint position sense (active or passive) and kinesthesia are components of proprioception and they are often used to assess proprioception.

Physiological changes caused by inactivity, injury, aging, adiposity can contribute to loss of balance and proprioception. As stated above, optimal control of balance and proprioceptive capabilities of the body are essential requirements for sport (performance enhancement, talent identification), daily activities, or for the protection from injury (Anderson & Behm, 2005). When people move the joint or act with force, proprioception can adjust the posture or enforce the accurate movements automatically.

Ankle and knee injuries are among the most frequent injuries in sports and daily activities (Baltaci & Kohl, 2003). Knee joint proprioception is essential for adequate joint movement and stability which may play a protective role in acute knee injury.

There is a conflict in the literature about the effects of instability training on proprioception. Some authors indicated that a stiffening strategy was emerged when individuals are faced with a threat of instability. This type of stiffening strategy may affect the voluntary movements negatively (Adkin, Frank, Carpenter, Peysar, 2002). Based on this information, instability-induced alterations in muscle activation, kinetics and muscle stiffness would likely have an adverse effect upon proprioception and co-ordination. Thus according to Behm et al. (2010) the decrements associated with instability devices may not provide as many training advantages as ground based lifting. Conversely, other researchers defend that balance training has the most fundamental impact on the proprioceptive control and somatosensory systems (Bernier & Perrin, 1998; Lephart, Pincivero, Giraldo, & Fu, 1997; Yaggie & Campbell, 2006).

The majority of literature in this area examines the effect of proprioceptive training on spinal stability (Carter, Beam, McMahan, Barr, & Brown, 2006; Kolber & Beekhuizen, 2007; Vera-Garcia, Elvira, Brown, & McGill, 2007; Verhagen, Tulder, Beek, Bouter, & Mechelen, 2005). Although there is some research in the literature which addressed the effects of instability training on limb proprioception, specifically, there is no known published study which investigates the effects of Swiss ball training on limb proprioception.

Bernier and Perrin (1998) implemented a study to understand the effects of 6 weeks wobble board training on ankle proprioception and postural sway of participants with functional ankle instability. 45 participants were randomly assigned to a control (Group 1), sham (Group 2), or experimental (Group 3) group. Electrical stimulation (sham treatment) was given the brevis and peroneus longus muscles' of participants in Group 2 (N = 14) The experimental group was trained for 3 days per week, 10 minutes each day, consisting of various proprioception and balance exercises. At the end of 6 weeks training there were no significant differences found between groups with respect to joint position sense. But some postural sway parameters were improved in group 3. Authors concluded that effectiveness of the balance and coordination training on joint position sense in participants with functionally instable ankles is questionable that is , related with insignificant joint position sense 10 minutes per day, 3 days per week, for 6 weeks is inadequate stimulus load to provoke any physiological change in the peripheral afferents.

Clark and Burden (2005) investigated the effects of 4 weeks wobble board proprioceptive training on muscle onset latency in participants with functionally unstable ankle. Proprioception not only consists of the ability to know body position in the space but also involves stimulus detection. 19 male who had sustained 3 sprains in the last 2 years participated in the study. Experimental group (n=10) underwent 4-week wobble board training (10 min, 3 times per week). After 4 weeks wobble board training muscle onset latency decreased significantly in experimental group. Authors concluded that wobble board is an effective and important tool to prevent injury.

Naughton, Adams, and Maher (2005) conducted a study to understand the effect of 4 weeks upper body wobble board training on shoulder joint proprioception in participants with and without shoulder dislocation. Totally, 60 shoulders were analyzed from 15 participants with previous anterior dislocations (mean age =22.4 ± 4.8; 14 male, 1 female) and from 15 (mean age= 23.5 ± 8.19; 9 male, 6 female) uninjured participants. Injured group underwent upper-body wobble board training for 10 min per day, 5–6 days per week, for 4 weeks. Exercise was not progressed during 4 weeks. Each participant was given a Swiss ball (diameter 75 cm) and a wobble board (diameter 42 cm). Participants were asked to maintain their balance while lying on Swiss ball in prone position. After 4-week of upper-body wobble board training, there was a significant movement perception development at the shoulders of prior dislocators compared to controls, and a superior development was observed for the involved compared to the uninvolved limb.

Chiang and Wu (1997) implemented a study to investigate the effect of different surface types (stable and foam surface) on selected variables. 15 male participants were attended to study. Then, participants were asked to step on the rotational platform with barefoot and the 25 cm feet apart. During testing, participants were asked to keep their balance as possible as steady and not to move their feet. Each participant was tested 5 times on both stable and foam surface. Following testing, authors stated that standing on foam affects the signals of both cutaneous mechanoreceptors and joint receptors.

One of the indicators of improved proprioception is decreased injury rate. Mcguine and Keene (2006) used balance training to decrease ankle sprains in high school athletes. 523 girls and 242 boys who members of their school's soccer or basketball team were randomly assigned to either an intervention group (27 teams, 373 participants) or control group (28 teams, 392 participants). Intervention group received balance training program addition to their routine exercise program. Control group was told performed only their routine exercise program. First 2 weeks of 5-week balance training program executed on stable surface and last 3 weeks participants executed ankle disc training. The exercise program included (1) maintaining a single leg position on a smooth surface with closed and open eyes; (2)

performing sport specific movements such as dribbling, catching, throwing and on single leg stance; (3) maintaining upright standing position on the balance board; (4) maintaining a one leg position on the balance board with closed and opened eyes; and (5) performing sport specific movements on balance board with one leg stance. Following to training, ankle sprain ratio was significantly decreased in the intervention group. Athletes who had previous ankle sprain in the control group had a two-fold increased risk of sustaining a sprain on the other hand athletes in the experiment group decreased their risk of a sprain by one half.

Unstable surface training is a common addition to conventional strength and rehabilitation exercises with the purpose of increasing exercise difficulty, improving joint proprioception and enhancing muscle activity. Instability training aims to increase efficiency of afferent-efferent system to decrease injury risk (Cressey, West, Tiberio, Kraemer, & Maresh, 2007) Effective afferent-efferent system have significant importance on neuromuscular excitation; possible progress in this respect consist quicker proprioceptive signal storage, signal transfer to the central nervous system (CNS), and information processing by the CNS (Gruber & Gollhofer, 2004). Effective afferent system shortens the latency times prior to muscle activity which allow for quick tightening of joint (Gollhofer, 2003).

CHAPTER 3

MATERIALS AND METHODS

3.1 Design

In this thesis, two different studies were conducted. In order to evaluate the effect of Swiss ball training on knee proprioception and core strength, 3 days per week training was conducted throughout 10 weeks (Study 1). In order to evaluate the effect of Swiss ball training on dynamic balance, 2 days per week training was conducted throughout 10 weeks (Study 2). The reason of different training duration between first and second study was; in study 1, two different parameters (knee proprioception and core strength) were tested. In study 2, only one parameter (dynamic balance) was tested. In some points, proprioceptive and balance training may have similar characteristics. In order to examine the effect of Swiss ball training on knee proprioception and dynamic balance separately, two different studies were conducted. The study 2 was conducted after 4 months of finishing the study 1's post assessments.

Requirement of follow-up assessments were decided according to changes from pre to posttest with respect to knee proprioception and dynamic balance. However, follow-up assessments were not conducted for core strength, regardless of any significant changes. Thus, strength gain or loss can be observed in short time periods.

Participants were divided into two groups: Swiss ball training group and the control group (both first and second sample). For the first sample, Swiss ball exercises were conducted 3 days (Mon-Wed-Fri) per week. For the second sample, Swiss ball exercises were conducted 2 days (Tuesday- Thursday) per week. All of the participants were tested at the beginning and at the end of 10-week Swiss ball training (Figure 3.1, 3.2).

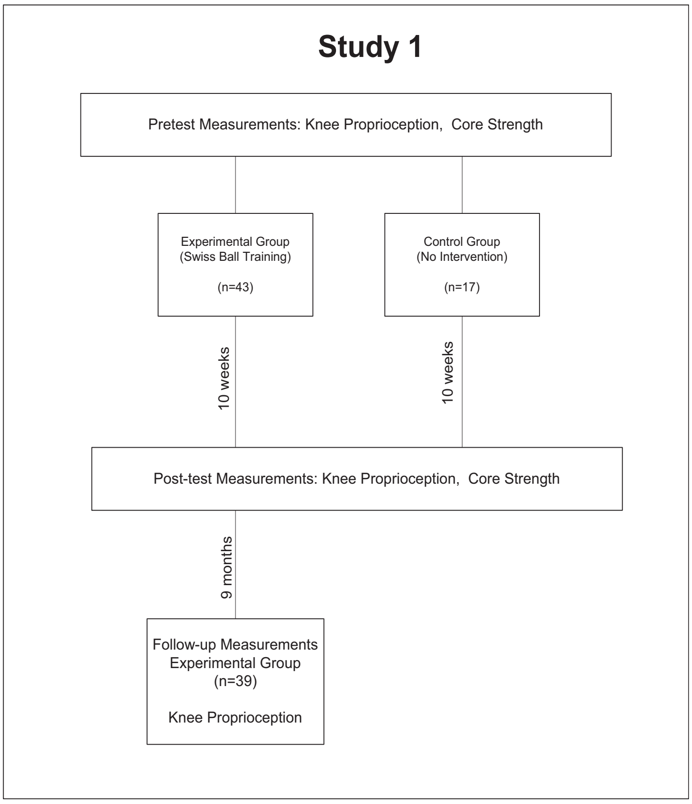

Figure 3.1 The first study's design

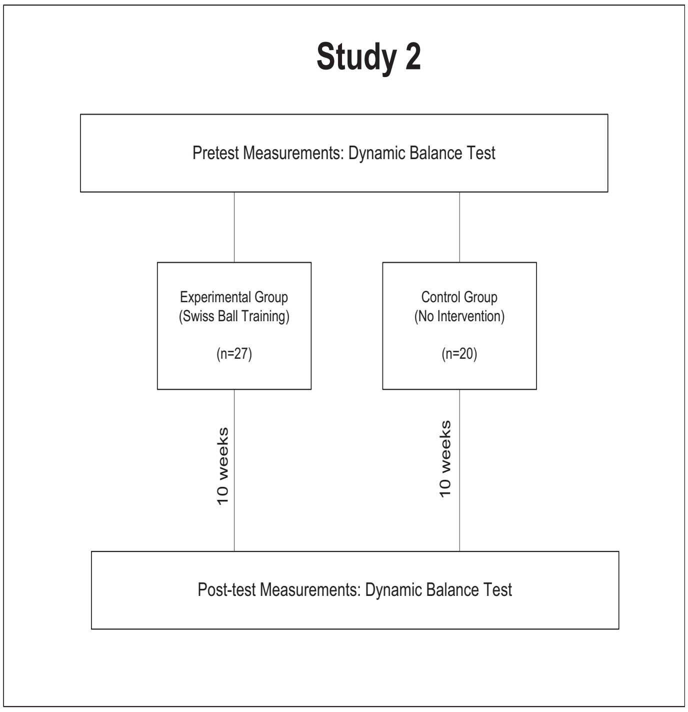

Figure 3.2 The second study's design

Independent variables in this thesis were time (1-pre and 2-post) and group (1-experimental and 2-control). Dependent variables are knee proprioception, core muscle strength parameters and dynamic balance scores.

After getting permission from the Ethical Board of the university and having the participants sign a letter of approval, the study could be performed. Prior to participation in the investigation, each participant was informed of the risks, discomfort and procedures involved in participating in this investigation.

Convenient sampling controlled experimental study procedures were mainly followed in this study. Participants were voluntary university students who took elective courses from the Department of Physical Education and Sports. Elective classes were proposed by the Department of Physical Education and Sport to other departments of the university; hence students from the physical education and sport department were not accepted to this study for both samples. Participants in control groups were selected from students who were taking theoretical courses. So as to satisfy the requirements of the elective courses, participants had to be free from medical problems with a sedentary life style who had no regular exercise background.

3.2 Participants

3.2.1. Participants (First study's sample)

60 participants participated in the study. All of the participants were students of Middle East Technical University. Out of the 60 participants, 43 of them (27 males, 16 females) were assigned to the experiment group, and 17 (9 males, 8 females) of them were assigned to the control group. Core muscle strength and knee proprioception assessment were conducted to this first sample group. For first sample, the Swiss ball group completed training sessions throughout the total 30 training sessions (90% participation rate). Characteristics of the first study's sample was given in Table 3.1

Table 3.1 Descriptive statistics (mean ± SD) for experiment and control group for first sample

	Experimental group (n=43)		Control group (n=17)	
	Male (n=27)	Female (n=16)	Male (n=9)	Female (n=8)
Age (year)	21.67 ± 1.51	21.81 ± 1.16	23.44 ± 2.87	23.25 ± 1.67
Height (m)	1.73 ± 0.06	1.64 ± 0.05	1.74 ± 0.04	1.63 ±0.07
Weight (kg)	72.67 ± 9.41	57.18 ± 12.18	77 ± 9.69	57.5 ± 11.74
BMI(kg/m^2)	24.19 ± 2.91	21.08 ± 3.85	25.2 ± 2.93	21.6 ± 3.5

3.2.2. Participants (Second study's sample)

47 participants participated in the study. All participants were students of Middle East Technical University. Out of the 47 participants, 27 of them (12 males, 15 females) were assigned to experiment group and 20 (11 males, 9 females) of them were assigned to control group. Only dynamic balance assessment was conducted to this second sample group. For second sample, the Swiss ball group completed training sessions throughout the total 20 training sessions (92% participation rate). Characteristics of the second study's sample was given in Table 3.2

A general health status questionnaire was given to understand the general health conditions of the participants and exercise stages of change levels questionnaire (Cengiz, Ince, & Cicek, 2009) was given to obtain information on their sportive activities. The inclusion criteria were: a) no physical activity for a minimum of six months b) absence of neurological, cardiovascular, metabolic, rheumatic or vestibular diseases c) no injuries or previous surgery on the legs and d) absence of knee instability.

Body height was measured without shoes. Participants' body weight was measured by electronic bascule. Unit of the body height is meter and for body weight is kilograms. Body Mass Index was calculated with the formula of bodyweight (kg)/ body height (meter) ^{2}.

Table 3.2 Descriptive statistics (mean ± SD) for experiment and control group for second sample

	Experiment group (n=27)		Control group n=(20)	
	Male (n=12)	Female (n=15)	Male (n=11)	Female (n=9)
Age (year)	22.17 ± 1.9	21.6 ± 1.24	22 ± 2.24	20.89 ± 1.17
Height (m)	1.78 ± 0.6	1.64 ± 0.6	1.78 ± 0.8	1.63 ± 0.5
Weight (kg)	72.65 ± 12.16	60.9 ± 7.43	73.91 ± 9.49	57.08 ± 7.76
BMI (kg/m^2)	22.78 ± 2.89	22.64 ± 2	23.23 ± 1.92	21.35 ± 2.3

3.3 Assessment Devices and Protocols

3.3.1 Proprioception testing protocol

Testing for passive reproduction of passive positioning protocol (PRPP) was conducted using Biodex isokinetic dynamometer. This dynamometer was found valid and reliable not only for strength measurement but also joint position sense assessments (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004; Dvir, 2004). The participants were instructed to sit up upright position on the dynamometer's chair. Lateral malleol of the testing leg was aligned with the axis of the knee joint assessment apparatus. Participants were asked to wear shorts in order to minimize sensoric signal of dress texture to the skin throughout the assessments. The leg used to kick the ball was identified as the dominant leg. Only 3 participants in the experiment group and 2 participants in the control group have the left leg dominance. During the test, participants were blindfolded (Figure 3.1). There was no priority for dominant or non-dominant leg assessments. If the first participant started with right leg and then finished with left leg, the second participant started with left leg and finished with the right leg.

Figure 3.3 Positioning of the participants for testing passive positioning protocol

The participants' leg was placed at an initial angle of 90^0 of the knee flexion for each trial. The participant's leg was then passively moved to the test angle of 45^0 of knee flexion by the examiner at an angular velocity of 4^0/sec. Participants concentrated on the sensation of the presented angle (45^0 of knee flexion) for approximately 3 seconds. The participants' leg was then returned passively to the starting position (90^0 of the knee flexion) by the examiner. This familiarization procedure was conducted two times.

Following a five second rest period the dynamometer passively moved the participant's leg (from 90^0 knee flexion to knee extension) at an angular velocity of 2^0/sec. The participants were informed to press a stop button at the moment they felt that the target angle had been reached. The amount of error, in the participants' ability to match the target angle, was recorded manually (in degrees). The two values were averaged and the average value was used for statistical analysis.

3.3.2 Isokinetic core muscle strength measurement

Before the core muscle strength measurements, the participants warmed up on a bicycle ergo meter for 5 minutes and then stretched their body parts, especially abdominal and back region. Before the test trials, participants were instructed to perform their maximum efforts. Participants were encouraged verbally during the test to perform their best performance.

Trunk extensor\flexor strength was assessed on Biodex System III Isokinetic Dynamometer concentrically at speeds of 90° s^{-1} for 10 repetitions (Karatas, Gogus, & Meray, 2002). Participants were positioned in the dynamometer seated with their neck and back supported with the adjustable pads. The thighs, pelvis and chest were fastened by firm cords to prevent trunk rotation, thus only abdominal and low back strength were assessed (Sekendiz, Altun, Korkusuz, & Akin, 2007). Knee block position was individually adjusted. Participants were informed to keep their heads and arms in a fixed position during the assessment. Prior to assessments, each participant was asked to complete 2 repetitions for test familiarization. After familiarization trials participants rested 10 seconds.

Figure 3.4 Starting position of core muscle strength assessments

Figure 3.5 Finishing position of repetitions

Peak torque to body weight (PT/BW), total work and agonist/antagonist ratio were chosen for core muscle strength parameters. Peak torque relative to body weight parameter was chosen because peak torque normalized to body weight (dividing peak torque by body weight) enables to compare participants despite varying body size and structure (Dvir, 2004). Also total work performed over multiple contractions can also represent endurance capacity. Agonist/antagonist ratio indicates abdominal strength/low back strength which enables to detect asymmetrical strength gain.

3.3.3 Dynamic balance measurement

Biodex Stability System SD (Biodex, Inc., Shirley, NY, USA) was used for assessments of dynamic balance. Biodex Stability System SD (Biodex, Inc., Shirley, NY, USA), which comprises of a movable balance platform provide up to 20^0 of surface tilt in a 360^0 range of motion. A new version of BSS has 12 dynamic stability levels. Level 12 is the most rigid (easiest) and level 1 the most fluctuating (most difficult) level. The measure of postural stability includes the overall (OASI), the anteroposterior (APSI) and the mediolateral (MLSI) stability index scores. A high score implies poor balance. Scores present the angle between the platform and the ground in average. Participants were asked to step on to the platform of the BSS and have a comfortable position while sustaining little flexion in the knees 15^0, to look straight ahead (to screen), and to place arms across the chest. Participants were tested barefoot. All participants were evaluated with their eyes open and allowed to see their track in the BSS screen. Participants were tested at stability level 1 six times for 20 seconds. Rest interval between trials was 60 seconds (Table 3.3). The best score of the 6 trials was taken for statistical analysis.

Table 3.3 Assessment protocol for dynamic balance test with Biodex Stability System

1.trial	Rest	2.trial	Rest	3.trial	Rest	4.trial	Rest	5.trial	Rest	6.trial
20 sec	60 sec	20 sec	60 sec	20 sec	60 sec	20 sec	60 sec	20 sec	60 sec	20 sec

Figure 3.6 Positioning of the participants

3.4 Swiss ball training

Swiss ball exercises were conducted 3 days (Monday-Wednesday-Friday) per week for core strength and knee proprioception (first sample) and 2 days (Tuesday-Thursday) per week for dynamic balance (second sample). Each participant was given a Swiss ball in accordance to their height. The size of the Swiss balls were conducive to accomplishing >90° angle at both the hip and knee while sitting on the Swiss ball (Norris, 2000). The stability balls were either 55 or 65 cm in height. The volume of the exercise program (Table 3.4 and Table 3.5) gradually increased by increasing the repetitions and increasing the duration. Before each session, participants performed a 6-8 minute warm-up, and then stretching. The rest interval between the sets and circuits was approximately 30 seconds. Exercise session lasted 30 minutes for week 1 and gradually increased up to 50 minutes in progress of the time. Before the week 1, ball familiarization movement was conducted for 2 weeks. All of the sessions were instructed and supervised by the same trainer. In each session and movement, participants were reminded to focus on the specific muscles which were activated while performing movement (for example quadriceps muscles during squat). The control group was told not to join any exercise program and to continue their routine daily activities.

Table 3.4 Swiss ball training for the first sample (3 days per week) (Adapted from Stanton, 2004)

	Wk 1	**Wk 2**	**Wk 3**	**Wk 4**	**Wk 5**	**Wk 6**	**Wk 7**	**Wk 8**	**Wk 9**	**Wk 10**
Abdominal crunch	2*6	2*8	2*10	2*12	2*14	3*8	3*10	3*12	3*14	3*14
Squat	2*6	2*8	2*10	2*12	3*6	3*8	3*10	3*12	3*14	3*14
Back extension	2*6	2*8	2*10	2*12	2*14	3*8	3*10	3*12	3*14	3*14
Hamstring curl	2*6	2*8	2*10	2*12	3*6	3*8	3*10	3*12	3*14	3*14
Kneeling on the ball	30 sc *2	35 sc*2	40 sc*2	45 sc*2	50 sc*2	50 sc*2	55 sc*2	55 sc*2	60 sc*2	60 sc*2
Standing on the ball	30 sc *2	35 sc*2	40 sc*2	45 sc*2	50 sc*2	50 sc*2	55 sc*2	55 sc*2	60 sc*2	60 sc*2

Table 3.5 Swiss ball exercises for the second sample (2 days per week) (Adapted from Stanton, 2004)

	Wk 1	**Wk 2**	**Wk 3**	**Wk 4**	**Wk 5**	**Wk 6**	**Wk 7**	**Wk 8**	**Wk 9**	**Wk 10**
Kneeling on the ball	30 sc *2	35 sc*2	40 sc*2	45 sc*2	50 sc*2	50 sc*2	55 sc*2	55 sc*2	60 sc*2	60 sc*2
Crunch with leg raise (each leg)	2*6	2*6	2*8	2*8	2*10	2*10	2*12	2*12	2*14	2*14
Standing on the ball	30 sc *2	35 sc*2	40 sc*2	45 sc*2	50 sc*2	50 sc*2	55 sc*2	55 sc*2	60 sc*2	60 sc*2
Back extension	2*6	2*8	2*10	2*12	2*14	3*8	3*10	3*12	3*14	3*14
Squat on the ball	2*6	2*6	2*8	2*8	2*10	2*10	2*12	2*12	2*14	2*14
Single leg supine bridge (each leg)	30 sc *2	35 sc*2	40 sc*2	45 sc*2	50 sc*2	50 sc*2	55 sc*2	55 sc*2	60 sc*2	60 sc*2

Figure 3.7 Kneeling on the ball

Kneeling on the ball

Knee should be placed on the ball with hip width apart. Arms are crossed at the chest. Lower leg should be parallel to the floor. Knee, hip, upper body should be holed in a straight line (L position) (Figure 3.7)

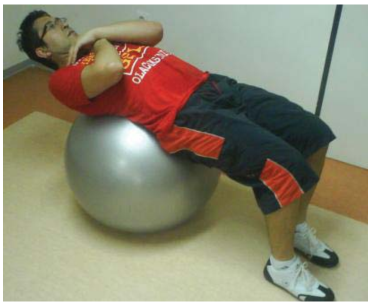

Figure 3.8 Starting position of crunch with leg raise

Figure 3.9 Finishing position of crunch with leg raise

Crunch with leg raise

Lie supine on the stability ball with the lower to middle section of the back on the apex of the ball; place the feet about hip width apart. Thigh and the lower abdomen approximately parallel to the floor. The arms are crossed at the chest. While curling the torso to raise it 50-60 degrees from the starting position, knee approaches the upper body. Keep the feet stationary on the floor. After completing the crunch, allow the torso to uncurl back down to the starting position. (Figure 3.8,3.9)

Figure 3.10 Abdominal crunch

Abdominal crunch

Lie supine on the stability ball with the lower to middle section of the back on the apex of the ball, and place the feet about hip width apart. Thigh and the lower abdomen approximately parallel to the floor. The arms are crossed the chest. Curl the torso to raise it 40-45 degrees from the starting position. After completing the crunch, allow the torso to uncurl back down to the starting position. (Figure 3.10)

Figure 3.11 Starting position of wall squat

Figure 3.12 Finishing position of wall squat

Swiss ball wall squat

Begin with the ball placed between the back and wall. Stand leaning the ball. Slowly squat down and roll the ball. Stretch out the arms and bend the knees until upper legs become parallel to the floor. Gently stand up allowing the ball roll. In the starting position, knee should not be fully extended.(Figure 3.11,3.12)

Figure 3.13 Standing on the ball

Standing on the ball

Place your legs on the ball shoulder width. Bend knees slightly. Arms should be at a relaxed position. Try to keep your balance at this position by tightening and focusing on knees and ankles. (Figure 3.13)

Figure 3.14 Starting position hamstring curl

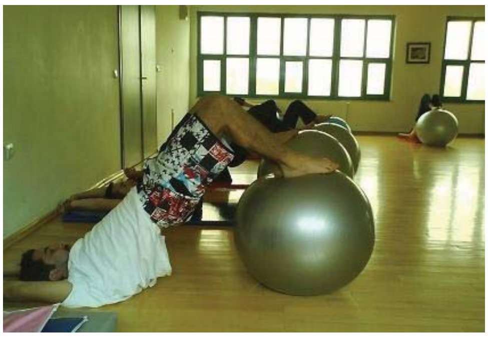

Figure 3.15 Finishing position of hamstring curl

Hamstring curl

Lie supine on the ground and put calf and ankle on the ball. Extend the arms on the ground. Raise the hips off the floor until there is a straight line from the heels to upper back like a bridge. Begin rolling the ball toward the hips until the soles of the feet touch with the ball (approximately 90 degrees), then roll back the ball forward. (Figure 3.14,3.15)

Figure 3.16 Squat on the Swiss ball

Squat on the Swiss ball

Place the feet on the ball with shoulder width apart. Arms crossed at the chest. Slowly squat down, avoid tilting, when your thighs are parallel (or nearly parallel) to floor slowly stand up. (Figure 3.16)

Figure 3.17 Single leg supine bridge

Single leg supine bridge

Lower to mid back should be placed to apex of the ball. Arms crossed at the chest. Cross one leg to other. Knee, hip, upper body and head should be in a straight line. Foot should be at neutral position. (Figure 3.17)

Figure 3.18 Back extension

Back extension

Lie prone on the Swiss ball; fix the foot and knees extended, arms cross the chest. Lift the torso approximately 30-40 degrees from the starting position. After completing the extension allow the torso to lower and return to the starting position.(Figure 3.18)

3.5 Statistical Analyses

3.5.1 Knee proprioception

Descriptive statistics were calculated for demographic data and proprioception scores. Independent sample t-tests were performed for pretests scores to test baseline equivalence between exercise and control groups on knee proprioception. The effect of the Swiss ball exercise interventions on knee proprioception was tested with 2 x 2 mixed design repeated measures. MANOVA (Group: exercise/control X time: pre/posttest). Paired sample t-test was conducted to investigate the difference between pre and post changes with regard to knee proprioception within each group among right and left legs. Repeated measure ANOVAs' were also performed to track independent changes in exercise group across pretests (time-1), posttests (time-2) and follow-up tests (time-3).

3.5.2 Core muscle strength

Multivariate ANOVA (MANOVA) was used for pretests scores to test baseline equivalence between exercise and control groups. Effects of 10 week Swiss ball exercises on trunk extension strength was examined by performing 2 x 2 (Group: exercise/control X time: pre/posttest) mixed design repeated measures of MANOVA. Univariate ANOVA's were conducted in order to interpret main effect(s) and/or interaction effects. Paired sample t-tests were performed to examine independent changes for both the exercise and the control group from pre to post measurements.

3.5.3 Dynamic balance

A 2 x 2 (Group: exercise/control X time: pre/posttest) mixed design repeated measure MANOVA was conducted to examine the effects of Swiss ball exercises on overall, medio-lateral and anterio-posterior balance scores of participants. For follow up test univariate ANOVA was conducted. Paired sample t-tests were conducted to analysis changes in the each group.

All analyses were performed using the Statistical Package for Social Sciences 15.0 version (SPSS for Windows). P value set as ≤ 0.05.

CHAPTER 4

RESULTS

4.1 Knee Proprioception

Research Hypothesis 1: Swiss ball exercises will improve knee proprioception scores.

Swiss ball and control groups have similar proprioceptive skills at the beginning of the study, according to independent sample t-tests scores both on right ($t(58)=0.29$, $p>.05$) and left ($t(58)=0.08$, $p>.05$) leg (Table 4.1).

Table 4.1 Proprioception scores of the groups with respect to right and left knee

	Groups									
	Exercise					Control				
	Pretest		Posttest			Pretest		Posttest		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*
Proprioception										
Right Knee	5.94	3.36	2.89	1.72	.00	5.61	5.27	5.88	3.26	.82
Left Knee	5.90	3.57	3.65	3.04	.00	6.00	5.44	5.73	4.91	.85

p values indicate within group changes.

2 x 2 MANOVA results showed that Swiss ball training have significant effect on proprioception scores (Wilks' Lambda=.88, F (2, 57) = 4.03, p <0.05. η^2 = .13) but this improvement became insignificant when Swiss ball group compared the control group (Wilks' Lambda=.95, F (2, 57) = 1.66, p>0.05. η^2 = .05). To investigate the individual group improvement, paired sample t-tests were conducted and these tests again showed that Swiss ball exercises have significant effect on knee proprioception

(Table 4.2 and Figure 4.1), whereas proprioception scores for control group remained statistically unchanged (Table 4.2 and Figure 4.1).

Table 4.2.Comparison of proprioception scores of both groups from pre to posttest

	Exercise		Control	
	t	*p*	*t*	*p*
Preright-Postright	5.50	.00	.23	.82
Preleft-Postleft	2.95	.00	.19	.85

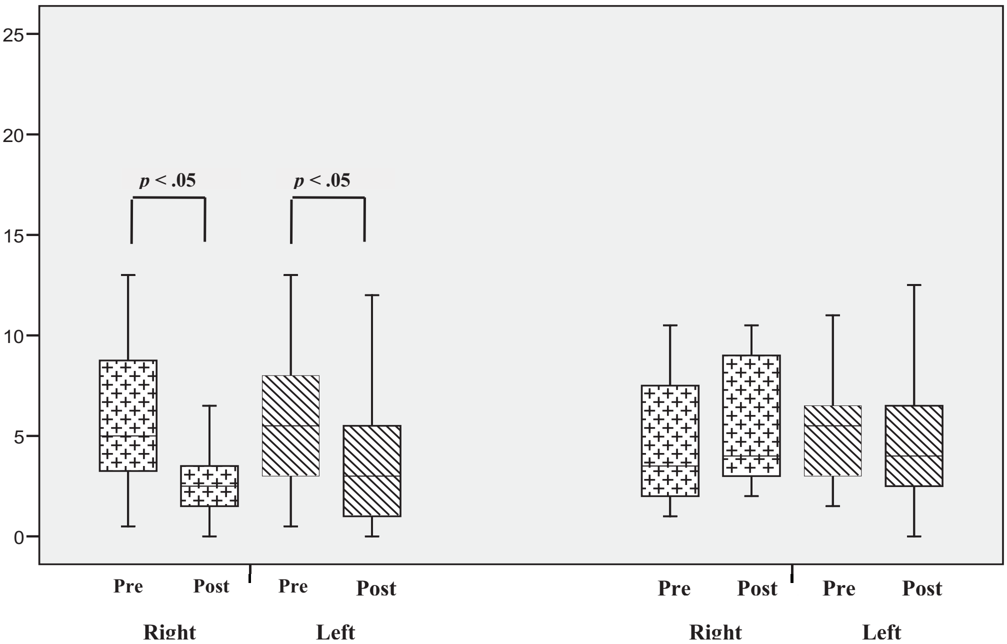

Figure 4.1 Changes in proprioception scores from pre to post measurements

Proprioception was tested 3 times (1-pre, 2-post, and 3-follow-up) in order to investigate the permanence of improvement in Swiss ball group. Control group which completed pre and posttest measurements, did not attend to follow up assessments because of insignificant changes from pre to post test. Permanence of Swiss ball training on knee proprioception was analyzed with repeated measure Anova's; pretests (time-1), posttests (time-2) and follow-up tests (time-3). Scores showed that when the participants stopped the Swiss ball training, improvement in their proprioceptive skills became worsened both right and left leg's (Wilks' Lambda=.54, F (2, 37) = 15.51, p <0.05. η^2 = .13), (Wilks' Lambda=.80, F (2, 37) = 4.65, p <0.05. η^2 = .20), respectively. For right leg follow-up performance, although proprioception scores significantly worsened from posttest to follow-up test (F (1, 38) = 5.68, p <0.05, η^2 = .13), it was significantly better than initial level (F (1, 38) = 10.41, p <0.05, η^2 = .22) (Figure 4.2). For left leg, knee proprioception score was worsened significantly (F (1, 38) = 4.95, p <0.05, η^2 = .12) (p<0.05) from posttest to follow up test, however, it was better than pretest score (F (1, 38) = 1.29, p >0.05, η^2 = .03), but this difference was not found significant.

Overall proprioception results indicated that although exercise group improved their proprioceptive skills from pre to posttests, these improvements may disappear after finishing exercise interventions, With regard to group comparisons results seems to suggest that independent improvements in proprioceptive skills in the exercise group were not significant compared to control group.

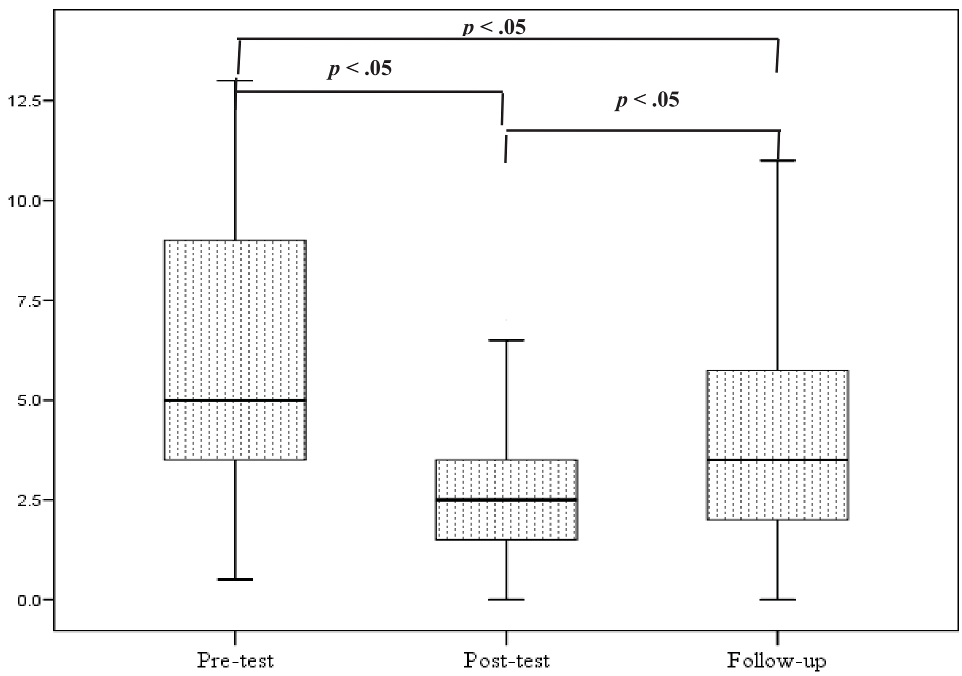

Figure 4.2 Changes of right knee proprioception scores of experiment groups

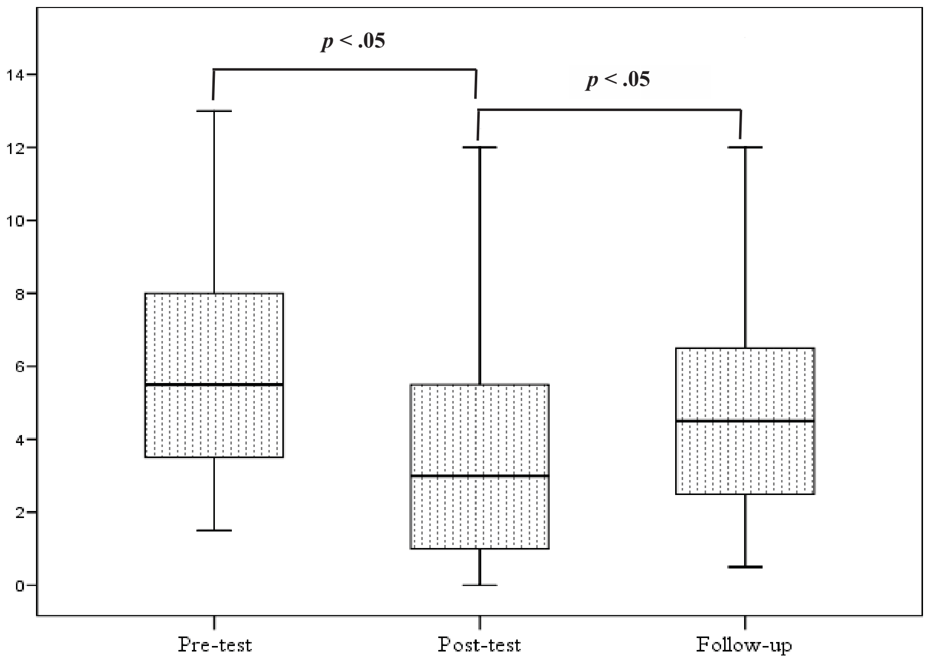

Figure 4.3 Changes of left knee proprioception scores of experiment groups

4.2 Core Muscle Strength

Research Hypothesis 2: Swiss ball exercises will improve the core muscles (abdominal and low back) strength parameters.

4.2.1 Trunk extension (Low back strength)

Swiss ball and control groups have similar low back strength parameters in terms of their peak torque/body weight, total work and agonist antagonist ratio scores (Wilks' Lambda=.96, F (3, 56) = 0.77, p >0.05. η^2 = .04) at the beginning of the study, according to MANOVA results. Trunk extension strength scores were shown in Table 4.3.

Table 4.3 Isokinetic trunk extension strength parameters

	Groups									
	Exercise (n=43)					Control (n=17)				
	Pretest		Posttest			Pretest		Posttest		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*
Peak Torque/BW	321.76	79.72	397.90	78.42	.02	333.59	121.70	310.81	114.86	.12
Total Work	1490.85	561.19	1790.82	502.61	.03	1560.61	698.49	1455.45	653.85	.09
Ratio	72.32	17.72	70.00	11.40	.26	78.68	26.71	84.96	28.39	.08

p values indicate within group changes.

Results showed that Swiss ball training have significant effect on low back strength parameters (Wilks' Lambda=0.76, F (3, 56) = 5.77, p <0.05. η^2 = 0.24) but this improvement became insignificant when Swiss ball group compared the control group (Wilks' Lambda= 0.92, F (3, 56) = 1.69, p>0.05. η^2 = .08). More specifically, follow-up ANOVA results revealed that Swiss ball training has significant effect on low back strength's peak torque/body weight (F (1, 58) = 13.64, p <0.05, η^2 = .19) and total work scores (F (1, 58) = 6.80, p <0.05, η^2 = .11), whereas no significant training effect was found for agonist antagonist ratio scores (F (1, 58) =0.65, p>0.05, η^2 = .01). Agonist/Antagonist ratio means that trunk flexion strength / trunk extension strength or abdominal strength/low back strength. From pre to posttest, both scores were improved in experiment group; so, insignificant change in agonist/antagonist ratio results is expectable.

4.2.2. Trunk Flexion (Abdominal Strength)

Descriptive characteristics of the trunk flexion strength scores were provided in Table 4.4.

Table 4.4 Isokinetic trunk flexion strength parameters

	Groups									
	Exercise (n=43)					Control (n=17)				
	Pretest		Posttest			Pretest		Posttest		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*
Peak Torque/BW	234.13	52.97	276.49	61.51	.03	238.12	52.43	237.07	42.11	.52
Total Work	974.11	337.44	1062.47	337.58	.03	892.58	392.80	947.32	334.94	.09

p values indicate within group changes.

Similar to trunk extension (low back strength) results, trunk flexion (abdominal strength) strength scores of the Swiss ball and the control group have similar (Wilks' Lambda=.97, $F_{(2, 57)} = 0.93$, $p > 0.05$. $\eta^2 = .03$) in terms of their peak torque/body weight and total work scores at the beginning of the study. 2 x 2 MANOVA results showed that Swiss ball training have significant effect on low back strength parameters (Wilks' Lambda=.81, F (2, 57) = 6.36, $p < 0.05$. $\eta^2 = .18$), but this improvement became insignificant when Swiss ball group compared the control group (Wilks' Lambda=.97, F (2, 57) = 0.80, $p > 0.05$. $\eta^2 = .03$). Follow-up ANOVA results revealed significant Swiss ball training effects for peak torque/body weight (F (1, 58) = 9.30, $p < 0.05$, $\eta^2 = .14$) and total work scores (F (1, 58) = 9.80, $p < 0.05$, $\eta^2 = .14$).

Following these results, paired sample t-tests were performed to test independent changes both for the exercise and the control group from pre to post measurements. The results showed that the exercise group significantly improved their trunk extension, flexion peak torque/body weight (Figure 4.4 and Figure 4.6, respectively) and total work (Figure 4.5 and Figure 4.7, respectively) scores from pre to post measurements whereas the control group has remained statistically unchanged (Figure 4.4, Figure 4.5, Figure 4.6, Figure 4.7) Furthermore, agonist/antagonist ratio scores of both groups did not change significantly.

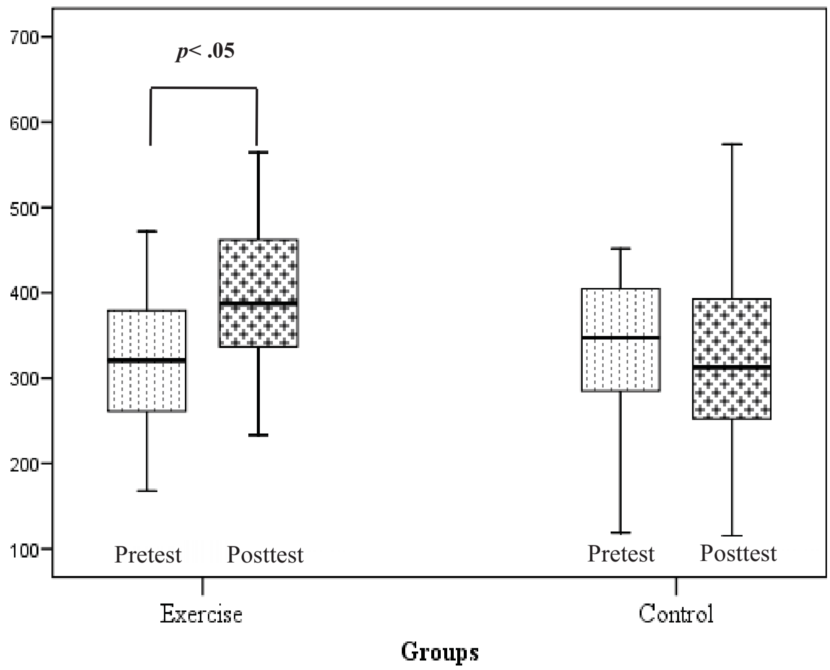

Figure 4.4 Changes in trunk extension peak torque/ body weight scores from pre to post measurements

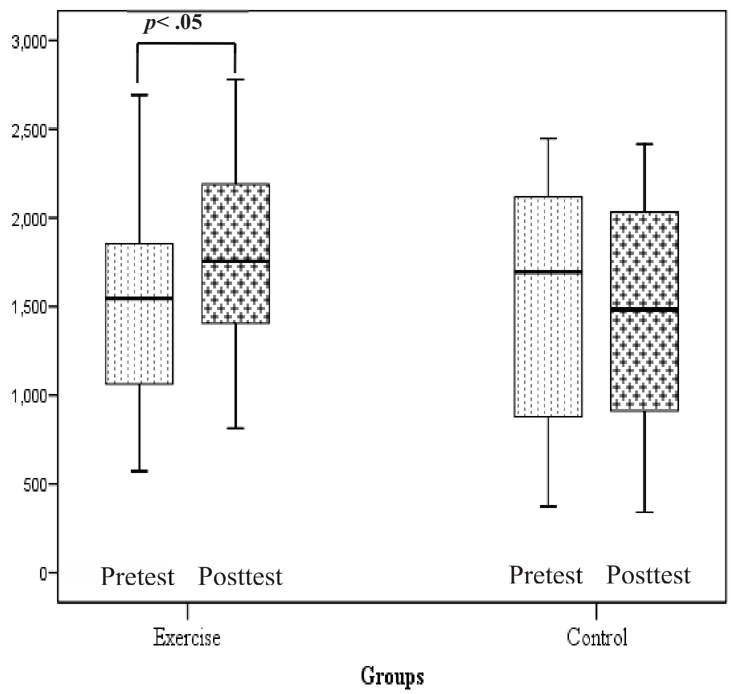

Figure 4.5 Changes in trunk extension total work scores from pre to post measurements

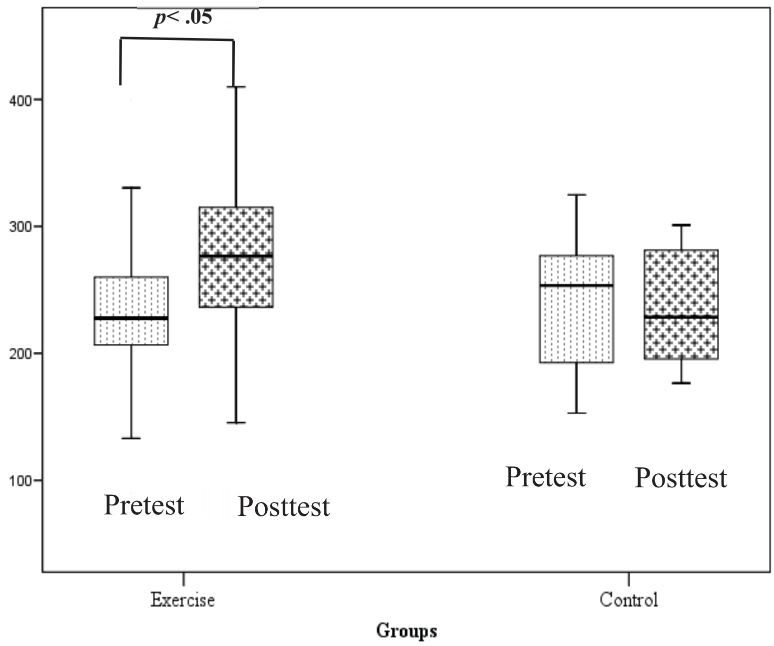

Figure 4.6 Changes in trunk flexion peak torque/body weight scores from pre to post measurements

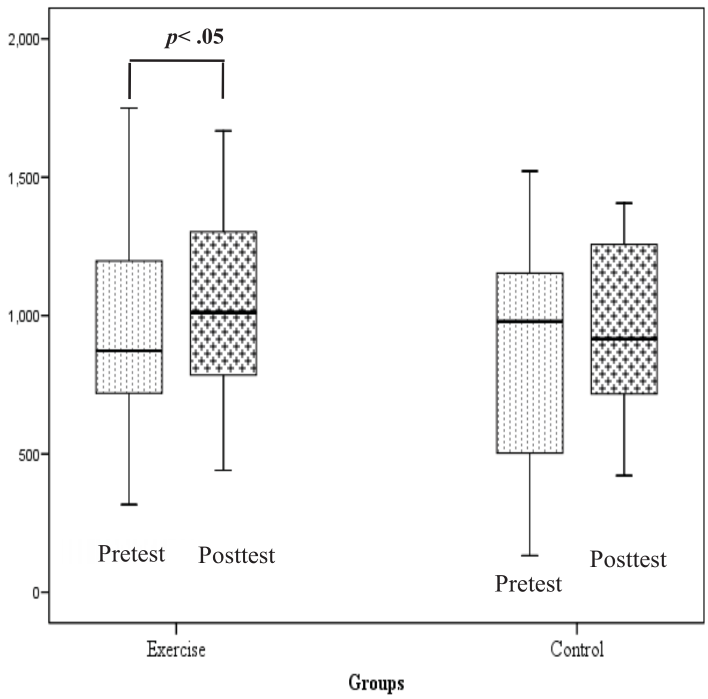

Figure 4.7 Changes in trunk flexion total work scores from pre to post measurements

4.3 Dynamic balance

Research Hypothesis 3: Swiss ball exercises will improve dynamic balance (overall, anterior-posterior and medial-lateral) scores

MANOVA results showed that Swiss ball and control groups have similar (Wilks' Lambda=.97, $F_{(3, 43)} = 0.45$, $p > 0.05$. $\eta^2 = .03$) dynamic balance parameters in terms of all stability index scores at the beginning of the study; overall ($F_{(1,45)} = 0.68$, $p > 0.05$. $\eta^2 = .01$), anterio-posterior ($F_{(1,45)} = 0.28$, $p > 0.05$. $\eta^2 = .01$) and medio-lateral ($F_{(1,45)} = 0.34$, $p > 0.05$. $\eta^2 = .02$). Both pre and posttest descriptive characteristics of overall stability index, anterio-posterior stability index, medio-lateral stability index scores were presented in (Table 4.5).

Table 4.5 Stability index scores of both experiment and control group from pre to posttest

	Groups									
	Exercise (n=27)					Control (n=20)				
	Pretest		Posttest			Pretest		Posttest		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*p*
Overall stability index (^{0})	1.45	0.84	1.05	0.54	.00	1.70	1.17	1.25	0.85	.00
Anterio-posterior stability index(^{0})	1.04	0.54	0.81	0.49	.00	1.20	0.77	0.92	0.56	.00
Medio-Lateral stability index(^{0})	0.79	0.58	0.55	0.32	.0o	0.96	0.77	0.65	0.52	.00

p values indicate within group changes.

A 2 x 2 MANOVA results revealed that both groups improved their balance scores from pre to posttest (time effect; Wilks' Lambda=.64, $F_{(3, 43)} = 8.04$, $p <0.05$. $\eta^2 = .36$, group effect; Wilks' Lambda=.97, $F_{(3, 43)} = 0.44$, $p > 0.05$. $\eta^2 = .03$). From first week to tenth week all stability index scores; overall balance ($F_{(1, 45)} = 24.80$, $p <0.05$, $\eta^2 = .35$) (Figure 4.8), anterio-posterior balance ($F_{(1, 45)} = 19.09$, $p <0.05$, $\eta^2 = .30$) (Figure 4.9), medio-lateral balance ($F_{(1, 45)} = 16.67$, $p <0.05$, $\eta^2 = .28$) (Figure 4.10) were improved without considering group comparisons. Follow-up assessments were not conducted for dynamic balance because significant changes were observed in both Swiss ball and control groups.

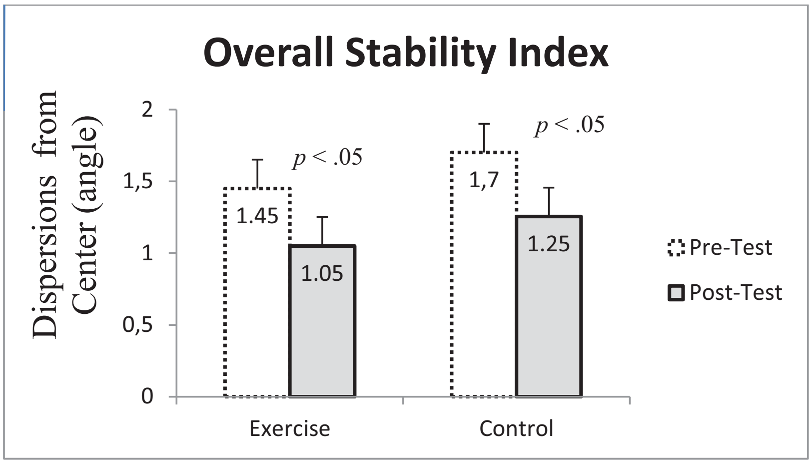

Figure 4.8 Changes in Overall Balance Scores from Pre to Post Measurements

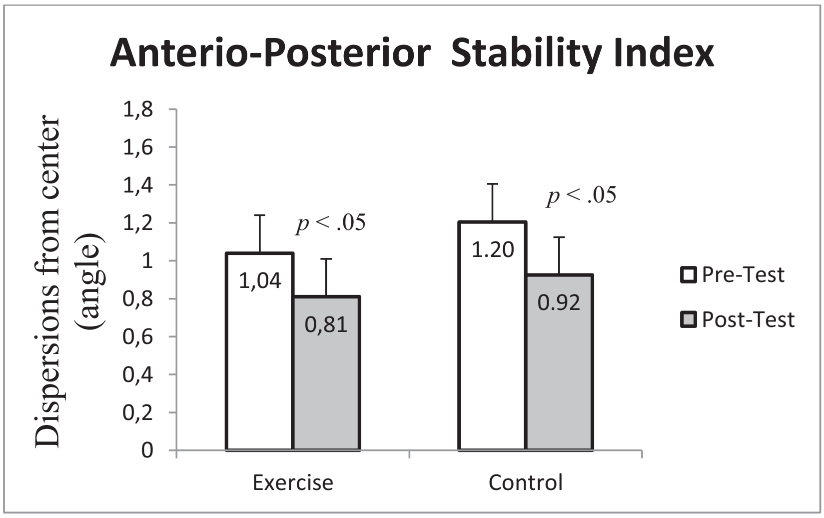

Figure 4.9 Changes in Anterio-posterior Balance Scores from Pre to Post Measurements

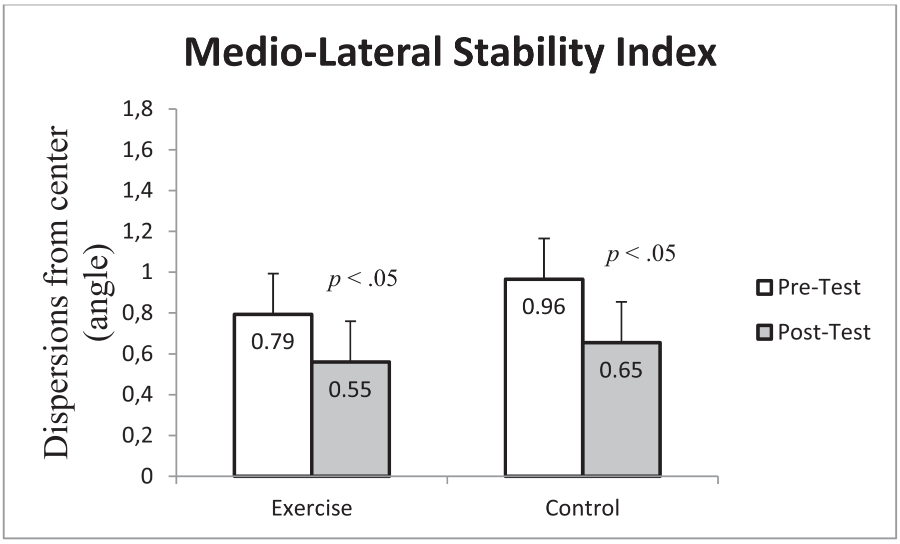

Figure 4.10 Changes in Medio-Lateral Balance Scores from Pre to Post Measurements

In accordance univariate Anova group comparisons, paired sample t-tests showed that both the exercise and control groups (Table 4.6 and 4.7) significantly improved themselves from pre to post measurements in all characteristics of dynamic balance.

Table 4.6 Paired Sample t-tests for the Exercise Group

	t	*df*	*p*
Overall Balance	3.59	26	.001
Anterio-Posterior Balance	2.91	26	.007
Medio-Lateral Balance	2.88	26	.008

Table 4.7 Paired sample t-tests for the control group

	t	*df*	*p*
Overall Balance	3.47	19	.003
Anterio-Posterior Balance	3.35	19	.003
Medio-Lateral Balance	3.00	19	.007

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the effects of 10-week Swiss ball training on knee proprioception, core muscle strength and dynamic balance. As it was stated, the main goal of the instability training is not to gain explicit strength gains (especially power and maximum strength), but to improve balance, stability and proprioceptive capabilities (Behm & Anderson, 2006).

5.1 Knee Proprioception

At the end of the 10-week (3 days per week) Swiss ball training, it can be noted that unstable surface exercises can be effective to improve knee proprioception.

Follow-up assessments were not conducted in the control group because of insignificant change between pre and post assessments. With respect to experiment group's follow-up result (T3), both dominant and non-dominant leg scores decreased when compared to post test scores (T2). Dominant leg's follow-up score (T3) was significantly better than pretest score (T1) ($p < .05$). Non-dominant leg's follow-up (T3) score was also better than pretest (T1) but this difference was not found significant ($p > .05$).

When fear of falling (threat of instability) emerges, individuals respond to this threat by stiffening himself/herself (Carpenter, Adkin, Campbell, & Chua, 2008). This type of stiffening strategy may affect the voluntary movements negatively (Adkin, Frank, Carpenter, & Peysar, 2002). Based on this information, instability-induced alterations in muscle activation, kinetics and muscle stiffness could have an adverse effect upon proprioception and co-ordination. The decrements associated with instability devices may not provide as many training advantages as ground based lifting (Behm, Drinkwater, Willardson, & Cowley, 2010a). There is little information in the literature on the effects of instability training on limb proprioception. While balance training programs have been shown to improve stability, their effect on specific joint proprioception is not clear yet. The accuracy of discrete ankle inversion was improved following 12 weeks of wobble board training (Waddington, Seward, Wrigley, Lacey, & Adams, 2000). It is not clear whether the training challenges (decreased force, power and increased muscle stiffness and cocontractions) presented by instability exercises on a Swiss ball would have positive or negative training effects upon joint proprioception.

As it was stated before, 10-week (3 days per week) Swiss ball training improved knee joint proprioception. In this part, conceivable mechanisms will be discussed.

5.1.1 Feedback loop

A movement should include sudden alteration in joint position, velocity as well as balance and postural activities to be able to have proprioceptive characteristics. Therefore, unstable surface exercises can be a convenient way to enhance proprioceptive capabilities. During the training with the Swiss ball, some exercises such as standing on the ball movement, provide unstable conditions to the joints, muscles, ligaments and tendons that may stimulate proprioceptors to provide feedback for the maintenance of balance and detection of body position (Mattacola & Dwyer, 2002). Instability induces rapid acute changes in muscle-tendon unit length, tension, and neuromuscular activity, which develop the ability to detect (afferent proprioception) and to respond (muscle efferent activity) to immediate changes in balance (Behm & Anderson, 2006; Ivanenko, Levik, Talis, & Gurfinkel, 1997).

5.1.2 Co-contractile activity during instability

Knee joint can be primarily capable of flexion and extension movement and also slight transverse rotation. Kneeling on the ball movement, which participants performed during 10-week focuses on the flexion and the extension movements. In this position, there is a cohesion need for the quadriceps (agonist) and the hamstring (antagonist) muscles to be able to do the exercise. Co-contractile activity (antagonist muscle activity) has a tendency to increase when training on unstable surfaces. Behm and colleagues (2005) reported that resisted plantar flexion and leg extension muscle actions performed under unstable conditions experienced 30.7% and 40.2% greater antagonist activity than the stable conditions, respectively. When the same exercises are performed on the unstable surface, antagonist/agonist muscle unit recruitment ratio is higher. To be able to maintain balance on unstable surface, joints should be stiffened by increasing antagonist activity (Karst & Hasan, 1987). Swiss ball training may force the antagonist muscles to give continuous and quick response to saltatory situation because of the fear of falling. Besides, balance training can increase the sensitivity of the afferent-efferent pathway, reduce response times, and improve precision of the position sense of both agonistic and antagonistic muscles (Kollmitzer, Ebenbichler, Sabo, Kerschan, & Bochdansky, 2000).

5.1.3 More motor unit recruitment

Motor units of muscles are activated more by unstable surface than the traditional floor exercises due to the unstable design of the ball. During the dynamic movements with the Swiss ball, such as hamstring curl, various training stimuli should serve the purpose automatically, such as (1) movement, (2) stability during movement and (3) equal force production. Both local and global muscles work in these movements. It means that more motor units are involved to perform the movement. If a person recruits more motor units during resistance training with unstable surface, in theory, this could cause higher levels of balance, proprioception, neuromuscular control, joint stability, and strength.

5.1.4 Closed kinetic chain exercises

Closed kinetic chain exercises involve a fixed distal segment and a relatively free proximal segment such as squat, push up, and chin up. Proprioceptive mechanisms are located in different parts of the body such as skin, muscles, joints, tendons, ligaments and they give information to the central nerve system about joint pressure, joint tension, change of position and motion. Closed kinetic chain activities (squat, squat on the Swiss ball, standing on the Swiss ball) may facilitate the integration of proprioceptive feedback coming from different proprioceptive mechanisms such as Pacinian corpuscles, Ruffini endings and Golgi Mazzoni corpuscles (Prentice, 2004). This integration may contribute to a reduction in joint shear forces, increased proprioceptive activity in joints and tendons and improved postural and stabilization mechanics (Peterson, 2001).

5.1.5 Follow-up test results

The positive knee position sense training adaptations were still evident after 9 months post training. Although statistically there was an overall improvement in knee proprioception, it was the right knee that demonstrated significantly less deviation from the reference angle, whereas the left knee was numerically better than the pre-test but it was not significant. As the right leg was the dominant limb with almost all participants, there may be a more persistent training effect with the dominant side. During training and post-training, there may have been an increased reliance on the dominant limb permitting a greater training perseverance. Performing exercises on the ball cannot guarantee the equal improvement in the limbs. Participants can perform the exercises on the ball in both symmetric and asymmetric positions. Even though participants perform the movement in symmetric position, he/she may activate the dominant side in greater degree unintentionally because of high reliance of dominant limb.

5.2 Core Muscle Strength

At the end of the 10-week (3 days per week) Swiss ball training, core muscle strength scores of the Swiss ball group were developed for both abdominal and low back muscles. On the other hand, there was no significant change observed in control group concerning either abdominal muscle scores or low back muscle scores.

The strengthening of trunk or core stabilizing muscles has significant importance for daily life activities, athletic performance, and the rehabilitation and protection from LBP. The Canadian Society for Exercise Physiology (CSEP) recommended to instability resistance exercise to train core muscles for athletes and sedentary people. For the non-injured and sedentary people, training the core muscle is crucial to maintain musculoskeletal health, especially in prevention of low back pain (Behm & Anderson, 2006). Low back pain (LBP) is a very common health problem and the most frequent cause of disability for individuals younger than 45 years of age. In accordance with the estimates, more than half of the general population (approximately 70% - 90%) will face LBP in their life (Cleland, Fritz, Childs, & Kulig, 2006).

Many studies have reported increased trunk (core) muscle activity when performing exercises with unstable environments (Behm, Anderson, & Curnew, 2002; Gaetz, 2004; Lehman, Hoda & Oliver, 2005; Norwood, Anderson, Gaetz, & Twist, 2007). On the other hand, there is little scientific research in the literature regarding the effect of unstable surface exercises on core muscle strength (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003; Sekendiz, Cug, & Korkusuz, 2010). While the literature provides many acute instability studies, there are fewer instability training studies. A number of studies have been conducted concerning instability training protocols measuring physiological, functional and athletic performance (Behm & Sparkes, 2010; Cressey, West, Tiberio, Kraemer, & Maresh, 2007; Sato & Mokha, 2009) but these studies did not measure changes in trunk strength. Other studies, which are of quite short duration (3-6 weeks) showed positive adaptations for lordotic curve stability (Stanton, Reaburn, & Humphries, 2004) and postural control (Yaggie & Campbell, 2006). Stanforth & Stanforth (1998) conducted a 10-week instability program and found improved lordotic curve stability but no difference with the traditional training group for trunk and abdominal endurance. Cowley, Swensen, Sforzo (2007) also did not find any significant difference in trunk power between a stable and unstable training group. However, their training program was only 3 weeks in duration. Conversely, Carter et al. (2006) reported improvements in trunk power and endurance with 10-week of instability training. Sekendiz, Cuğ, Korkusuz (2010) described improved trunk flexion and extension strength and endurance with 12-week Swiss ball training. However, there was no control group in this study. Therefore, the results of this study can fill a gap concerning the effects of prolonged Swiss ball training on trunk strength. Possible strength gain mechanicms of unstable surface training will be explained under some subtitles.

5.2.1 Neural adaptations

Strength gains can be achieved not only by resistance training but also by neuromuscular training (Behm & Anderson, 2006). Instability resistance training can load extra stress on the neuromuscular system. The aim of the neuromuscular training is to improve coordination of synergists, agonist, antagonist, and stabilizers muscles, and also to increase recruitment or activation of motor units. Therefore, muscles may be used effectively with less movement uncertainty, resulting in energy conservation and movement efficiency (Rutherford & Jones, 1986).

5.2.2 Activation of local muscles

The trunk muscles can be categorized as the global muscle system (movement) and the local muscle system (stabilization). Global muscles are bigger than local muscles and they are located in superficial parts of the body and composed of fast-twitch fibers. They also transfer the power coming from lower extremities to upper extremities, act as prime movers during dynamic activities and maneuver the spinal column as a whole (e.g., erector spinae, rectus abdominis, external oblique abdominis) (Behm, Drinkwater, Willardson, & Cowley, 2010b). The second category is the local muscle system. The local muscles are smaller than global muscles; they are composed of slow-twitch fibers and located deeper than the global muscles. Local muscles are mainly responsible for proprioception and sustaining stiffness through the spine and postural control. They are also responsible for producing only small amounts of force (McGill, 1998; Norris, 2000).

While performing exercises on an unstable surface, such as on Swiss ball, the motor control system originates the collaboration of both systems to stabilize the spine, to maintain balance, and prevent falling off the unstable equipment. In other words, unstable surface training stimulates the activation of local muscles. Traditional exercises such as the sit-up have focused on improving the performance of global (system) musculature, not local system (Faries & Greenwood, 2007). In the literature, it is stated that maintaining the stability of the body while performing a movement with Swiss ball mainly activates the local muscles (Carter, Beam, McMahan, Barr, & Brown, 2006)

5.2.3 Co-contractile activity and Increases in muscle activation

As stated above, increased co-contractile activity during unstable surface training provides joint stiffness and promotes stability. However, that is not the single profit of co-contractile activity. Additionally, some authors speculated that antagonist muscles may be used effectively and such movement uncertainty may decrease, resulting in energy conservation and movement efficiency (Anderson & Behm, 2005).

Unstable surfaces increases muscle activation, as opposed to performing the same exercises under stable conditions (Anderson & Behm, 2004; Arjmand & Shirazi-Adl, 2005; Vera-Garcia, Elvira, Brown, & McGill, 2007). The unstable characteristics of these balls provide an environment to stimulate more motor units. The greater the instability, the greater the muscle recruitment is because of stabilization requirement. As stressed above, anecdotally, if more motor units work while performing unstable surface training, this could cause to higher levels of balance, proprioception, neuromuscular control, joint stability, and strength (Jakubek, 2007).

5.3 Dynamic Balance

At the end of the 10 weeks' (2 days per week) Swiss ball training, dynamic balance scores (overall; ant/post; med/lat) of the both groups (Swiss ball and control) were improved. In this part, mainly two questions tried to be answered; 1- How control group improved their balance scores, and 2- How Swiss ball training group could not transferred exercise effect to balance test even if they performed exercises more accurately in time. The first question will be explained by; (1) Learning effect, (2) Visual feedback and (3) Concentration and motivation. The second question can be answered by (1) non-transferability of balance skills and (2) balance assessment problems with computerized laboratory devices.

5.3.1 Learning effect

Learning or practice effect can be defined as the effect that the previous experience of taking a test has on taking that same test again. It usually results in higher scores than before. The more unusual the activities, the greater the learning effects take place (Valovich, Perrin, & Gansneder, 2003). Without previous experiences during new and novel postural movement, body sway responses can be observed both quantitatively and qualitatively (Fransson, Johansson, Tjernstrom, & Magnusson, 2003). The possible reason why post test scores of the control group were improved may be explained by long term adaptation; to be more specific, the profound effect of the earlier experience concerning that of the postural task on the development of a tactic for sustaining postural stability (i.e., enhancing the stiffness in the ankles, knees). (Tjernstrom, Fransson, Hafstrom, & Magnusson, 2002). Maintaining the balance is most probably a skill that partial is learned and familiarized by way of training (Tjernstrom, Fransson, Hafstrom, & Magnusson, 2002).

5.3.2 Visual feedback

Control of the upright posture is closely linked with sensory proprioception (Fitzpatrick & Mccloskey, 1994), vestibular information (Nashner, Black, & Wall, 1982), cutaneous sources (Kavounoudias, Roll, & Roll, 1999) and also visual feedback (Buchanan & Horak, 2001; Duarte & Zatsiorsky, 2002).

Vision procures significant feedback information regarding body sway and supplementary message provided by the other receptor systems (Allum, Keshner, & Pfaltz, 1985; Black & Paloski, 1998; Diener, Dichgans, Guschlbauer, & Bacher, 1986). Vision might also contribute to postural stability by providing information leading to anticipatory arrangement of motor activity (Tjernstrom, Fransson, Hafstrom, & Magnusson, 2002). Visual feedback becomes more important when the surface is unfamiliar. When mechanical feedback mechanisms cannot provide sufficient information to maintain postural control, visual feedback tries to compensate for this shortfall. Convenience of the feedback makes the compensation easier. One of the most appropriate feedbacks in balance tests is seeing the center of gravity point in target board in real-time as it was conducted in the present study.

5.3.3 Concentration & Motivation

Other possible factors that can affect the balance assessments are concentration and motivation. It was observed in the present study that participants saw their own stability index scores at the end of each test, and in the new test they tried to reach or exceed this previous score. They kept their motivation and concentration at high level. There were lots of examples which address the importance of concentration, motivation, encouragement on performance test (McNair, Depledge, Brettkelly, & Stanley, 1996).

5.3.4 Non-Transferability of balance skills

Training specificity is an essential training factor to reach success in sports. Exercises that are selected to enhance performance should reflect the competition settings by means of velocity, repetition, force production, direction of movement, muscle recruitment pattern. However, again there is no warranty that exercise performance will directly be transferred to sports performance. Even though the movement forms of the chosen exercises and competition appear similar, the underlying neuromuscular and proprioceptive feedback mechanisms may be absolutely dissimilar (Adams, 1987; Drowatzky & Zuccato, 1967). For example, specialization on wobble board balance may not enhance slack line performance because balance is specific to certain skill (Willardson, 2004). Anderson and Behm stated (2005) that "the transferability of unstable surface training to daily life activities and athletic performance is unknown precisely". Performing exercises on unstable surface will improve personal mastery. The more repetition provided, more familiarization and accuracy when performing exercises is obtained; but that does not mean this proficiency will transfer to other balance skills. Drowatzky and Zuccato (1967) asserted that different balance tests measure different balance skills. They analyzed the relationship between 3 static (stork stand, divers stand, and stick test) and 3 dynamic tests (sideward leap, bass steppingstone test, and balance-beam test). Pearson product-moment correlation coefficients showed that only 1 of the correlation was significant out of 15 correlations which were between sideward leap and bass stepping-stone tests. However with the predictive value was small ($r = 0.31$). The authors concluded that balance is skill specific and each of the balance tests assessed different balance types. From specificity perspectives, in the present study although some exercises were similar to the BSS testing, spherical shape of a stability ball may actually reduce surface specificity. In other words, even if the movement specificity is provided, surface specificity cannot.

5.3.5 Balance assessments problems with computerized devices

The concept of dynamic stability has been extensively studied; however**,** Anderson and Behm (2005) stated that much is known about static balance, but little is known about how muscles maintain dynamic balance. There have been different test used to quantify dynamic stability, computerized laboratory assessment devices (Biodex Stability System, Chattex Balance System, Kinesthetic Ability Trainer, Pro Balance Master) and field tests (star excursion balance tests, balance error scoring system...). In literature, it has been stressed that laboratory measurement techniques for balance are expensive, unmovable, quite technical. Besides, these techniques are often not convenient for manage in a clinical setting or for research in a large field based clinical trial. Furthermore, these clinical tools are not suitable for use in the healthy active population (Emery,Cassidy,Klassen, Rosychuk, Rowe, 2005). Many of these tools were originated for use in elderly people and people with neurological problems (Bohannon & Walsh, 1992; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Podsiadlo & Richardson, 1991; Stones & Kozma, 1987; Weiner, Duncan, Chandler, Prescott, & Studenski, 1990). The equipment and variables measured to quantify balance across laboratory techniques different between researches (i.e., postural sway velocities in various planes, acceleration of postural sway movements, maximum excursion of center of pressure, ground reaction forces) (Emery, Cassidy, Klassen, Rosychuk, Rowe, 2005).

CHAPTER 6

SUMMARY, CONCLUSIONS & PRACTICAL IMPLICATIONS

6.1 Summary

The purpose of this study was to investigate the effect of 10-week Swiss ball training on (1) knee joint proprioception, (2) core muscle strength and (3) dynamic balance. The results of the study indicated that Swiss ball training has significant effect on knee proprioception and core muscle strength. The trained group increased ($p<0.05$) trunk extension peak torque/body weight (23.6%) and total work output (20.1%) from pre- to post-training while the control group decreased ($p > 0.05$) by 6.8% and 6.7% respectively. The exercise group increased their trunk flexion peak torque/body weight ratios by 18.1% while the control group decreased by 0.4%. Trained group also improved ($p<0.05$) right and left knee proprioception scores from pre to post test (51% and 38.1% respectively). Changes in the control group (left 4.81% and right 4.5%) were not found significant. For experiment group's right leg, follow-up score was better than pretest score ($p<0.05$), however it was lower ($p<0.05$) than post test score. For left leg, follow-up score significantly lower ($p<0.05$) than posttest; however, it was better than pretest score, but this difference was not found significant. For dynamic balance, at the end of the 10 weeks' (2 days per week) Swiss ball training, both groups (Swiss ball and control) overall stability index scores (27.6% and 26.4%, respectively),anterior-posterior stability index scores (22.1% and 23.3%, respectively) and medio-lateral stability index scores (30.3% and 32.29% ,respectively) were improved significantly. Therefore, effect of the Swiss ball training on dynamic balance could not be determined.

6.2 Conclusions

A general 10 week instability training program utilizing Swiss balls and body mass as a resistance proved effective for improving knee proprioception as well as trunk flexion and extension strength in sedentary individuals. The present study demonstrates that the use of body weight as a resistance under unstable conditions can provide significant improvements in knee proprioception and trunk strength for the untrained population that should contribute to general health and functionality.

6.3 Practical Implications

1. Although traditional ground based free weight resistance exercises have been recommended as most beneficial for improving strength and power in athletes, an instability training program using Swiss balls and body weight as a resistance would provide an excellent starting point for the sedentary untrained population.
2. As it is well documented that force or strength is decreased when unbalanced and balance training programs improve balance, this type of instability resistance training program would provide significant neuromuscular adaptations to improve trunk strength especially in an untrained population.
3. This type of training should also be incorporated into a new program as the improvements in joint proprioception may help protect from joint injuries over a protracted period.
4. The finding that improved joint proprioception persists for months after training should be emphasized to those individuals whose training is regularly or inconsistently interrupted.

6.4 Future recommedations

1. By adding a traditional floor exercise, stable group and unstable group comparison can be conducted with respect to strength gain.
2. Different joint proprioception can be measured (ankle, shoulder…).
3. Different balance tests can be used.
4. Participant can be tested eyes open and without seeing condition Biodex Stability Sytem screen.
5. Special population (person with balance disorder, elder…) can be assessed.

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Appendix A: INFORMED CONSENT FORM

BİLGİLENDİRİLMİŞ ONAY FORMU

Bu çalışmanın amacı 10 hafta süreyle yapılacak olan Swiss ball egzersizlerinin dizin propriosepsiyonuna, karın-bel kası kuvvetine ve dinamik denge üzerine etkisini araştırmaktır.

Swiss ball egzersizleri ODTÜ Spor Merkezinde; dizin propriosepsiyonu, karın-bel kası kuvveti ve dinamik denge ölçümleri ODTÜ Sağlık ve Rehberlik Merkezi, Fizik Tedavi ve Rehabilitasyon Bölümünde gerçekleştirilecektir. Ölçümler 10 haftalık Swiss ball egzersizlerinin başında ve sonunda yapılacaktır. Herhangi bir kan veya doku örneği alınmayacaktır. Ölçümler ve 10 haftalık Swiss ball egzersizleri esnasında herhangi bir komplikasyon beklenmemektedir. Egzersizlerin ilk haftalarında antrenmana adaptasyona bağlı olarak kassal ağrılar, kuvvet testini takiben karın ve bel kaslarınızda ağrılar görülebilir. Beklenmeyen acil bir durumun oluşması halinde ODTÜ Sağlık Merkezi Acil Servisine başvurulacaktır. Bu çalışmaya katılmanız için sizden herhangi bir ücret istenmeyecektir aynı zamanda çalısmaya katıldığınız için size herhangi bir ödeme de yapılmayacaktır. Bu araştırmaya katılmak tamamen isteğe bağlıdır. Bu çalışmaya katılmayı reddedebilirsiniz. Çalışmanın herhangi bir aşamasında çekilme hakkına sahipsiniz. Eğer bu çalışma ile ilgili başka sorularınız var ise veya sonuçlarınızı öğrenmek isterseniz bize 210 4025 ve 0505 468 88 01 no'lu telefondan ulaşabilirsiniz.

Söz konusu araştırmaya hiçbir baskı ve zorlama olmaksızın, tamamen kendi isteğimle gönüllü olarak katılmayı kabul ediyorum. Bu formun imzalı bir kopyasını aldım.

Gönüllünün

Adı- Soyadı:

İmzası:

Yaş ve Cinsiyeti:

Adresi:

Tel No:

Açıklamaları Yapan Araştırmacı

Adı- Soyadı:

İmzası:

Görevi:

Appendix B: Ethical Approval

1956

Orta Doğu Teknik Üniversitesi
Middle East Technical University

Fen Bilimleri Enstitüsü
Graduate School of
Natural and Applied Sciences

06531 Ankara, Türkiye
Phone: +90 (312) 2102292
Fax: +90 (312) 2107959
www.fbe.metu.edu.tr

Sayı: B.30.2.ODT.0.AH.00.00/126/ 78 – 1597

4 Aralık 2009

To : Prof.Dr. Feza Korkusuz
Physical Education and Sports Department

From : Prof. Dr. Canan Özgen
Vice Chairperson of Human Research Ethic Committee

Subject : Ethical Approval

The study titled "The Effect of Swiss Ball Training on Balance, Knee Proprioception, Knee and Trunk Strength in Healthy Sedentary Collegiate Student" was approved by "Human Researches Ethical Committee".

Sincerely,

Ethic Committee Approval

Uygundur

4/12/2009

Prof.Dr. Canan ÖZGEN
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

Appendix C: Health Status Questionnaire

HEALTH STATUS QUESTIONNAIRE

Prior to the start of any exercise program or testing a health fitness instructor must first administer to their client a Health Status Questionnaire. This tool will aid the personal trainer in deciding what course of action should be followed in regards to program recommendations.

Instructions

Complete each question as accurately as possible. All information is confidential.

Part 1. General information

1. Social security number_________-_______-_________Date____________________
2. Name_______________________________________ Nickname________________
3. Mailing Address______________________________ Phone (H)________________

   ______________________________ Phone (W)________________
4. *EI* Personal Physician__________________________ Phone____________________

   Physician Address______________________________

   ____
5. *EI* Person to contact in case of emergency_______________ Phone_____________
6. Gender (circle one): Female Male *RF*
7. *RF* Date of birth______/_______/_______
8. Number of hours worked per week: Less than 20 20-40 41-60 over 60
9. *SLA* More than 25% of the time at your job is spent (circle all that apply)

   Sitting at desk Lifting loads Standing Walking Driving

Part 2. Medical History

10. *RF* Circle any who died of heart attack before age 50:

    Father Mother Brother Sister Grandparent
11. Date of

    Last medical physical exam:_____________

    Last physical fitness test:________________
12. Circle any operations that you have had:

    Back *SLA* Heart *MC* Kidney *SLA* Eyes *SLA* Joint *SLA* Neck *SLA*

    Ears *SLA* Hernia *SLA* Lung *SLA* Other________________________

13. Circle all medicine taken in last 6 months:

Blood thinner *MC*	Epilepsy medication *SEP*	Nitroglycerin *MC*
Diabetic *SEP*	Heart rhythm medication *MC*	Other__________
Digitalis *MC*	High blood pressure medication *MC*	
Diuretic *MC*	Insulin *MC*	

14. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism *SEP*	Diabetes *SEP*	Kidney problem *MC*
Anemia, sickle cell *SEP*	Emphysema *SEP*	Mental illness *SEP*
Anemia, other *SEP*	Epilepsy *SEP*	Neck strain *SLA*
Asthma *SEP*	Eye problems *SLA*	Obesity *RF*
Back strain *SLA*	Gout *SLA*	Phlebitis *MC*
Bleeding trait *SEP*	Hearing loss *SLA*	Rheumatoid arthritis *SL*
Bronchitis, chronic *SEP*	Heart problems *MC*	Stroke *MC*
Cancer *SEP*	High blood pressure *RF*	Thyroid problem *SEP*
Cirrhosis *MC*	HIV *SEP*	Ulcer *SEP*
Concussion *MC*	Hypoglycemia *SEP*	Other________
Congenital defect *SEP*	Hyperlipidemia *RF*	

15. Any of these health symptoms that occurs frequently requires medical attention. Circle the number indicating how often you have each of the following:

5= Very often
4= Fairly often
3= Sometimes
2= Infrequently
1= Practically never

a. Cough up blood *MC*
1 2 3 4 5
b. Abdominal pain *MC*
1 2 3 4 5
c. Low-back pain *MC*
1 2 3 4 5
d. Leg Pain *MC*
1 2 3 4 5
e. Arm or shoulder pain *MC*
1 2 3 4 5
f. Chest pain *RF MC*
1 2 3 4 5

g. Swollen joints *MC*
1 2 3 4 5
h. Feel faint *MC*
1 2 3 4 5
i. Dizziness *MC*
1 2 3 4 5
j. Breathlessness with slight exertion *MC*
1 2 3 4 5
k. Palpitation or fast heart beat *MC*
1 2 3 4 5
l. Unusual fatigue with normal activity *MC*
1 2 3 4 5

Part 3. Health-related behaviors

16. *RF* Do you now smoke? Yes No

17. *RF* If you are a smoker, indicate the number smoked per day:

    Cigarettes: 40 or more 20-39 10-19 1-9

    Cigars or pipes only: 5 or more or any inhaled less than 5

18. *RF* Do you exercise regularly? Yes No

19. How many days a week do you accumulate 30 minutes of moderate activity?

    0 1 2 3 4 5 6 7 days per week

20. How many days per week do you normally spend at least 20 minutes in vigorous exercise?

    0 1 2 3 4 5 6 7 days per week

21. Can you walk 4 miles briskly without fatigue? Yes No

22. Can you jog 3 mile at a moderate pace without discomfort? Yes No

23. Weight now:__________lb. One year ago:_________ Age 21:_________

Part 4. Health-related attitudes

24. These are traits that have been associated with coronary-prone behavior. Circle the number that corresponds to how you feel towards the following statement:

    I am an impatient , time-conscious, hard-driving individual.

Circle the number that best describes how you feel:

6= strongly agree
5= Moderately agree
4= Slightly agree
3= Slightly disagree
2= Moderately disagree
1= Strongly disagree

25. List everything not included on this questionnaire that may cause you problems in a fitness test or fitness program:

Code For Health Status Questionnaire

EI = Emergency Information-must be made readily available.
MC = Medical Clearance needed-do not allow to exercise without physician's permission.
SEP = Special Emergency procedure needed-do not let participant exercise alone; make sure the person's exercise partner knows what to do in case of emergency.
RF = Risk factor for CHD (educational materials and workshops needed)
SLA = Special or Limited activities may be needed-you may want to include or exclude specific exercises.
OTHER (not marked) = Personal information that may be helpful for files or research.

Appendix D: Physical Activity Stages of Change Level Questionnaire

Egzersiz Davranişi Değişim Basamaklari Anketi

Her soru için **EVET** veya **HAYIR** seçeneğini işaretleyiniz. Lütfen soruları dikkatlice okuyunuz.		
Orta düzeyde fiziksel aktiviteler nefes alımında ve kalp atımında biraz artış gözlenen aktivitelerdir. Ritimli yürüyüş, dans, bahçe işleri, düşük şiddette yüzme veya arazide bisiklet sürme gibi aktiviteler orta düzeyde aktivite olarak değerlendirilir.		
1) Şu anda orta düzeyde fiziksel aktiviteye katılmaktayım.	**HAYIR**	**EVET**
2) Gelecek 6 ayda orta düzeyde fiziksel aktiviteye katılımımı arttırmak niyetindeyim.	**HAYIR**	**EVET**
Orta düzeyde fiziksel aktivitenin düzenli sayılabilmesi için, aktivitenin haftada 5 veya daha fazla günde 30 dakika veya daha fazla olması gerekir. Örneğin, 30 dakika süreyle yürüyüş yapabilir veya 10 dakikalık 3 farklı aktivite ile 30 dakikayı doldurabilirsiniz.		
3) Şu anda düzenli olarak orta düzeyde fiziksel aktivite yapmaktayım.	**HAYIR**	**EVET**
4) Son 6 aydır düzenli olarak orta düzeyde fiziksel aktiviteye katılmaktayım.	**HAYIR**	**EVET**

Appendix E: Curriculum Vitae

PERSONAL DETAILS	
Name:	Mutlu CUĞ
Date of Birth:	23/03/1980
Place Of Birth:	Sivas
Current Occupation:	Research Assistant
CONTACT DETAILS	
Telephone:	+90 505 468 88 01
Post:	Middle East Technical University - Department of Physical Education and Sports 06531 Ankara / Turkey
Electronic Mail:	mutlucug@gmail.com
EDUCATIONAL DETAILS	
Secondary Education:	Sivas Cumhuriyet Anadolu High School 1997
Tertiary Education:	B.S. 1997-2001 Cumhuriyet University – Physical Education & Sports Department M.Sc. 2001-2005 Hacettepe University School of Sports Science and Technology
EMPLOYEMENT AND EXPERIENCE	
2001 (October) – 2002(October)	Physical Education Teacher Mersin-Gülnar-Gülnar High School
2002 (October) - 2003(December)	Physical Education Teacher Ankara-Şereflikoçhisar-Şereflikoçhisar High School
2004 (January) - 2006 (February)	Research Assistant-Cumhuriyet University Physical Education & Sports Department
2006 (February) - present	Research Assistant-METU- Physical Education & Sports Department

RESEARCH INTERESTS

- Exercise & Fitness

• Swiss Ball-unstable surface
• Strength, proprioception, balance

PUBLICATIONS

International Publications:

- SEKENDİZ B., **CUĞ M.**, KORKUSUZ F. Effects of Swiss-Ball Core Strength Training on Strength, Endurance, Flexibility and Balance in Sedentary Women. Journal of Strength and Conditioning Research, 2010 ; (24),11 : 3032-3040

National Publications:

- **CUĞ, M.,** KOÇAK, S. Short term jivamukti yoga improved psychological and physiological outcomes in yoga beginners. Gazi Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi, 2007 ; 1 : 25-32
- **CUĞ M.** , DÜLGEROĞLU D." Biodex denge sisteminde cihaza alışmak için yapılan denemelerin gerçek ölçümler üzerine iyileştirici etkisi". Gazi Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi, 2009 ; 3 :17 - 25
- ÖZDEMİR, R.A., **CUĞ, M.,** ÇELİK, Ö." Genç Yetişkin Üniversite Öğrencilerinde Farklı Türde Egzersiz Uygulamalarının Sosyal Fizik Kaygı Düzeyine Etkisi". Hacettepe Spor Bilimleri Dergisi, 2010; 21,(2) : 60-70

International Congress and Presentations:
Poster Presentations.

- **CUĞ, M.,** BABAYİĞİT İREZ, G., HÜNÜK, D.*AKPINAR, S., ARSAL, G. Dynamic Balance And Posture In Visually Impaired Soccer Players: A Pilot Study. VIth World Congress on Science & Football, 2007, January, 16-20.
- **CUĞ, M.** Auditory Reaction Times of Visually Impaired Athletes , Sedantery, and Sighted Sedantery People. IV Uluslararası Akdeniz Spor Bilimleri Kongresi, Antalya, 2007, Kasım, 9-11.
- OZGİDER, C., KORKUSUZ, F., OZDEMİR, R.A., SALCİ, Y., **CUĞ, M.**, ARTUT, V. Flutter Kick Swimming Velocity Is Related To Isokinetic Knee Muscle Strength But Not To Isokinetic Trunk Muscle Strength In Elite Male

Underwater Hockey Players. 16th Annual Congress of the European College of Sport Science (ECSS) 6-9 July 2011. Liverpool, UK.

Oral Presentations:

- AK, E., SÖĞÜT, M., YILDIRIM,A., UYGUR, M., **CUĞ, M**., ÖZGİDER, C., KORKUSUZ, F. The effects of 6-week calisthenics training on 10-13 years old tennis players' serve speed. IV Uluslararası Akdeniz Spor Bilimleri Kongresi, Antalya, 2007, Kasım, 9-11.
- **CUĞ, M.**, **KORKUSUZ F**. 10 Weeks Swiss Ball Exercises Improved Knee Joint Reposition Sense of Healhty Sedentary Collegiate Students. 15 th Annual congress of ECSS, Antalya, 2010, June, 23-26.

National Congress and Presentations:
Poster Presentations:

- **CUĞ, M.,** TURNAGÖL H. (2005). The Effect of different beverages on Anaerobic Threshold**.** X. Ulusal Spor Hekimliği Kongresi, İzmir, August, 12-15

Appendix E: Türkçe Özet

SPOR YAPMAYAN ÜNİVERSİTE ÖĞRENCİLERİNDE İSVİÇRE TOPU ANTRENMANININ DİZ EKLEMİ YENİDEN POZİSYONLANMA ALGISI, KARIN&BEL KASI KUVVETİ VE DİNAMİK DENGE ÜZERİNE ETKİSİ

Giriş

Sporun insan sağlığına olan etkileri tartışma götürmez gerçeklerdir. Bununla birlikte insanlar defalarca spora başlamakta ve bırakmaktadırlar. Kişilerin spor yapma heyecanlarını canlı tutabilmek içinde spor firmaları, spor merkezleri sürekli olarak değişik antrenman ekipman ve materyallerini spora entegre ederek devamlılığı sağlamaya çalışmaktadırlar. Bu ekipmanlardan birisi de İsviçre Topu'dur. Bu büyük topların etkisini ve etkisizliğini gösteren çalışmalar da mevcuttur. Bilimsel perspsektiften bu çalışmalara bakıldığında gözönünde bulundurulması gereken en önemli parametrelerden bazıları çalışılan örneklem grubu ve gelişmesi beklenen özellik olmalıdır. İsviçre topu egzersizleri, profesyonel sporcularda çokta anlamlı etkiler göstermese de, rekreatif amaçla spor yapan bireyler üzerinde kazanımlar sağlayabilmektedir. İsviçre topu egzersizlerinin bilimsel olarak ortaya konulan en net kazanımı, kastaki elektriksel aktivasyonu artırdığı yönündedir. Bir başka deyişle, aynı egzersizin sabit bir zeminde yapılmasıyla hareketli zemin arasında yapılması karşılaştırıldığında, hareketli zeminde yapılan egzersizlerin kastaki elektriksel aktivasyonu daha fazla artırdığı görülmektedir. Teorikte, daha fazla motor ünitenin devreye girmesinin kuvvet kazanımı, denge ve proprioseptif özellikleri geliştirebileceği bilgisi literatürde bulunmaktadır. Pratikte ise İsviçre topu egzersizlerinin proprioseptif duyu üzerine etkisine yönelik literatürde herhangi bir çalışma yokken, denge ile ilgili çelişkili sonuçlar mevcuttur. Kuvvet kazanımına gelince, İsviçre topu karşıtları, sabit zemin egzersizlerinin de kuvvet kazanımını geliştirdiği bu yüzden hareketli zemin egzersizlerine gerek olmadığını savunurken, İsviçre topu savunucuları kuvvet kazanımı açısından fark olmasa bile karın bel bölgesi için yapılan kuvvet antrenmalarının aynı zamanda omiriliği destekleme özelliğinin de olması gerektiğini savunmuşlardır.

Literatürde "Core" olarak tanımlanan bölge karın ve bel bölgesidir. Vücudumuzun "merkez" bölgesi bir kutuya benzetilebilir. Çatı olarak diyafram, taban olarak kalça kemeri, önde karın kasları, arkada bel kasları yanlarda ise oblique kasları bulunur. Merkez bölgesi 29 çift kastan oluşmaktadır. Yüzeyde, hareketten ve güç üretiminden sorumlu olan global (genel) kaslar bulunurken, daha derinde sabitleme ve propriosepsiyondan sorumlu local (yerel) kaslar bulunur. Neredeyse bütün hareketler merkez bölgesinden başlar ve antrenman bilimcilere göre en önce antrene edilmesi gereken bölge merkez bölgesidir. Merkez bölgesinin kinetik zincir içeren hareketlerde momentumun alt vücuttan üst tarafa transfer edilmesinde de yadsınamaz rolleri bulunmaktadır. Literatürde bel ağrısının, insanların %85' inde, hayatlarının bir bölümünde karşılaşacakları bir sağlık problemi olduğu yazmaktadır (Nourbakhsh & Arab, 2002). Merkez bölgesi zayıflığıyla bel ağrısının arasında yüksek korelasyon olduğunu gösteren çalışmalar bulunmaktadır. Bu yüzden merkez bölgesinin kuvvetlendirilmesi hem günlük hayat hem de sportif performans için önem arz etmektedir. Omurga doğuştan sabit olmayan bir yapıya sahiptir ve hareketler esnasında sabitlenme gerekliliği bulunmaktadır. Merkez bölgesi egzersizlerinin amacı bu bölgedeki kasları kuvvetlendirmektir. Bununla birlikte bu bölgedeki kasların sadece kuvvetlenmesi değil aynı zamanda omurgayı sabitleme kapasitelerinin de artırılması gerekmektedir. Bu yüzden İsviçre topu savunucuları merkez bölgesi egzersizlerinin sabit olmayan bir zeminde yapılmasını önermektedir.

Propriosepsiyon, kısaca eklem farkındalığıdır. Proprioseptif cisimcikler deride, eklem boşluklarında, eklem sonlarında, tendon ve ligamentlerde bulunur ve merkezi sinir sistemine eklemin pozisyonu, eklemin hareketi, eklemin yönü, eklemin momentumu ile ilgili bilgileri iletir. Proprioseptif algının iyi olması hareketlerin daha kusursuz yapılmasını sağlamakla birlikte sakatlıklardan korunmak için de kilit rol oynamaktadır. Herhangi bir eklem sakatlığında proprioseptif cisimcikler zarar görür. Bu durumda beyinle eklem arasındaki iletişim zayıflar ve o bölgeden beyne giden uyarılar sekteye uğrar. Rehabilitasyon süreci verimli geçmezse aynı bölgede aynı tarzda sakatlıklar tekrarlayabilir. Rehabilitasyon sürecinde sadece kuvvetin değil, proprioseptif algının da eski düzeyine ulaştırılması gerekir. Propriosepsiyon ve denge antrenmanlarının temelde 3 amacı vardır; (1) Sakatlıkların önlenmesi, (2) sportif performansı artırmak, (3) sakatlık sonrası rehabilitasyon. İsviçre topu egzersizlerinin asıl amacı vücut için hareketli bir zemin oluşturarak vücudun pozisyonunu sürekli olarak değiştirmek ve böylece beyin ve eklemler arasındaki uyarı-cevap iletiminin hem hızını hem de sıklığını artırmaktır. Böylelikle hem reaksiyon zamanı hem de proprioseptif mekanizmalar geliştirilerek sakatlıklardan korunulabilir, sportif performans artırılabilir. Rehabilitasyon açısından İsviçre topu egzersizlerinin yararı ise, sakatlanan bölgede ki elektriksel aktivasyonu artırarak iyileşme sürecini hızlandırmaktadır.

Yukarıda belirtildiği üzere İsviçre topu egzersizlerinin proprioseptif algı üzerine etkisiyle ilgili çalışmaya rastlanmamış, kuvvet ve denge konularıyla ilgili de çelişkili sonuçlar olması dolayısıyla bu çalışma yapılmıştır.

Materyal ve metod

Bu çalışma, 10 haftalık Swiss ball egzersizlerinin (1) diz eklemi yeniden pozisyonlanma algısı (propriosepsiyon), (2) karın bel kası kuvveti, (3) dinamik denge üzerine etkisini araştırmak amacıyla planlanmıştır. Dinamik denge ölçümleri için gerekli olan Biodex denge cihazı ilk ve son testler arasında arızalandığı için denge ölçümleri yapılamamıştır. Bu yüzden ikinci bir örneklem grubu çalışmaya dahil edilmiştir. Propriosepsiyon ve kuvvet ölçümleri birinci örneklem grubunda, dinamik denge ölçümleri ikinci örneklem grubunda yapılmıştır. İkinci örneklem grubu çalışmaya, birinci örneklem grubunun ölçümleri tamamlandıktan yaklaşık 4 ay sonra dahil edilmiştir. Birinci örneklem grubunda kuvvet, denge ve proprioseptif egzersizler içeren egzersizler haftada 3 defa (Pzt, Çrş, Cuma) günde 1 saat olmak üzere 10 hafta süresince uygulanırken, çalışmaya sonradan dahil edilen ikinci örneklem gurubuna ağırlıklı olarak denge egzersizleri içeren egzersizler haftada 2 kez (Salı,Prş) günde 1 saat olmak üzere 10 hafta süresince uygulanmıştır. Bütün katılımcıların ölçümleri, 10 haftalık İsviçre topu egzersizlerinin öncesinde ve sonrasında yapılmıştır. Her iki örneklem grubu içinde katılımcılarla benzer özelliklere sahip kontrol grupları oluşturulmuştur. Diğer ölçüm prosedürlerinden farklı olarak birinci örneklem grubundaki egzersiz grubunun dizin propriosepsiyon ölçümleri, olası gelişim ve kalıcılığı test etmek için 3 defa (1-ilk test,2- son test, 3-takip) ölçülmüştür. Takip ölçümleri son test bittikten 9 ay sonra yapılmıştır. Birinci örneklem grubundaki kontrol grubunda takip ölçümleri yapılmamıştır. Takip testinde katılımcıların sayısı 43’ten 39’a düşmüştür.

Bu çalışmaya katılabilme kriterleri, katılımcıların herhangi bir sağlık problemi olmaması ve düzenli spor yapmamalarıydı. Katılımcıların sağlık problemi olup olmadığını anlamak için “Genel Sağlık Durumu Anketi”, spor yapma durumlarını anlamak için "Egzersiz Davranışı Değişim Basamakları Anketi" kullanılmıştır. Bu tezde, amaçlı örnekleme yöntemi kullanılmıştır. Bağımlı değişkenler dizin propriosepsiyonu, karın bel kası kuvveti ve dinamik denge skorları; bağımsız değişkenler ise zaman (1-ilk 2-son) ve grup (1-deney 2- kontrol)'tu. Etik kurul izni alındıktan sonra ve katılımcılar bilgilendirilmiş onay formunu imzaladıktan sonra çalışma yapılmıştır.

Birinci örneklem grubu 43 deney (27 erkek, 16 kız) ve 17 kontrol (9 erkek, 8 kız) grubundan olmak üzere toplam 60 katılımcıdan, ikinci örneklem grubu ise 27 deney (12 erkek, 15 kız) ve 20 kontrol (11 erkek, 9 kız) olmak üzere toplam 47 kişiden oluşmuştur.

Ölçüm Cihazları ve ölçüm protokolleri

Diz eklemi pasif yeniden pozisyon algılama (propriosepsiyon) becerilerinin ölçümü için Biodex izokinetik kuvvet dinamometresi kullanıldı. Dominant bacağı belirlemek için katılımcıya hangi ayağıyla futbol topuna vurmayı tercih ettiği soruldu. Ölçümler esnasında sağ veya sol bacak ölçümü için bir öncelik yoktu. Bütün katılımcılar gözleri kapalı olarak şortla test edildi. Hedef açı olarak 45^0 belirlendi. Bu açının katılımcılara tanıtılma hızı 4^0/sn olarak belirlendi. Hedef açı, katılımcıya gözleri kapalıyken 2 kez tanıtıldı. Test esnasında cihazın hızı 2^0/sn idi. Katılımcıdan hedef açıya geldiğini hissettiği anda elindeki düğmeye basması istendi. 45^0 olan hedef açı ile katılımcının test esnasında düğmeye bastığı andaki açı arasındaki fark (hata payı) dizin propriosepsiyon skoru olarak kaydedildi. Katılımcının yaptığı 2 ölçümün ortalaması kaydedilerek diğer bacağın testine geçildi.

Karın ve bel kası kuvveti ölçümlerinde Biodex izokinetik kuvvet dinamometresi kullanıldı. Konsantrik modda 90º/sn açısal hızda 10 tekrardan oluşan bir protokol uygulandı. Zirve tork / vücut ağırlığı (PT/BW), toplam iş çıktısı (total work) ve karın kası / bel kası oranları (agonist/antagonist ratio) değerlendirilmeye alındı.

Dinamik denge ölçümleri için Biodex Denge Cihazı kullanıldı. Katılımcılar en zor seviye olan "seviye 1" de, çift ayak durma pozisyonunda test edildi. Ölçüm süresi 20 sn idi. Katılımcılar 1 dakika aralarla toplam 6 deneme yaptılar ve bu 6 denemenin en iyisi kaydedildi.

İsviçre Topu Egzersizleri

Birinci örneklem grubuna 10 hafta süresince haftada 3 kez (Pzt, Çrş, Cuma), ikinci örneklem grubuna haftada 2 kez (Salı,Prş) olan bir protokol uygulandı. Katılımcılara boylarına uygun olan toplar (55-65 cm) verildi. Katılımcılar egzersiz öncesinde 6-8 dakikalık ısınma koşusunun ardından açma-germe hareketleri yaptılar. Birinci haftadan onuncu haftaya kadar egzersizlerin tekrar sayıları, set sayıları veya süreleri giderek artırıldı. Bütün seanslar aynı eğitmen tarafından yaptırıldı. Katılımcılara topun üstünde dizlerin üzerinde durma, bir bacağı kaldırarak mekik, topun üzerinde mekik, skuat, hamstring çekme, topun üzerinde durma, top üzerinde skuat, arkaya erişme hareketleri yaptırıldı. Kontrol grubundaki bireylere herhangi bir fiziksel aktiviteye katılmamaları ve rutin hayatlarına devam etmeleri konusunda uyarılar yapıldı.

Dizin propriosepsiyon ölçümlerinin analizi için bağımlı ve bağımsız örneklemlerde t testi (paired sample t test, independent sample t test), 2 x 2 karışık dizayn çok değişkenli varyans analizi (2 x 2 mixed design MANOVA), tekrarlı ölçümlerde varyans analizi (Repeated measures ANOVA), tek değişkenli varyans analizi (ANOVA); karın bel kası ölçümlerinde çok değişkenli varyans analizi (MANOVA), bağımlı örneklemlerde t testi (paired sample t test), 2 x 2 karışık dizayn çok değişkenli varyans analizi (2 x 2 mixed design MANOVA), dinamik denge ölçümleri için 2 x 2 karışık dizayn çok değişkenli varyans analizi (2 x 2 mixed design MANOVA), tek değişkenli varyans analizi (ANOVA), bağımlı örneklemlerde t testi (paired sample t test) uygulanmıştır. Alfa yanılma derecesi 0.05 olarak kabul edildi. İstatistiksel analizlerde SPSS programı kullanıldı.

Sonuçlar

İsviçre topu ile yapılan 10 haftalık egzersizler sonunda deney grubunun her iki dizinin propriosepsiyon skorlarında anlamlı gelişme kaydedilmiştir. Sağ bacağın propriosepsiyon skorları 5.94^{0}'ten 2.89^{0}'a düşerek ($p<.05$), sol bacağın skorlarıysa 5.90^{0}'dan 3.04^{0}'e düşerek ($p<.05$) anlamlı bir gelişme kaydetmiştir. Kontrol grubunda görülen değişiklik anlamlı bulunmamıştır ($p>.05$). Takip testi sonuçlarına gelindiğinde ise, sağ bacağın takip skorları son test skorlarına göre anlamlı derece de gerilemiş ($p<.05$), fakat ilk test skorlarından anlamlı derece de daha iyi olarak bulunmuştur ($p<0.5$). Sol bacağın takip skorları, son test sonuçlarından anlamlı derece de gerilemiş (p<.05), ilk test skorlarından daha iyi bulunmakla birlikte aradaki bu fark istatistiksel açıdan anlamlı bulunmamıştır (p>.05).

İzokinetik kuvvet sonuçlarına göre, deney grubunun bel kuvveti parametrelerinden zirve tork / vücut ağırlığı (PT/BW) skoru 321.76 N-m/kg'dan 397.90 N-m/kg'a (p<.05) ve toplam iş çıktısı (total work) 1490.85 J'den 1790.82 J'e yükselmiştir (p<.05). Kontrol grubunun skorları ilk testten son teste anlamlı bir değişiklik göstermemiştir (p>.05). Hem deney hem de kontrol gruplarının karın/bel kası oranlarında anlamlı bir değişiklik gözlenmemiştir. Karın kası sonuçlarında ise, deney grubu ilk testten sonteste zirve tork / vücut ağırlığı (PT/BW) skorunu 234.13 N-m/kg'dan 276.49 N-m/kg'a (p<.05), toplam iş çıktısı skorlarını (total work) 974.11 J'den 1062.47 J'e yükselmiştir (p<.05). Kontrol grubunda görülen değişiklikler anlamlı bulunmamıştır (p>.05).

Dinamik denge sonuçlarına göre, 10 haftalık İsviçre topu egzersizleri sonunda, her iki grubunda (İsviçre topu ve kontrol) toplam denge indeksi (27.6% and 26.4%, bahsedilen sıraya göre) (p<.0.05), ön-arka denge indeksi (22.1% and 23.3%, bahsedilen sıraya göre) (p<.0.05), iç-dış denge indeksi (30.3% ve 32.29%, bahsedilen sıraya gore) (p<.0.05) anlamlı olarak gelişmiştir. Bu yüzden İsviçre topu egzersizlerinin dinamik denge üzerine etkisi olup olmadığı anlaşılamamıştır.

Tartışma ve sonuç

Hareketli zemin egzersizlerinden birisi olan İsviçre topu egzersizlerinin amacı, çeşitli ve etkili bir antrenman uyaranı sağlamaktır. Bu toplarla yapılan egzersizler kuvveti, dengeyi, kontrolü ve proprioseptif algıyı geliştirmek amaçlı olmalıdır. Bununla birlikte sakatlanma riskinden dolayı maksimum kuvvet gelişimi için veya patlayıcılığın gelişimi için kullanılması önerilmemektedir.

Bu tezin literatür taraması bölümünde de vurgulandığı üzere, İsviçre topu egzersizlerinin propriosepsiyon üzerine etkisini araştıran herhangi bir çalışmaya rastlanmamıştır. Farklı hareketli zemin ekipmanlarıyla (salınım tahtası, köpük gibi) yapılan egzersizlerin propriosepsiyon üzerine etkisini gösteren ve gösteremeyen çalışmalarda mevcuttur. Bernier ve Perrin (1998)'in ayak bilekleri sürekli olarak burkulan bireylerle yaptıkları çalışmalarında, 6 hafta süresince, haftada 3 kez ve günde 10 dakika yapılan salınım tahtası egzersizinin ayak bileği propriosepsiyonunu geliştirebilecek kadar yeterli bir uyaran olmadığını bulmuştur. Clark ve Burden (2005) ise, yine ayak bileği sürekli burkulan bireylerle yaptıkları çalışmalarında, 4 hafta süresince haftada 3 kez ve günde 10 dakika yapılan salınım tahtası egzersizinin bacak kaslarının cevap verme süresini iyileştirerek sakatlık önleme de kullanılabileceğini bulmuşlardır. Naughton ve arkadaşları (2005) omzu çıkan (n=15) ve çıkmayan bireylerin (n=15) her 2 omzunu da proprioseptif olarak test ettikleri çalışmalarında, omzu sakat olan katılımcılara 4 hafta süresince haftada 5-6 gün, günde 10 dakika salınım tahtası egzersizleri uygulamıştır. Toplam 60 omuz ölçümü yapılan çalışmada sakat olan omzun olmayan omuza göre daha iyi bir seviyeye geldiğini bulmuşlardır. Yukarıda belirtildiği üzere farklı çalışmalarda farklı sonuçlar bulunmakla birlikte, genel eğilim hareketli zemin egzersizlerinin sakatlık sonrası proprioseptif dokuların onarımında ve sakatlıkları önlemek için antrenman programlarına entegre edilebileceği yönündedir. Bu tezde bulunan sonuçlara bakıldığında ise İsviçre topu egzersizlerinin dizin propriosepsiyonunu geliştirme de etkin bir ekipman olduğu söylenebilir. Son testler bittikten sonra yapılan takip testi sonuçlarına göre, hem sağ bacak hem sol bacak ta antrenman bittikten sonraki 9 aylık süreçte bir gerileme görülmüştür. Sağ bacak için, son test (T2) ile takip testi (T3) karşılaştırıldığında, takip testi skorları anlamlı derece de gerilese bile bu gerileme ilk test (T1) skorlarından anlamlı derece de daha iyidir. Sol bacak içinse, son test (T2) ile takip testi (T3) karşılaştırıldığında, takip testi skorları anlamlı derece de gerilemiştir. Rakamsal olarak takip skorları ilk test skorlarından daha iyi olmasına rağmen aradaki bu fark istatistiksel olarak anlamlı bulunmamıştır. Antrenmanın "geriye dönülebilirlik" ilkesine göre, kazanılan özellikler, kullanılmadığı zaman veya antrenman sonlandırıldığı zaman başlangıç noktasına dönecektir. Bununla birlikte şu noktanın da altını çizmekte fayda vardır ki ; 10 haftalık bir süre zarfında yapılan egzersizlerin etkisinin 9 ay (36 hafta) sonra bile görülebilmesi bu egzersizlerin kalıcılığını da yadsımamak gerektiğini ortaya koymaktadır. Sağ bacaktaki (dominant) kalıcılığın sol bacaktan (dominant olmayan) daha fazla olmasının olası nedeni, katılımcıların İsviçre topu ile egzersizleri yaparken dominant bacağın bilinçsiz bir şekilde daha aktif olması olabilir. Topla yapılan egzersizlerde karşılaşılan düşme korkusu, dominant tarafa olan güvenle birleşince dominant taraf bu egzersizlerden daha fazla yararlanmış olabilir. Hareketlerin topla yapılması her iki tarafında eşit çalışacağının garantisi değildir. Hareket son derece simetrik gözükse bile farklı taraflara farklı miktarda uyaran gidiyor olabilir. Bu yüzden simetrik gelişimin önemli olduğu durumlarda katılımcılara vücutlarının her iki tarafını da eşit oranda çalıştırmaya gayret göstermeleri gerektiği konusunda egzersizler öncesinde uyarılar yapılması uygun olabilir.

İzokinetik kuvvet parametre sonuçlarına göre, İsviçre topu egzersizleri merkez bölgenin kuvvetlendirilmesinde etkilidir. Hareketli zemin egzersizleri ve merkez bölgesi söz konusu olduğu zaman yapılan çalışmaların çoğu merkez bölgedeki elektriksel aktivasyonun nasıl değişeceği üzerinedir. Aynı hareketin (mesela mekik hareketi) hem sabit bir zeminde hem de hareketli bir zeminde yapılmasının karşılaştırıldığı onlarca çalışma mevcuttur (Behm, Anderson, & Curnew, 2002; Gaetz, 2004; Holtzmann, 2004; Lehman, Gordon, Langley, Pemrose, Tregaskis, 2005; Lehman, Hoda, Oliver, 2005; Marshall & Murphy, 2006). Bu çalışma sonuçlarına göre, hareketli zemin egzersizleri kassal aktivasyonu anlamlı oranda artırırken, kaldırılabilen yük miktarında anlamlı bir düşüşe neden olduğu bulunmuştur. Bu yüzden, İsviçre topu egzersizleri maksimum kuvvet kazanımı ve patlayıcılık için önerilmemektedir. Genel kuvvet kazanımı ve kuvvette dayanıklılığın gelişiminde kullanılması ise oldukça uygundur. Bunun nedeni ise omurga doğuştan sabit olmayan bir yapıya sahiptir ve hareketler esnasında sabitlenme gerekliliği bulunmaktadır. Lokal kaslar olarak adlandırılan daha derindeki kaslar omurgayı sabitleme özelliğine sahiptir ve bu kaslar hareketli bir ekipmanla antrene edilebilir. Merkez bölgesi egzersizlerinin amacı bu bölgede bulunan global kasların kuvvetini artırmak, lokal kasların ise sabitleme özelliklerini artırmaktır. Sekendiz, Cuğ ve Korkusuz (2010) yaptıkları çalışmada, 12 hafta süresince haftada 3 kez günde 45 dakika yapılan İsviçre topu egzersizlerinin spor yapmayan bayanların izokinetik merkez bölgesi kuvvet parametrelerini artırdığı bulmuşlardır.

İsviçre topu egzersizleri ile sabit zemin egzersizlerinin kuvvet gelişimine etkisinin araştırıldığı çalışmalarda; kuvvet kazanımı açısından İsviçre topu egzersizlerinin üstün bir yanı olmadığı, her iki grubunda gelişim kaydettiği ve bu gelişimlerin benzer olduğu yönünde açıklamalar mevcuttur. Nitekim, Cosio-Lima ve ark. (2003) 5 haftalık İsviçre topu egzersizleri ve yer egzersizlerinin kuvvet kazanımına etkisini karşılaştırdığı çalışmalarında her iki grubunda kuvvetini geliştirdiğini ve gruplar arasında istatistiksel açıdan bir fark olmadığını bulmuşlardır. Merkez bölgenin antrene edilmesi için İsviçre topu egzersizleri yapılmasını savunanların açıklaması “Omurgayı sabitleyen kasların sadece kuvvetlenmesi değil aynı zamanda sabitleme özelliklerinin gelişmesi gerekmektedir”. Sabitleme özelliğinin geliştirilmesi ise hareketli zemin egzersizleriyle daha amaca uygun olabilir” yönündedir. Ayrıca omurga söz konusu olduğunda önemli olan omurga kaslarının ne kadar kuvvetli oldukları değil ne kadar dayanıklı olduklarıdır. Omurga kaslarının son derece kuvvetli olması omurga üzerinde bir takım komplikasyonlara da yol açabilmektedir.

İsviçre topunun küresel ve sabit olmayan yapısı düşünüldüğü zaman, bu topla yapılan egzersizlerin denge üzerine etkili olabileceği çıkarımında bulunulabilir. Bu topların teorikteki yararlarının dengeyi artırmak olduğu da vurgulanmıştır. Bununla birlikte Behm (2010), statik denge ile ilgili bir çok mekanizma anlaşılmış olmasına rağmen dinamik denge halen anlaşılamamıştır açıklamasını yapmıştır. Bu tezde de dinamik denge testi skorlarından elde edilen sonuçlara göre, bütün denge indeksi skorları (toplam denge indeksi, ön-arka denge indeksi, iç-dış denge indeksi) hem deney hem de kontrol grupta ilk test ve son test sonuçlarına göre anlamlı bir gelişim göstermiştir. Bu noktada 2 konu üzerinde durulacaktır; 1- Kontrol grubunun skorları neden gelişti? 2- Deney grubundaki katılımcıların denge skorları kontrol gruba oranla anlamlı olmasa bile denge içeren hareketleri haftalar ilerledikçe nasıl daha kusursuz yapabildiler?

Kontrol grubunun denge skorlarında gelişme olması olası bir “öğrenme etkisi” ni ortaya koymaktadır. Dinamik denge sadece doğuştan gelen bir yetenek değil aynı zamanda öğrenilen ve geliştirilebilen bir yetenektir. Biodex denge cihazının kullanıldığı çalışmalarda yapılan cihaza aşina olma denemeleri neredeyse her çalışma için farklılık göstermektedir. Bu çalışmalarda, herhangi bir standardın olmaması oldukça önemli bir handikap sayılabilir. Bu tezde yapılan 6 ölçüm sonrasında katılımcıların “öğrenme”lerini tamamlayacağı ve son testte de ilk teste benzer skorlar alacağı düşünülmüştür. Bununla birlikte son testte katılımcılar skorlarını geliştirmeye devam ettiler. Bu nedenle Biodex cihazı sağlıklı bireyler için uygun olmayabilir sonucuna varılabilir. Bu cihazla ilgili karşılaşılan sorunlardan bir tanesi, zorluk seviyesi maximumda olmasına rağmen katılımcıların yine de çok iyi skorlar almasıdır. Bir başka deyişle, kolay ve orta derece de alınan iyi skorlar en zor derece de bile kötüleşmemektedir. Olması gereken, zorluk derecesi ile skorlar arasındaki ters orantı çok iyi işlememektedir. Normalde beklenen, cihazın seviyesinin zorlaştığında alınan skorların kötüleşmesi (artması) yönündedir. Her ne kadar bu ters orantı bu cihaz içinde geçerli olsa da bu orantının katsayısı yeterli oranda olmayabilir. Bu sebeplerden dolayı, Biodex cihazı sağlıklı bireylerin test edilmesi için uygun olmayabilir. Bu sonuçlara göre; cihazı test ölçümleri için kullanmak yerine rehabilitasyon ve antrenman vermek amacıyla kullanmak daha uygun olabilir.

Denge ölçümlerini etkileyebilecek bir diğer faktörde konsatrasyon ve motivasyondur. Çalışmada gözlemlenen durumlardan bir tanesi de katılımcıların her denemenin sonunda denge indeksi skorlarını görmeleri ve bu skoru bir sonraki deneme için ulaşılması ve/veya geçilmesi gereken bir hedef olarak algılamalarıdır. Bu durum, katılımcıların konsantrasyon seviyelerini yüksek tutarak dengenin giderek iyileşmesine yol açmış olabilir. İleriki çalışmalar için, katılımcıların gözlerinin açık ama ekranı görmedikleri bir protokol takip edilmesi uygun olabilir.

Denge ölçümlerini etkileyebilecek en önemli unsurlardan birisi de, uygun bir geri dönüttür. Katılımcıların vücut ağırlığı noktalarını gerçek zamanlı olarak bir hedef tahtası üzerinde görmeleri dengeyi sağlayabilmek için alınabilecek en uygun geridönütlerden biridir.

Deney grubundaki katılımcıların haftalar ilerledikçe denge içeren hareketleri daha kusursuz yapabilmeleri şu şekilde açıklanabilir: İsviçre topu egzersizlerinde vücut her yöne gidebilme potansiyeline sahiptir. Vücut topun üzerinde öne doğru gitme eğilimi gösterdiğin de bu uyarı hızla beyine iletilir, beyin vücudun arkaya ağırlık vermesi yönünde bir cevap oluşturulur ve bu cevap hızlı bir şekilde gerekli kas, eklem, tendon ve ligamentlere iletilerek denge yeniden sağlanır. Beyin ve vücut arasında ki bu hızlı uyaran ve cevap etkileşimi hareketli zeminlerde sürekli olarak tekrar etmektedir. Böylelikle denge, kaybolma eğilimi içerisine girdiğinde antrene edilen bu mekanizma hızla cevabı taşıyarak dengenin yeniden sağlanmasına olanak sağlar.

Son söz olarak, bu tezde 10 haftalık İsviçre topu egzersizlerinin dizin propriosepsiyonu ve karın bel kası kuvveti üzerinde etkili olduğu gösterilirken, dinamik denge üzerinde etkisinin olup olmadığı gösterilememiştir.

Appendix G. TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü

Sosyal Bilimler Enstitüsü

Uygulamalı Matematik Enstitüsü

Enformatik Enstitüsü

Deniz Bilimleri Enstitüsü

YAZARIN

Soyadı : CUĞ

Adı : MUTLU

Bölümü : Beden Eğitimi ve Spor- Physical Education and Sport

TEZİN ADI (İngilizce) : EFFECTS OF SWISS BALL TRAINING ON KNEE JOINT REPOSITION SENSE, CORE STRENGTH AND DYNAMIC BALANCE IN SEDENTARY COLLEGIATE STUDENTS

TEZİN TÜRÜ : Yüksek Lisans Doktora

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir.
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir.
3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz.

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: