EFFECTS OF ECCENTRIC HAMSTRING TRAINING ON LOWER EXTREMITY STRENGTH & LANDING KINETICS IN FEMALE RECREATIONAL ATHLETES

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ABSTRACT

EFFECTS OF ECCENTRIC HAMSTRING TRAINING ON LOWER EXTREMITY STRENGTH AND LANDING KINETICS IN FEMALE ATHLETES

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The purpose of this study was to display increase in eccentric hamstring strength after 10-weeks training program. Secondly, if such an increase occurred, would this strength change result in altered landing kinetics and improved jumping performance?

27 recreational female athletes assigned into experimental (n = 14) and control (n = 13) groups. Baseline measures of landing kinetics were collected using a force plate, strength data and proprioceptive measurements were evaluated using an isokinetic dynamometer and vertical jump performance were determined by a jumping mat.

Results indicated that NHST group increased their eccentric hamstring strength after eccentric strength training program (week-1 = 233.6±27.5, week-10 = 253.8±28.4 Nm/kgbw; $p<.05$). The results demonstrated that there were significant differences in landing mechanics for NHST group. PVGRF (week-1

= 6.2±0.9, week-5 = 5.3±0.9; $p<.05$), PAPGRF (week-1 = 1.1±0.2 & week-10 = 0.8±0.3; $p<.05$) and APImp results demonstrated significant differences in trained group (week-1 = 78.1±13.6 & week-10 = 67.8±9.2; $p<.05$). NHST group exhibited significant increase in vertical jumping ability (week-1 = 0.25±0.0 & week-10 = 0.27±0.0 cm; $p<.01$).

This study supported the following points: 1) increases in the eccentric hamstring strength were evident after NHST program, 2) the increases in isokinetic strength were sufficient to cause alterations in landing kinetics to decrease the applied joint forces, so the NHST program would be an influential factor in decreasing the lower extremity injuries, and 3) the increase in the efficiency of force transfer at the final take off phase of jumping contributed to a higher performance in vertical jump.

Keywords: Eccentric training, Isokinetic strength, Landing kinetics, Vertical jumping, Knee proprioception.

ÖZ

REKREASYONEL BAYAN SPORCULARDA EKSANTRİK HAMSTRİNG ANTRENMANININ ALT EKSTREMİTE KUVVETİ VE YERE DÜŞÜŞ KİNETİĞİNE ETKİLERİ

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Bu çalışmanın amacı 10 haftalık eksantrik Hamstring kuvvet antrenmanı sonrasında kuvvette meydana gelecek artışı göstermektir. İkinci olarak ta eğer kuvvette artış olursa bu artış yere düşüş kinetiğini ve dikey sıçrama performansını etkiliyor mu sorusuna cevap vermektir.

Çalışmada 27 rekreasyonel bayan sporcu iki gruba ayrılarak NHST (n = 14) ve kontrol (n = 13) gruplarını meydana getirdi. Ölçümler 10 haftalık egzersiz programının başında, ortasında ve sonunda yapıldı. Katılımcıların bu dönemlerde yere düşüş kinetiği parametreleri kuvvet platformunda, alt ekstremite kuvvetleri ve propriyosepsiyonu kuvvet dinamometresiyle ve dikey sıçrama performansları sıçrama minderi ile değerlendirildi.

Sonuçlar NHST grubunun antrenman programı sonunda eksantrik hamstring kuvvetlerini arttırdıklarını gösterdi (hafta-1 = 233.6 ± 27.5, hafta-10 = 253.8 ± 28.4 Nm/kgbw; $p < .05$). Anlamlı farklılıklar NHST grubunu yere düşüş

mekaniği ölçüm değerlendirmelerinde de gözlendi. PVGRF (hafta-1 = 6.2 ± 0.9, hafta-5 = 5.3 ± 0.9; $p < .05$), PAPGRF (hafta-1 = 1.1 ± 0.2 & hafta-10 = 0.8 ± 0.3; $p < .05$), ve APImp (hafta-1 = 78.1 ± 13.6 & hafta-10 = 67.8 ± 9.2; $p < .05$) sonuçlarında anlamlı azalmalar belirlendi. Bunların yanında NHST grubunun dikey sıçrama performansında da anlamlı artış görüldü (hafta-1 = 0.25 ± 0.0 & hafta-10 = 0.27 ± 0.0 cm; $p < .01$).

Çalışmanın sonunda; 1) antrenmanının NHST grubunda kuvvet artırımı etkisi, 2) bu artışın yere düşüş biyomekaniğini etkilediği ve eklemlere binen yükü azaltarak yaralanma riskini azaltabileceği, ve 3) sıçrama hareketinde "take off phase" olarak adlandırılan anda ki kuvvet transferinin etkinliğinin arttırıldığı ve dikey sıçrama performansını geliştirdiği gözlenmiştir.

Anahtar Kelimeler: Eksantrik antrenman, İzokinetik kuvvet, Yere düşüş kinetiği, Dikey sıçrama, Diz propriyosepsiyonu.

To My Love Aygen
My Parents

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

A well-planed exercise program is the most beneficial instruction which someone can follow for achieving the sense of well-being. For everyone performing exercise is one of the cheapest ways to keep away from the illnesses. Doing regular physical exercises may help in lowering the cholesterol level, keeping the proper body weight, lowering the stress level and improving the mental health of the performer. Beside these all, the need of the well-programmed exercise prescription is inevitable therefore the performer should get expert assistance to become conscious about the healthy exercise. However, beside the benefit of performing exercise, people can face with sport injuries also while trying to getting healthy.

Jumping, sprinting, quick changes of direction and sudden stop-and-go actions are indispensable parts of most of sports which depends to a great extent on lower extremity strength. Strength and conditioning programs not only improve players' performance but also assist in injury prevention.

The hamstring injury is a well-known and well recognized problem by sport scientists. These injuries are the major cause of time lost from any sport (Garrett, Ross Rich, Nikolaou & Vogler, 1989), and these injuries can be saddening to an athlete because hamstring injury heals slowly and has a strong tendency to recur due to the injury's healing by inelastic, fibrous scar tissue (Burkett, 1970).

Many predisposing factors for hamstring strain have been suggested in several studies, which are muscle imbalance between the hamstring group and the quadriceps group (Kujala, Orava, & Jörvinen, 1997), muscle weakness (Orchard, Marsden, Lord, & Garlick, 1997), poor flexibility (Hartig & Henderson, 1999), fatigue (Kujala et al, 1997), and previous injury (Bennell, Wajswelner, Lew, Schall-Riaucour, Leslie, Plant, & Cirone, 1998).

Although in some cases injury is unavoidable, prevention is also possible if the athlete is prepared for the sport activity, both physically and mentally. While performing physical exercises try to do a moderate level of physical activity throughout the week, before the activity do warm-up exercises and stretching, after the activity remember to do cool-down, remember proper wearing, increase the level of exercise gradually, and finally perform a total body workout of cardiovascular, strength training and flexibility exercises, which decreases the injury occurrence while improving total fitness (NIH, 2004).

In particular, it may be advantageous to continue lower extremity strength training which targets the hamstring and quadriceps and focuses on improving the co-contraction pattern of these muscle groups. Notably, while running, the knee extensors contract concentrically for acceleration but for deceleration the flexors are called into action using eccentric activation. It was also stated that an antagonist co-contraction during rapid, high force contractions may act as a protective 'breaking mechanism' to decelerate the lower limb and increase stability of the knee joint (Sale, 1988). Thus a strength training program should include eccentric as well as concentric components.

During eccentric muscle action the contraction quality is different then the isometric and concentric muscle actions (Rodgers & Berger, 1974). Concentric muscle action can be explained as muscle fibers shorten while overcoming a load (Housh et al., 2003). Isometric muscle contraction is one in which the muscle is activated, however, it is not lengthen or shorten, it is held at a stable length. An eccentric muscle contraction action is when the muscle lengthens to lower a load (Housh et al., 2003). During the daily life, we often perform such activity which lengthens the muscle fibers. While walking when the knee extensors active just after the heel strike, flexors start to flex the knee at that phase eccentric contraction take places. Eccentric exercise requiring investigations are very popular for several reasons. But the main reason is the greatest magnitude forces take places in muscle while it is actively lengthening.

Previous studies have demonstrated the effectiveness of eccentric strength training for the hamstring muscles in different ages and sports (Aagard, Simonsen, Trolle, Bangsbo, and Klausen, 1996; Arnason, Andersen, Holme, Engebretsen, and Bahr, 2008; Askling, Karlsson, and Thorstensson, 2003; Brockett, Morgan, and Proske, 2001; Clark, Bryant, Culgan, and Hartley, 2005; Mjolsnes, Arnason, Osthagen, Raastad, and Bahr, 2004; Olsen, Myklebust, Engebretsen, Holme, and Bahr, 2005). However, there at the time of designing the present study we could not trace a prior investigation that examined the biomechanical effects of eccentric hamstring training beside the strength measures.

1.2 Rationale of Study

The following investigations proved the superiority of eccentric training for developing strength (Seger, Arvidsson, & Thorstensson, 1998; Fartling & Chilibeck, 2003; Askling et al., 2003; Mjolsnes et al., 2004; Tansel, Salci, Yildirim, Kocak, & Korkusuz, 2008). Although numerous studies included effects of strength training programs on lower extremity strength, few studies focused on kinetic influences on performance.

Therefore, it is important to investigate the newly developed practical eccentric hamstring exercise effects on both strength and jumping performance in combination with biomechanical perspectives. A key question is if lower extremity strength training results in changes in landing kinetics. If alterations in landing kinetics were evident after NHST program, then further studies investigating the exact nature of the landing mechanics by merging kinetic, kinematic and inverse dynamics would be worthwhile.

1.3 Research Questions

Does 10-weeks NHST program improve (a) lower extremity strength, (b) landing kinetics, (c) knee proprioception and (d) explosive power in recreational female athletes?

1.4 Purpose of the Study

The purpose of this study was to display increase in hamstring strength after 10-weeks NHST program. Secondly, if such an increase occurred, would this strength change result in altered landing kinetics, knee proprioception, and explosive leg power in recreational female athletes?

1.5 Research Hypotheses

1. There will be no change in the lower extremity strength following the NHST program.
2. There will be no change in landing kinetics following the NHST program.
3. There will be no change in the proprioceptive sense following the NHST program.

4. There will be no change in vertical jumping performance following the NHST program.

1.6 Delimitations

1. Participants consisted of 18-25 years old recreational female athletes.
2. All participants received the same strength training program in experimental group.
3. Participants who had sustained previous lower extremity injuries were excluded from the study.
4. All measurements were performed using the same set-up throughout the course of testing for both groups.

1.7 Limitations

1. As a result of equipment failure kinematic data were not recorded during the data acquisition in landing maneuver.
2. Tests were conducted in laboratory settings.
3. Daily activities of the participants were not controlled.
4. There was no only NHST group as a third group without volleyball training.
5. Participants were female.

1.8 Definition of Terms

The following are definitions of terms that were operationally defined throughout this study.

<u>Anterior/Posterior Ground Reaction Force (APGRF):</u> Applied anterior and posterior shear forces to the ground in landing maneuver.

Anterior/Posterior Impulse: The area under the anterior/posterior ground reaction force by time curve.

Average Peak Torque (AvgPT): The average of maximum torques that can be obtained from maximum muscle contractions.

Concentric Muscle Contraction: The type of muscle contraction occurs when a muscle shortens in length and develops tension.

Eccentric Muscle Contraction: The type of muscle contraction in which the muscles lengthens while generating force.

Hamstring Strength: Peak torque of the hamstrings generated from the maximum isokinetic contraction, recorded by isokinetic dynamometer.

Hamstring to Quadriceps Ratio: The value of peak torque of the hamstrings generated from the maximum isokinetic contraction divided by peak torque of the quadriceps generated from the maximum isokinetic contraction.

Knee Joint Proprioception: The ability to sense the position and location and orientation and movement of the knee joint.

Landing Maneuver: Simulated movement that represents the phase of landing after a jumping maneuver.

Medial/Lateral Ground Reaction Forces (MLGRF): Applied forces while landing in the direction of medial and lateral to the ground.

Peak Torque: The maximum torque that can be obtained from a maximum muscle contraction.

Peak Vertical Ground Reaction Force (PVGRF): The peak force which is applied to the force plates as Newton.

Proprioception: It is the awareness of posture, movement, and changes in the knowledge of position of joint in relation to the body.

Quadriceps Strength: Peak torque of the quadriceps generated from the maximum isokinetic contraction, recorded by isokinetic dynamometer.

Time to Peak Force (Time to PF): A measure of the time from the initial contact of the foot to the point of the highest force development in landing maneuver.

Vertical Impulse: The area under the vertical force by time curve.

CHAPTER 2

REVIEW OF LITERATURE

This chapter gives detailed information about the subject related studies which are background information needed to understand the (1) eccentric strength training, (2) landing biomechanics, (3), function and form of knee joint, (4) lower extremity injuries, (5) explosive leg power and (6) proprioceptive sense.

2.1 Eccentric Strength Training

The increased popularity of physical activity induces a very challenging environment and needs quality in training factors. Therefore, physical readiness is important to prepare the athletes even if they are recreational athletes. The improved nature of physical activity, as well as the quality of the players, has necessitated the maximization of player preparation. Jumping, sprinting, quick changes of direction and sudden stop-and-go actions are indispensable parts of even all sports which almost rely on lower extremity strength. Therefore, strength training is a currently very popular area of study for these reasons. One of the important considerations when designing strength training program is the mode specificity which was supported by earlier investigations (Kaminski, Wabbersen & Murphy, 1998; Seger et al., 1998). Although there are several factors effecting the concept of the training specificity, for example training task, muscle length, and muscle contraction velocity (Seger et al, 1998) current study was only concentrated on muscle action type, especially eccentric one.

When muscles are contracting normally, it is thought that muscle is shortening as it generates force. However, muscle contracts in many different ways: first one is the concentric type, when a muscle is contracted and imposed a load, the muscle begins to shorten. So the muscle activation which permits the muscle to shorten is known as concentric contractions, and the second one is the isometric contraction. In this contraction muscle is activated but the length of the muscle is not changed, it is held at a constant length. The third contraction type is the eccentric contraction. In that way the muscles are lengthened while activated. While the load on the muscle increases, it finally reaches a point where the external force on the muscle is greater than the force that the muscle can generate (UCSD, 2006). That's why the muscle might be fully activated because of the external force. The contraction mechanism of the eccentric contraction is still debating because the cross-bridge theory describes the concentric contraction but not as successful in describing the eccentric one (UCSD, 2006).

Eccentric contraction and exercise are currently very popular subjects for researchers for several reasons. Firstly, eccentric training when compared to concentric training enables greater increases in strength than concentric training. The following investigations were proved the superiority of eccentric training for developing strength. Mjolsnes et al, (2004) implemented a 10-week eccentric strength training program which was more effective than a comparable training program with regular concentric exercise in developing maximal eccentric hamstring strength. According to Farthing and Chilibeck (2003) eccentric isokinetic training had also more improving effect on muscle strength than concentric isokinetic training.

Secondly, hypertrophy is another advantage of the eccentric exercise. The reason for that is the stimulation of the growth through a greater process of breakdown, possibly the greater tension on the muscle contractile elements through eccentric action combined with the greater protein degradation would promote a more positive anabolic response (Behm, 1995). Farthing and Chilibeck (2003) concluded that eccentric isokinetic training is more effective than the concentric one in terms of the muscle hypertrophy. Therefore it can be said that the greater tension on the muscle contractile elements through eccentric contraction related with the greater protein degradation.

Lastly, the energy cost for eccentric contractions is unusually low and the magnitude of the force produced is unusually high (Lindstedt, LaStayo & Reich, 2001). The study of Durand et al. (2003) has proved theory of eccentric exercise that requires a lower energy cost than concentric exercise. The people who have low levels of aerobic capacity may use such source of training without the accompanying loss of energy.

Beside the advantages of the eccentric exercise, there are several disadvantages of performing such an exercise. The most complained issue is the soreness. Soreness can be the reason to stop the eccentric exercise; however, athlete should be informed about the benefits and necessity of eccentric exercise. Acute strength loss is another negative effect of the eccentric exercise. About 48 to 72 hours there can be such a strength loss and because of this reason, well-planned strength program need to be planned so the loss of strength can increase the injury occurrence.

Kaminski et al. (1998) tried to compare the effects of eccentric and concentric training on hamstring muscles. They studied with twenty-seven healthy male subjects who were randomly assigned into three groups as eccentric training, concentric training and control group. They implemented their training program 2 days per week for 6 weeks. As a strength measurement isokinetic knee flexion and 1RM were tested. In eccentric training group 1RM/BW ratios increased 29% and 19% in the concentric group at the end of 6 weeks training.

Moreover, only eccentric group improved the eccentric isokinetic strength 38% and 22% in both 60º/s and 180º/s velocities. They suggested that concentric training could not be able improve eccentric isokinetic strength alone and also it was interesting that eccentric training significantly improved over all hamstring muscles both isotonic and isokinetic performance.

Seger et al. (1998) also studied effects of both eccentric and concentric training on muscle strength and morphology. Ten participants were divided into two groups and trained three times per week for ten weeks, separately for each leg. Mainly muscle strength by isokinetic dynamometer, muscle biopsy by means of using a needle biopsy technique and cross-sectional area of quadriceps was measured by magnetic resonance imaging technique. The average eccentric and concentric strength increased 18% and 2% for the eccentric training group and 10% and 14% for the concentric training group, respectively. Magnetic resonance imaging results demonstrated that cross-sectional area of the quadriceps increased 3% and 4% in both group but only the eccentric training group showed significant difference in analysis. Both group showed no major differences in muscle fiber composition. As conclusion, eccentric training had a superiority in terms of mode and speed specific than the concentric training.

Mjolsnes et al. (2004) has also studied the mode specificity of the training. They implemented 10 weeks eccentric and concentric training program on two groups. While the concentric group performing traditional hamstrings exercise, the eccentric group performed the Nordic hamstring exercise. By means of the isokinetic strength dynamometer leg strength of the athletes were measured at the beginning and after the training period. Eccentric training group increased eccentric hamstring strength 11% and 7% isometric hamstring strength. Beside the hamstring to quadriceps ratio was demonstrated significant increase (11%)

in the eccentric strength training group. No changes had been observed in concentric group in concentric and eccentric strength measurements. Based on their result, they claimed that for the improving eccentric strength, the Nordic hamstring exercise has more effective than traditional hamstring exercises. It is also superior in terms of the applicability of the exercise because it can be performed most of the sport places if there is a partner.

Clark et al. (2005) investigated the effects of eccentric training on vertical jumping performance, isokinetic strength and if there was a change in the position of the peak torque. Nine sportsmen male participants were included in this study. Pre- and post-training analysis showed that the vertical jumping performance increased significantly (6.6%) but the quadriceps peak torque demonstrated a significant reduction in strength (11.3%) and also the position of peak torque had showed significant difference in hamstrings from full knee extension (19.4%). Furthermore, the position of peak torque between dominant and non-dominant was significantly different (36.4%) in knee flexion angle towards full extension. Based on this study Nordic hamstring exercise was an effective method for both improving sport performance and decreasing the injury risk.

Farthing & Chilibeck (2003) also tried to examine the effect of isokinetic eccentric and concentric training at different velocities on muscle hypertrophy on elbow joint. First group was fast trained (180º/sec) and second was the slow velocity (30º/sec) training group. In first 8 weeks they trained their one arm eccentrically, and then the opposite arm was trained concentrically. There were also ten control subjects. Strength measurements before and after the treatment were performed with the isokinetic strength dynamometer. As indicated overall results eccentric training resulted in greater hypertrophy than concentric training for both fast and low velocities. Fast eccentric training (180º/sec) resulted in the greatest strength improvement. Therefore, the authors claimed that the fast training is the best way for muscle strength enhancement and muscle hypertrophy.

Higbie, Cureton, Warren & Prior (1996) compared the effects of concentric and eccentric isokinetic knee extensors muscle strength, cross-sectional area, and neural activation. They randomly assigned their 54 women participants into three concentric training (N = 16), eccentric training (N = 19) and control group (N = 19). Groups were taken under evaluation before and after the 10-week training. As a strength measure average peak torque was taken into consideration, at the end of 10-week period the concentric training group increased their concentric and eccentric strength 18 and 13%, eccentric group 7 and 36% and control group 5 and -2%, respectively. Group comparisons revealed that both eccentric and concentric group demonstrated significantly strength increase against their control counterparts ($p < .05$). The increase by eccentric training with eccentric testing was greater than the increase by the concentric training group with concentric testing. The changes pre-test to post-test in the electromyography measurements for both concentric and eccentric contraction during the strength testing were 22 and 20% in concentric training group, 7 and 17% in the eccentric training group and -8 and -9% in the control group, respectively. Beside these the magnetic resonance imaging results showed that eccentric training group increased significantly their quadriceps cross-sectional area (7%) then the concentric training group (5%). Based on these results researchers concluded that eccentric training is superior than the concentric training in terms of the eccentric isokinetic muscle action, and according to the concentric training it can also claimed that concentric training is more effective than eccentric training in developing the concentric isokinetic strength. Finally they suggested that because the concentric and eccentric muscle actions are mostly performed consecutively the training of both types of muscle action should be merged. Even the increase in muscle hypertrophy in eccentric training is slightly greater than the concentric one, the neural adaptations are similar.

The effectiveness of the eccentric hamstring training has also been demonstrated by Arnason et al. (2008) followed the Norwegian soccer players for four consecutive seasons. All teams included in this study participated in continues injury registration. After that the intervention program was implemented for eccentric strength performance and its flexibility. At the end intervention they concluded that eccentric strength training with Nordic hamstring lowers combined with warm-up stretching have positive effect on reducing the risk of hamstring strains.

In summary, human muscle contracts to move objects at different types. Eccentric muscle contraction creates greater forces than the concentric and isometric contractions. Beside it is controlled by different neural mechanism. The advantages of eccentric training have been reported as improving muscle strength and size, and lower energy cost in muscle action. Beside these eccentric exercises is strongly related with soreness, reduced neural reflexes and acute strength loss. The main concern in eccentric training is that it is almost common activity in most of the sports therefore athletes need to be adapted this kind of exercises or movements. It is accepted that all the eccentric exercises have not similar characteristics. Eccentric exercises can be classified as heavy eccentric training, stretch shortening cycle training and light or mild eccentric training. For the first two types of training the previously mentioned studies can be explanatory examples but the third type has not mentioned before, this type is used for rehabilitation of tendons. Additionally this eccentric rehabilitation training is characterized by mild or light movement with low loads. Clement, Taunton & Smart (1984), Alfredson, Pietila, Johnson, & Lorentzon (1998), Cook, Khan & Purdam (2001) and Langberg et al. (2007) in their studies demonstrated the effectiveness of the eccentric rehabilitation training on chronic Achilles and patella tendons.

While preparing training planning, the need of the performed branch requires careful analysis and in this planning the application of the eccentric exercise is indispensable because eccentric contraction inherent to sport activity. Beside the benefits, the negatives or "no pain, no gain" which is the expression of eccentric exercise in words, should be considered.

2.2 Landing Biomechanics

Over the years, many sport scientists worked on to jump higher by means of some exercise types such as plyometrics and strength training (Hauschildt, 2008). However, the jumping and landing are integral parts of many sport movements. Therefore, not only training to jump higher but also training to land as soft as possible is the secondary major concept. Sport scientists are now looking for how effectively an athlete could be able to absorb force as they are landing from a jump (Hauschildt, 2008).

Most of the athletes naturally may prefer to land stiff legged so the impact force is absorbed among the hip, knee and ankle joints, however, if the athlete lands softly in this maneuver he/she will be able to transfer their force to the glutes, hamstrings, quadriceps and calf musculature (Hauschildt, 2008).

Mainly, there are two important reasons for focusing on how athletes land; first one is injury prevention and the second one is the power production. All athletes can sustain from lower extremity injuries. One of the major concerns related to poor landing maneuver technique is the ACL injuries which will be discussed in part following parts (2.4.1). The ACL can be protected by proper landing maneuver when the athlete loads the glutes upon landing (Hauschildt, 2008). The role of the ACL in the knee joint is to prevent the tibia of the lower extremity from sliding forward during the landing movement. As mentioned before, landing biomechanics are highly important for power production in sports. If the athlete could not be able to land properly and decelerate him selves with a properly distributing his weight, this poor positioning may result in unwanted situation in consecutive sporting movement (Hauschildt, 2008). Therefore, the correct landing technique should be emphasized in workouts, and according to Hauschildt, (2008) the key point in teaching or training landing are; firstly land as softly as possible and also the landing forces should be absorbed by muscle not with joints. Secondly, landing with flat footed, by means of keeping weight evenly distributed over the entire foot can also increase the landing efficiency and lastly shifting the glutes back and keep the knees behind the toes while landing will also affect the quality of landing technique positively (Hauschildt, 2008).

There are two groups of forces acting on the body; first one is the “load” and the other is “shear”. Load can be defined by the weight of the subject and the shear is the interaction or friction between the body and the ground.

When the body contact with the ground, this movement turn back to body as a force. Think that a person stands on, this force is same with the person’s mass, so we can say that ground reaction force is the reaction to the force which a person put force on the ground. Such impacts are needed for absorbing these forces to protect the human skeleton, organ or soft tissue from possible damaging forces.

When studying ground reaction forces, the landing is the phase on which most of the emphasis is placed. During the landing, the joints of the lower extremity absorb the applied energy. Landing stability is accomplished by multi-joint control, allowing the individual to successfully accomplish the task (McNitt-Gray, 2000). Magnitude, direction, and the duration of the landings are the main determinants (Mc-Nitt Gray, 2000).

Hewett, Stroupe, Nance & Noyes (1996) experimentally tested whether plyometric training program had effect on landing biomechanics and lower extremity strength in female athletes. This study was mainly designed to reduce the applied ground reaction forces by enabling or teaching the neuromuscular control of the lower extremity while landing. Between two tests (pre and post) PVGRF was decreased nearly 20% in block jump, hamstring to quadriceps strength ratio increased 26% and 13% on both non-dominant and dominant leg, respectively. The dominant side also increased 44% hamstring strength and non-dominant part increased 21% by means of the plyometric training. Additionally, after training, vertical jump performance was also improved 10%.

Myer, Ford, Brent & Hewett (2006) investigated the effects of plyometric vs. dynamic stabilization and balance training on power, balance and landing force in female athletes. Nineteen subjects (plyometric group, 8 & balance group, 11) were participated in this study. They were trained 3 times a week for seven weeks. At the end of the study landing force results were interesting. The balance trained group demonstrated significantly difference in dominant side, they reduced their reaction force by 7%, however, plyometric group was increased their impact force 8%. The non-dominant side also demonstrated parallel results but the statistical result did not showed any significance. These results are not similar with the previous studies, Hewett et al., (1996) reported that plyometric training can reduce the impact landing forces. These findings could result from characteristic of the balance training which includes force dissipation technique.

Dufek and Bates (1990) studied on the impact forces of landing from three different heights (40, 60 & 100 cm), horizontal distances (40, 70 & 100 cm) and techniques (stiff, slightly flexed & flexed knee). As a result stiff landing technique found as the greatest peak vertical ground reaction forces in all heights and distances. Therefore, according to their investigation the key point in decreasing the ground reaction force is almost the knee flexion angle. This study was a valuable study among the landing studies but their three volunteer subject number was reasonably small.

Mizrahi and Susak (1982) studied on the effects of body position, range of flexion of lower extremity joints, softness of the ground in landing maneuver. Their result demonstrated that activation of muscle and joint movements are responsible for reducing peak forces during landing. Five subjects performed landing from 0.5 and 1.0 m above mounted force plates landing with one foot landing on each force plate. All subjects performed three drops from the lower height onto the balls of the feet, and onto flat feet. Three subjects performed four drops from the one meter height on the balls of the feet, two of which were followed by a lateral ground roll. Two subjects also performed "soft" landings onto a five centimeter thick foam mat. The gender of the subjects in the last two sets of trials was not reported. Landing onto flat feet resulted in greater first peak vertical force magnitudes compared with landings onto the toes or the soft surface. Landing which are performed on cushioned surface and those followed roll demonstrated decreased vertical force results.

Devita and Skelly (1992) worked on effects of different landing strategies on joint kinetics and energetic in the lower extremity. They mainly studied on ground reaction forces, joint moments, joint positions and muscle powers in two different landing maneuvers (soft and stiff landings). Eight healthy female athletes were included in this study and each subject performed ten successful landing trials from the 59 cm high platform. As a result, they found that soft landing 117 and stiff landing 77 demonstrated degrees of knee flexion. As assumed the stiff landing showed greater vertical ground reaction forces than the soft landing. As a conclusion, in soft landing compared to stiff one the muscular system absorbed 19% more kinetic energy which means soft landing may decrease the impact forces on the lower extremity.

Kovacs and his colleagues (1999) jumped their ten healthy male participants from 40 cm high platform which was one meter away from the target force plate. Their subjects performed two types of landings, forefoot landing and heel-toe landing. They reported that forefoot landing had a 3.4 times higher peak vertical ground reaction force result than the toe landing. Additionally, the first vertical impact ground reaction forces of forefoot landing were 3 times higher than the toe landing.

Changes in ground reaction forces were also studied on unhealthy subjects, Caulfield and Garrett (2004) performed one such study which requires comparison of ground reaction force in landing subjects with functional instability and healthy controls. They studied single leg jumps from 40 cm height platform and trails were repeated for five times. Authors reported that lateral and anterior force peaks observed earlier in unhealthy subjects. Other significant differences were found in time-averaged vertical, sagittal and frontal components of the ground reaction force. It was claimed that the instability in ankle may cause the disturbed force patterns in landing, and they also suggested that this disordered distribution are most likely caused by deficits in feed-forward motor control.

In summary, most of the sport movements involve landing maneuvers and as mentioned above a large amount of studies has been performed on the forces applied to body during the landing movement. While standing on the floor, the person contacts the ground and at the same time the ground in return applies an same or equal in magnitude and opposite force to the subjects. This force named as the ground reaction force. A force plate is the traditional instrument used to measure the ground reaction forces. Actually, this force can be found in three different directions. These directions are the vertical, anterior/posterior, and medial/lateral. Most of the jump and landing studies are interested in vertical ground reaction forces. Among these three components, the “Y” is along the direction of the motion which reflects the propulsion or the braking force, and the “Z” is the vertically applied force to the ground. The body response to a landing maneuver can be explained and investigated under these various conditions.

2.3 Function and Form of Knee Joint

The knee is classified as a hinge joint; in fact, it is the largest and the most complex joint in the body or it can be said that the knee joint is an extraordinary construction of living tissue structure. The kinetics and kinematics, along with the tissue’s cellular capacities and physiologic potentialities, comprise the form and function of the knee joint (Muller, 1996).

This joint allows flexion and extension in the sagittal plane by rolling, spinning, and gliding. The tibial plateau and asymmetrical condyles provide limited bony structural support while the soft tissue structures are largely responsible for providing static and dynamic support to the joint (Lephart, John & Ferris, 2002).

The knee joint composed of the femorotibial joint and the patellofemoral joint. The bony structure of the femur, tibia, and patella contribute to the overall stability of the knee joint.

The soft tissue structures that provide static support to the knee are the capsule, ligaments, and meniscus, which are also referred as primary stabilizers or restraints. These primary restrains are mechanical in nature and are responsible for stabilizing and guiding the skeletal components.

The medial and lateral menisci have several functions in knee joint. First of all, as stabilizers, the intact menisci interact with the stabilizing function of the ligaments and are the most effective when the surrounding ligaments are intact. The menisci act as spacers between the femur and the tibia. By doing so, they prevent friction between these two bones and allow for the diffusion of the normal joint fluid. Finally, the biconcave C-shaped pieces of tissue lower the stress conducted to the articular cartilage, and thereby have a role in preventing the development of degenerative arthritis.

In addition, the two cruciate ligaments anterior cruciate ligaments (ACL) and posterior cruciate ligament (PCL) form the central pivot point of the joint. The ACL is responsible for resisting anterior translation of the femur on the tibia, specifically resisting 80-85% of anterior transitory loads (Lephart et al., 2002). The ACL is made of three bundles, the anteromedial, intermediate, and posterolateral. Bundles rise from the posterior medial femoral condyle and insert into the anterior medial aspect of the tibial plateau (Lephart et al., 2002).

The soft tissues that provide dynamic stabilization to the knee are the muscles, which are referred as secondary restraints. The quadriceps, hamstrings, and gastrocnemius are the main dynamic stabilizers of the knee. The orientation of the proximal attachments of the gastrocnemius and the distal attachments of the hamstrings are important for the dynamic stabilization of the knee as they provide a posterior force on the tibia that counteracts anterior translation (Lephart et al., 2002). Specifically, the hamstring muscle group is synergistic to the ACL by unloading the ligament via increasing the load to failure rate, up to 40% (Solomonow et al., 1987). Previous research suggests that several neuromuscular characteristics contribute to this dynamic restraint mechanism (Huston & Wojtys, 1996).

The collateral ligaments which are lateral collateral ligament and medial collateral ligament are the myotendinous structures that receive direct signals from the muscle fibers. Moreover, in knee joint the dynamic balance occurs by means of this myotendinous relationship. Dynamic balance is also provided by balance of intrinsic and extrinsic forces. This assistance and force coordinating supplied by quadriceps muscle group and hamstring muscle groups (Muller, 1996).

2.4 Lower Extremity Injuries

Sports injuries are the injuries that are sustained as a direct result of performing sports activities or recreational physical activities. There are so many causes of sport injuries, such as inadequate sport equipment, lack of physical conditioning, wrong usage of sport techniques, overtraining, improper warm up and stretching. Some of the most common types of sport injuries requires ligament ruptures, muscle sprains, muscle strains, dislocations of the joints and bone fractures. Beside these reports, researchers are also interested in the prevalence of the injury regions according to sport branches. It is not easy or possible to anticipate the injury occurrence for the athlete his selves, however, most of the sport injuries can easily be prevented if the athlete starts a sensible exercise routine, follows the instruction of the sport experts, performs warm up before every exercise session and does stretching, and at the end performs cool down. On the other hand slow and incremental physical conditioning, allowing for the adequate rest and recovery and proper adaptation when exercising are the other preventive measures. In each year, lots of injuries occur caused by sport, resulting in decreased physical activity and beside this the substantial medical costs (Murphy, Connolly, & Beynnon, 2003). In all around the world, the cost of sports injuries has been estimated at $1 billion annually (Egger, 1990). The most common injury types were muscle strains, and ligament sprains (Murphy et al., 2003). This section focuses on the well-known lower extremity injuries of ACL and hamstring injuries.

2.4.1 ACL Injuries

The mechanism of injury often described as landing from jumping, stopping, cutting, twisting, and turning (Arendt & Dick, 1995). However, there are lots of possible risk factors that can cause the occurrence of an ACL injury. Injuries may depend on variations in quadriceps and hamstring muscle strength, knee joint laxity, shoe-surface interaction, intercondylar notch variations, joints biomechanics, and hormonal effects (Egland, 2000).

Strength coordination and the timely ability to recruit muscles (muscle reaction time) are needed to maintain knee stability. Several researchers have documented that women have significantly less muscle strength when normalized for body weight (Griffin, Tooms, Zwaag, Bertorini & O'Toole, 1993; Huston & Wojtys, 1996). This lack of quadriceps and hamstring muscle strength may place the female athlete at a significant disadvantage because the muscles surrounding the knee protect the joint from deleterious loads. Additionally, some female athletes seem to have different muscle activation patterns compared to their male counterparts (Huston, Greenfield & Wojtys, 2000). Female athletes tend to activate their quadriceps near full extension at the knee with little hamstring activity and to land with smaller angles of hip flexion and larger angles of valgus compared with males. The combined effects from these findings suggest that women are at an increased risk of ACL injury (Lephart, Ferris, Riemann, Myers & Fu, 2002).

Joint laxity is another risk factor that can contribute to injury. Preliminary data (Huston and Wojtys, 1996) presented that women have more joint laxity than their male counterparts. Therefore, in female athletes with above-average hamstring flexibility, the protective ability of this muscle group may be diminished and the forces required stabilizing the knee preferentially transferred to the ligaments. Though these anatomic parameters may not be the primary cause of ACL injury, they may predispose female athletes to ACL disruption. The ability to accurately measure hamstring flexibility and the interplay between the knee flexors and extensors require further study (Boden, Dean, Feagin & Garrett, 2000).

The knee is classified as a hinge joint; in fact, it is the largest and the most complex joint in the body. This tibiofemoral joint allows flexion and extension in the sagittal plane by rolling, spinning, and gliding. The tibial plateau and asymmetrical condyles provide limited bony structural support while the soft tissue structures are largely responsible for providing static and dynamic support to the joint (Lephart et al., 2002).

The soft tissue structures that provide static support to the knee are the capsule, ligaments, and meniscus, which are also referred as primary stabilizers or restraints. These primary restrains are mechanical in nature and are responsible for stabilizing and guiding the skeletal components. In addition, the ACL is responsible for resisting anterior translation of the femur on the tibia, specifically resisting 80-85% of anterior transitory loads (Lephart et al., 2002). The ACL is made of three bundles, the anteromedial, intermediate, and posterolateral. Bundles rise from the posterior medial femoral condyle and insert into the anterior medial aspect of the tibial plateau (Lephart et al., 2002).

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Playing surface and shoes must be considered as risk factors when evaluating ACL injuries. Researchers should also notice the contradiction between the effects of shoe-playing surface interaction on performance. High level of friction between the shoes and playing surface appear to increase the risk of

ACL injuries, but enhance performance (Maffulli, Yu, Kirkendall & Garrett, 2002).

Intercondylar notch geometry is one other intrinsic factor suspected to predispose individuals to ACL injury and may differ between males and females (Tillman et al. 2002). However, this finding is contradictory. Although, males and females incur ACL injuries at different rates (Lephart et al., 2002; Arent et al., 1995 and Messina, Farney & Delee, 1999), no definitive evidence exist that explains this anatomical difference in injury frequency.

Most of landing studies focused on several common biomechanical variables in an effort to characterize the role of different factors in injury. These variables include the joint kinematics and ground reaction force (GRF). The GRF is a concept that is used to describe the reaction force produced by the supporting ground surface. It is derived from Newton's third law (action-reaction) to represent the reaction force of the ground to acceleration of the body. It is of interest to landing biomechanics because it is the main contributor to the internal loads in the lower extremity during landing. These internal loads can cause injury if not sufficiently distributed or attenuated by the musculoskeletal system. A research approach used in the past to investigate the injury potential of landing was to determine how various aspects of landing influence the GRF (McNitt-Gray, 1993; McNitt-Gray, Hester, Mathiyakom & Munkasy, 2001; Egland, 2000). By learning how these aspects of landing influence the GRF, there exists the possibility to develop interventions to control the GRF and the internal loads associated with it. Kinematics is the study of the spatial and temporal characteristics of motion without regard to the forces producing the motion. In regards to landing biomechanics, kinematics describes the movement of body segments and joints in terms of position, velocity, and acceleration during the landing movement. The study of kinematics by itself has limited potential for investigating injury aspects of landing. Thus, it has such a large influence on the GRF that it is difficult to discuss one without the other (Madigan, 2001).

When analyzing human movement and noncontact injuries several forces that act on a body, including weight, ground reaction force, and joint reaction force, and muscle forces should be considered. Additionally, the biomechanical principle of impulse summarizes potential errors in landing techniques. Impulse is defined as the size of a force multiplied by the time of that forces application. One has ideal impulse if a force is absorbed over a longer period of time. To do so, joints must go through a complete range of motion to ensure the maximum time available to absorb that force was used. Applying this information to potentially dangerous knee injuries is the degree of knee flexion on landing and impact velocity. Lesser degrees of knee flexion may be associated with increased peak vertical or ground reaction forces. The lower the ground reaction forces the greater the impulse and less chance of injury (Lephart et al., 2002).

Hormone levels should be considered as another potential contributory factor. Relaxin, a hormone found only in pregnant women, causes ligamentous relaxation, which allows for pelvic changes that accommodate fetal passage through the birth canal and the role of estrogen and estrogen receptors and shed light on ACL injuries in female athletes, but very few data are currently available (Moeller & Lamb, 1997).

The higher incidence of ACL injuries among females has been well documented, for example, Lephart, et al. (2002) reported that females injure their ACL 2-8 times more frequently than their male counterparts with the risk of injury increasing with participation in basketball, soccer and volleyball. Arendt & Dick (1995), Messina, et al. (1999) and Hewett (2000) reported similar findings that non-contact ACL injury rates are 3-4 times greater for female athletes than their male counterparts. Additional investigations needed to identify factors that predispose women athletes to an increase rate of ACL injury.

2.4.2 Hamstring Injuries

The hamstring muscles are one of the most complex groups of muscles in the human body, which has a crucial role in locomotion and stabilization of the lower body. The hamstrings are actually consisted of three separate muscles, the biceps femoris, semitendinosus, and semimembranosus, which are originated under the gluteus maximus on the pelvic bone and attach on the tibia. Hamstrings are mainly fast-twitch muscles, responding low repetitions and powerful movements.

Hamstring injuries are common in most physical activity which requires high speed, acceleration, or jumping activities (Garrett, Califf & Bassett, 1984). These injuries can cause losing time from the performed sport because this type of injuries heals slowly and the reoccurrence rate is high (Garrett et al., 1989).

The hamstring injuries can be classified in two main risk factors which are intrinsic and extrinsic factors. Although the intrinsic factors are more forecasting the hamstring injuries (Croisier, 2004), mostly the combination of risk factors has the greatest risk of injury (Peterson & Holmich, 2005).

2.4.2.1 Factors Predisposing to Injury

Previous injury: Orchard (2001) reviewed 2255 Australian Rules of Football League matches and he concluded that previous injury was the strongest risk factor for the reoccurrence of the hamstring injuries. Hawkins, Hulse, Wilkinson, Hodson & Gibsont (2001) reported that hamstring muscle by itself was responsible for the highest repetition of occurrence rate of all injuries. Arnason et al. (2004), Bahr & Holme (2003) and Croisier (2004) had also parallel findings with this study and claimed that the history of hamstring injury is the main factor for the repetition of the injury.

Eccentric contraction: An eccentric muscle action is when the muscle fibers lengthen to lower a load. When the athlete performs sprinting, kicking, jumping or landing movement, the hamstring undergoes eccentric contraction. Proske, Morgan, Brockett, & Percival (2004) reported that pre-injured muscles are more susceptible to eccentric deformation while exercising. They also claimed that eccentric exercise is the only type of exercise routinely accompanied by muscular damage.

Flexibility: Lack of flexibility has also been shown to have a strong association with hamstring injury. Several authors has also emphasized that the stretching activity following the proper warm up, which enables decrease in muscle stiffness (Garrett, 1996), has a crucial impact on decreasing the injury occurrence risk.

Witvrouw, Daneels, Asselman, D'Have, & Cambier (2003) worked with 146 male soccer players to test the increased muscle tightness could be identify a soccer player at risk for a subsequent musculoskeletal lesion. Before the competition season started, they performed the flexibility measurements of subjects, and then the players followed for the whole season for documenting their muscle injuries. As a result, the injured players' lower extremity flexibility was found significantly different compared to injured players. Therefore, flexibility of lower extremity muscles can be considered as an important factor for the development of muscle injuries.

Strength: Jonhagen, Nemeth & Ericsson (1994) shown that weakness in lower extremity is strongly associated with hamstring injury occurrence. Orchard et al. (1997) studied on thirty-seven professional football players at pre-season and they measured lower extremity strength of players. Throughout the season hamstring muscle injury of players were diagnosed. They found that the injured hamstring muscles were significantly lower than the other leg in absolute values, and hamstring to quadriceps ratios were also lower in injured players. In conclusion, they claimed that the pre season strength testing may identify the risk of injury in hamstring muscles.

In summary, based on the current literature, there are some crucial questions about the effects of landing maneuver on lower extremity injuries. Actually, the lack of shock absorption in landing maneuver has been shown to be a related or effective factor in many lower extremity injuries. These injuries can be seen in all joints of the lower extremity especially in knee joint. Competitive athletes should have regular evaluations in order to avoid potentially disabling injuries.

2.5 Explosive Leg Power (Vertical Jump)

Vertical jumping performance can be served as a measure of power and also as a measure of the athletic performance. It assumed that if an athlete is a higher jumper, the probability the athletic success of him is also higher. In researchers perspectives, the vertical jumping performance is used to define power, multijoint coordination, and as a predictor of athletic success. Explosive leg power is an important factor for successful performance in many sport branches. Vertical jumping performance is affected by these factors, the lower leg muscle strength, ability of stretch-shortening cycle, the muscle contraction reserve or speed, the rate at which the muscles can develop force and the degree of the coordination in performed movement (Potteriger et al., 1999). Vertical jumping movements are very dynamic exercises. This type of exercises activates all muscle groups and organizes their actions.

Vertical jump can be categorized in three phases; the first phase is the preparatory phase, second one is the take off phase, and last phase is landing. Actually in first phase which can be expressed as starting position, the lower limb is totally flexed. The muscles are hold stretched (eccentric contraction) stimulating the stretch receptors (muscle spindles) increase in that phase (Chimera, Swanik, Swanik, Straub, 2004). When the athletes being in the second phase, the whole body extends and the muscles suddenly contract and produces a great amount of force (concentric contraction). Then the athlete faced with the gravity so the landing phase starts. The body turns back to the flexed position and the eccentric contraction occurs again to absorb the applied forces to the lower leg joints. Practice in vertical jumping performance is the key for success and a good vertical jump performance can be defined as the effective use of coordination and muscle strength. In order to increase or maximize the jumping performance the whole body has to move in coordination from foot to head. This can be provided by several methods, plyometric exercises are specific exercises to improve the vertical jumping performance.

There are several components related with the plyometric training. First one is the progression which has also several crucial components; intensity, volume, recovery and factor of detraining. These are all related in each other.

2.6 Proprioceptive Sense

While working with the concept of the proprioception it is crucial to know the basic sensory information processing. Limb position and movement are the products of sensory-nerve activity which is received and processed by the central nervous system. The central nervous system receives information form somatosensory, visual and the vestibular systems. In current research somatosensory system was referred to as a proprioception. Somatosensory system requires nerves located in the skin, bones, joints, and muscle-tendons. This system can detect pressure, pain, touch and especially joint motion and joint position. The somatosensory system is aided by two systems, the vestibular and the visual systems. The first one get information from the vestibules and semicircular canals of the inner ear, this system helps to maintain the overall body posture and balance. The second one, visual system also plays a large role in maintenance of balance. Basically, the visual system provides the central nervous system with visual cues for use as a reference points in orienting the body in space. However, the most important key role played by the somatosensory system which helps to explain why some athletes to injure certain joints over and over again.

The knee provides stability to the lower extremity, and affords the lower extremity with a large potential range of motion. The knee is assumed as the vulnerable joint in the lower extremity kinetic chain due to the relationship between high anatomical mobility and the high movement demands. Stability of the knee is achieved by ligaments, joint capsule, cartilage, and musculotendinous components. Proprioceptive organs located in musculotendinous structures; ligaments, joint capsules, and skin provide information relative to the joints position and motion in space to the central nervous system. This knowledge helps to regulate muscle responses aimed at protecting the joint from injury.

CHAPTER 3

MATERIALS AND METHODS

3.1 Participants

Twenty seven female recreational athletes between the ages of 18 and 22 participated in the study. All participants were students of Middle East Technical University. The subjects were divided into experimental (N=14) and control groups (N=13) while they were registering themselves to volleyball course. Actually, there were two sections, section one was the NHST group and the section two was the control one, and the section preference of the student was mainly determined by themselves according to their own department schedule without knowing the section effect. However, after the first strength testing session to provide the homogeneity of the groups two students were replaced their sections. This replacement was performed according to their eccentric hamstring strength which was a main determinant measurement in study title. A survey on previous lower extremity injury was conducted and only the applicants with no any previous lower extremity injury history such as undergoing any previous lower extremity surgery or lower extremity instability were registered. The exact nature of the studies' aim was explained to each voluntary subject and written consent and ethical approval of the Applied Ethical Research Center from METU was obtained.

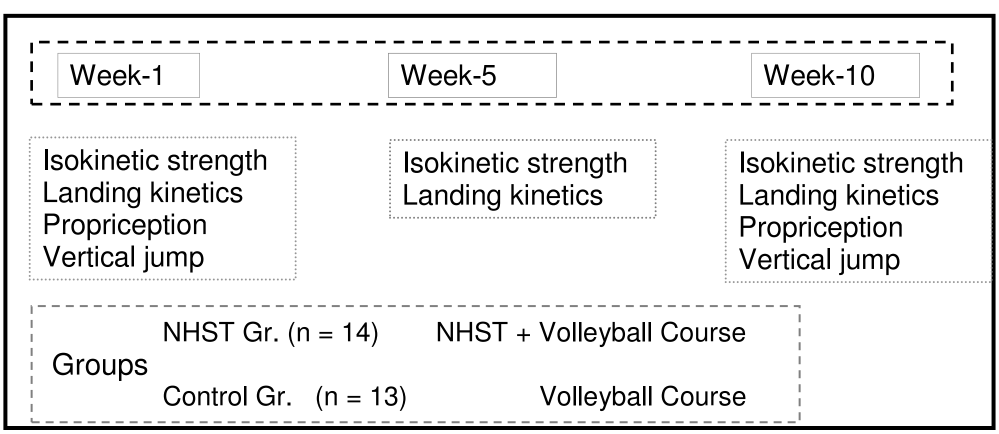
3.1.1 Anthropometric Measurements

Body height was measured without shoes in meters. Subjects' body weight was measured in kilograms using a calibrated platform. Body mass index (BMI) (kg/ht^2) was calculated to examine the relationship of height to weight.

3.2 Design

All the testing procedures were performed in the laboratories of the Middle East Technical University at Ankara. Subjects were divided into two groups of Nordic Hamstring Strength Training (NHST) group, participated in volleyball training and in addition performed Nordic Hamstring Strength Training, and the control group, participated in volleyball training only. Throughout the 10 week period both group attended volleyball training three times a week which required education of basic volleyball techniques in beginning level. During the testing procedures, each participant appeared on three separate occasions. Each test was administered before training program began. Second testing session was conducted on week-5 and week-10 tests were administered at the termination of the ten week training protocol. Participants were tested on field with vertical jumping measurements by BOSCOW MAT. Isokinetic measurements and proprioception assessments were recorded with the Biodex System Dynamometer (Biodex Medical Inc, Shirley, NY) in the physiotherapy laboratory.

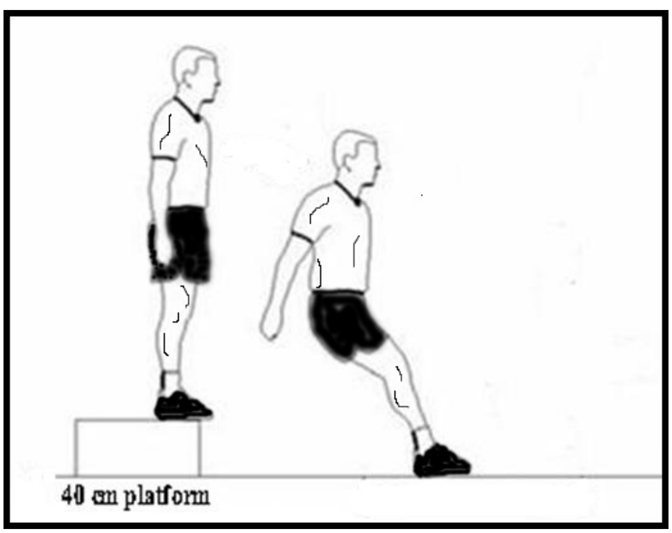
Figure 3.1 Study design and measured parameters throughout the study: independent (groups, test periods) and dependent (isokinetic strength, landing kinetics, proprioception, vertical jump) variables.



3.3 Landing Maneuver

Participants also performed three two-footed legs landing from a 40 cm box in Biomechanics Laboratory of Mechanical Engineering Department in METU (Figure 3.2). The box was placed 15 cm from the back edge of the force plate. Following a verbal start command, participants landed barefooted down from a platform as vertically as possible on a center of the force platform, evenly balanced on both feet. Each participant was introduced to carefully step-off the platform without jumping up or lowering her body prior to leaving the platform. During practice and test trials, subjects were instructed to land as safely and controlled as possible before each jump during session. Beside, after landing the subjects maintained a balanced position on both leg approximately four seconds. For all sessions, no feedback was given to the subjects regarding their lower limb motion. Each subjects had the opportunity to perform three practice trials. A trial was repeated as necessary in the event a subject did not perform the required landing.

Figure 3.2 Landing maneuver from a 40 cm platform.



3.4 Kinetic Measurements

Force plates (4060HT, Bertec Corp., Worthington, OH) were used to record ground reaction forces (GRFs) at a sampling rate of 500 samples per three seconds. GRFs were normalized to each participant's body weight (BW). This was performed to decrease the confound effects of differences in BW of subjects. In addition to this the all force measures were expressed as a percentage of body weight (%BW).

The following five biomechanical measures during the 300 ms following foot contact were chosen based on the assumption that the performer after landing reaches her own body weigh in that mean period on force plate measurements. As biomechanical measures peak anterior-posterior (Fy) force (PAPGRF), vertical (Fz) force (PVGRF), anterior-posterior force impulse (APImp), vertical impulse (VImp), and time to peak force (Time to PF) were chosen after the extensive literature review. Impulse calculations were performed by means of calculating integrals of the area under the force time curve.

As mentioned before, subjects performed three landing trials for each testing sessions (week-1, week-5 & week-10) and the representative trial was selected as the trial with the minimum sum of normalized absolute differences from the means. This calculation was performed in the following manner (Table 3.1).

For each variable, X_i (i ranging from 1 to 5), calculate the mean for all n trials

$$\overline{X}_i = \frac{\sum_{j=1}^{3} X_{i,j}}{n}$$

(n equal to 3) as where j represents the trial number.

Then calculate the normalized absolute difference from the mean, for each trial's (j) value of each variable (i) as

$$\widetilde{X}_{i,j} = \left| \frac{X_{i,j} - \overline{X}_i}{\overline{X}_i} \right|$$

Finally the sum of normalized differences were determined for each trials as

$$\sigma_j = \sum_{i=1}^{5} \widetilde{X}_{i,j}$$

and select the best representative as one with the smallest σ_j value.

Table 3.1 A variables table to calculate the "best representative trial"

	Trial #			Mean	Normalized differences from the M		
	T 1 (X_{i1})	T 2 (X_{i2})	T 3 (X_{i3})		T 1	T 2	T 3
Variable 1	X_{11}	X_{12}	X_{13}	M_{X1}	$(X_{11} - M_{X1})/M_{X1}$	$(X_{12} - M_{X1})/M_{X1}$	$(X_{13} - M_{X1})/M_{X1}$
Variable 2	X_{21}	X_{22}	X_{23}	M_{X2}	$(X_{21} - M_{X2})/M_{X2}$	$(X_{22} - M_{X2})/M_{X2}$	$(X_{23} - M_{X2})/M_{X2}$
Variable 3	X_{31}	X_{32}	X_{33}	M_{X3}	$(X_{31} - M_{X3})/M_{X3}$	$(X_{32} - M_{X3})/M_{X3}$	$(X_{33} - M_{X3})/M_{X3}$
Variable 4	X_{41}	X_{42}	X_{43}	M_{X4}	$(X_{41} - M_{X4})/M_{X4}$	$(X_{42} - M_{X4})/M_{X4}$	$(X_{43} - M_{X4})/M_{X4}$
Variable 5	X_{51}	X_{52}	X_{53}	M_{X5}	$(X_{51} - M_{X5})/M_{X5}$	$(X_{52} - M_{X5})/M_{X5}$	$(X_{53} - M_{X5})/M_{X5}$
				Sum	σ_1	σ_2	σ_3

The following table demonstrates a specific example of calculating the best representative trial for the PVGRF, PAPGRF, APImp, VImp and Time to PF biomechanical variables.

Table 3.2 A specific example of calculating the "best representative trial"

Biomechanical Variables	Trial #			Mean	Normalized differences from the M		
	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3
PVGRF	6.1	6.3	5.9	6.1	.00	.03	.03
PAPGRF	1.0	1.1	1.2	1.1	.06	.01	.07
APImp	869.7	860.1	887.5	872.5	.00	.01	.02
VImp	70.5	75.3	74.9	73.6	.04	.02	.02
Time to PF	50.2	58.3	58.7	55.7	.10	.05	.05
				Sum	.04	.02	.04

3.5 Isokinetic Strength Measurements

Isokinetic strength data were recorded with the Biodex System Dynamometer (Biodex Medical Inc, Shirley, NY) to assess strength of the quadriceps and hamstrings muscle groups. Subjects were placed in a comfortable upright-seated position on the Biodex dynamometer chair and was secured using thigh, pelvis and torso straps in order to minimize extraneous body movements. The lateral femoral epicondyle was used as the bony landmark for matching the axis of rotation of the knee joint with the axis rotation of the dynamometer resistance adapter. Once the subject was placed in apposition that allowed for a comfortable and unrestricted motion of knee extension and flexion from a position of 90 degrees of flexion to terminal extension. Gravity correction was obtained by measuring the torque exerted on the on the dynamometer resistance adapter with the knee in a relaxed state at terminal extension. Values for the isokinetic variables measured were automatically adjusted for gravity for the Biodex Advantage Software Rev. 3.27.

Before the measurements of physical performance, the subjects warmed up on a bicycle ergometer for 5 minutes and then stretched their body parts. Before the test trials, subjects were instructed to perform their maximum efforts and subjects did three isokinetic concentric knee flexion and extension at 60^{o}/sec, and three eccentric knee flexion and extension repetitions at 60^{o}/sec on their both limbs and the dominant leg was defined as the preferred kicking leg. As strength measures, peak torque to body weight (PT/BW), average peak torque (AvgPT), hamstring to quadriceps ratio (H/Q ratio) and dynamic control ratio (Hecc/Qcon ratio) were chosen strength analysis.

3.6 Proprioception Testing Protocol

Testing for passive reproduction of passive positioning protocol (PRPP) was conducted using the Biodex isokinetic dynamometer. The subject’s leg was placed at an initial angle of 90 degrees of knee flexion for each trial. The subject’s leg was then passively moved to the test angle of 30 degrees of knee flexion by the examiner at an angular velocity of 5º/sec. Subjects concentrated on the sensation of the presented angle (30 degrees of knee flexion) for 3 seconds. The subject's leg was then returned passively to the starting position by the examiner.

Following a three second rest period the dynamometer passively moved the subject’s leg at one of the test velocity 30 degrees of knee flexion for 10 seconds. The subject attempted to stop the dynamometer movement at the presented joint angle (30 degrees of knee flexion) before the dynamometer initiated the flexion movement at the end of the range of motion. Once the subject felt the test leg was in the position of the presented angle, the subject depressed the “hold/resume” switch preventing the dynamometer from further movement. The Biodex System 3 software interface recorded the absolute angular difference between the presented and reproduced angles. The two values were averaged and the average value was used for statistical analysis.

3.7 Explosive Leg Power (Vertical Jump) Measurement

The vertical jump (VJ) tests were used to measure each subject's ability to raise his center of gravity. Jumping height was measured by Bosco Timing Mat. The subjects were given instruction on correct jumping. A 30 second rest was given to subjects between the trials. Subjects placed on a mat with weight evenly distributed than the digital timer was reset and the athlete jumped vertically as high as possible using his arms and legs. Subjects performed three jumps and the score of the flying time in the air was converted to vertical jump height (Jumping height = $4.9 \times (0.5 \times \text{Time})^2$). A record of all trials was recorded and the average jump used in calculations.

3.8 Nordic Hamstring Strength Training

This exercise consists of the athlete starting in a kneeling position, with their torso from the knees upwards held rigid and straight. A training partner applied pressure to the athlete's heels to ensure the feet stay in contact with the ground throughout the movement, isolating the muscles of the hamstrings. The athlete begins the exercise by slowly lowering their body forwards against the force of gravity towards the ground, using the hamstrings to control descent into the prone position. This eccentric contraction of the hamstrings was held for as long as possible by the subjects during lowering of the body to ensure that the hamstrings were contracting at as long a length as possible. Once the athlete could no longer control descent using the eccentric contraction of the hamstrings, they performed a push-up followed by concentric contraction of the hamstrings to raise themselves back up to the starting position (Table 3.3).

Table 3.3 Training protocol for Nordic hamstring training group (Mjolsnes et al., 2004)

Week	Sessions per week	Sets & repetitions	Load
1	1	2 x 5	Load is increased as subject can withstand the forward fall longer. When managing to withstand the whole ROM for 12 reps, increase load by adding speed to the starting phase of the motion. The partner can also increase loading further by pushing at the back of shoulders.
2	2	2 x 6	
3	3	3 x 6-8	
4	3	3 x 8-10	
5 - 10	3	3 sets, 12-10-8 reps	

Figure 3.3 Nordic Hamstring Training Exercise

3.9 Statistical Analyses

The statistical analysis were performed using the computer program SPSS. The data were analyzed with separate 2x3 (groups and time) mixed repeated-measures ANOVA design with kinetic, isokinetic, explosive leg power, and proprioceptive sense values as the dependent measures. Separate analysis of variances was chosen because all of the dependent variables are of autonomous interest.

Bonferroni-adjusted paired-samples t-tests were employed for post-hoc analyses. A corrected p-value, which was p = .05 divided by number of comparisons for each dependent variable, was thus employed.

CHAPTER IV

RESULTS

4.1 Participants

Statistically significant differences were not observed between the NHST and control groups' age, height, and BMI (Table 4.1).

Table 4.1 Physical characteristics of participants.

		N #	Age (yrs)	Height (m)	Weight (kg)			BMI (kg/m^2)
					Week-1	Week-5	Week-10	
Groups	**NHST**	14	20.4±1.1	1.7±.0	56.2±6.4	56.5±6.7	56.4±6.2	20.5±2.2
	Control	13	21.0±1.5	1.7±.1	56.8±6.1	56.8±5.9	57.8±5.8	20.4±1.7

The NHST group completed 23.7 ± 1.1 hamstring strength training sessions throughout the total 27 training sessions (88% participation rate), while the control group completed 23.2 ± 1.2 training sessions (86% participation rate).

4.2 Strength Parameters

4.2.1 Eccentric Strength Variables

4.2.1.1 Eccentric Dominant Hamstring PT/BW

Dominant eccentric hamstring peak torque to BW results showed no significant main effect for group (F (1,25) = .61, $p > .05$, Eta-squared = .02) or time by group interactions (F (2,50) = .76, $p > .05$, Eta-squared = .03). Meanwhile, significant (F (2,50) = 4.55, $p < .05$) main effect (Eta-squared = .15) for Time was obtained.

Based on this result, it is only possible to examine the main effect for the time variable, a within-subjects factor. So the average score of all three of the test periods could be seen if there is an overall increase in the strength of participants from test to tests. However, overall modifications' ignoring the grouping is not answering our main concerns. For more extensive description of test effects, simple effect analysis was performed for the time within levels of treatment by using syntax command in SPSS. Dominant eccentric hamstring strength increased significantly with the time due to the NHST program (Table 4.2).

Table 4.2 Simple Effect Analysis of Time for Eccentric Hamstring Strength in the Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	4.6	.01*
Control Group	2	.9	.41

Differences between week-1, week-5 and week-10 were analyzed by Bonferroni-adjusted paired-samples t-tests. A corrected p-value of .017 ($p = .05$ divided by 3 comparisons for each dependent variable) was employed. Results indicated that the mean dominant eccentric hamstring strength PT/BW in week-10 ($\underline{M} = 253.8$, $\underline{SD} = 28.4$) was significantly greater than the mean strength for week-1 test ($\underline{M} = 233.6$, $\underline{SD} = 27.5$), $\underline{t}\ (13) = -3.3$, $p = .00$. Difference between week-1 and week-5 ($\underline{M} = 249.7$, $\underline{SD} = 32.8$) was also significantly different ($\underline{t}\ (13) = -3.3$, $p = .01$) (Figure 4.1).

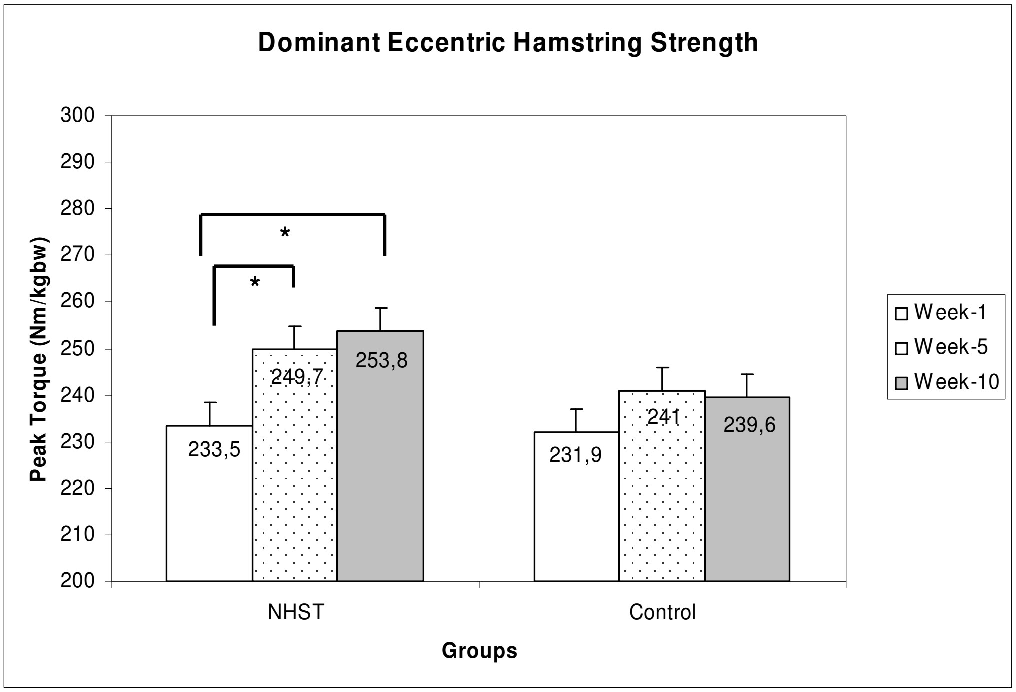


Figure 4.1 Dominant Eccentric Hamstring PT/BW Differences ($p < .017$).

4.2.1.2 Eccentric Non-Dominant Hamstring PT/BW

Non-dominant eccentric hamstring peak torque to BW results showed no significant main effect for time ($F(2,50) = .65$, $p > .05$, Eta-squared = .03) or group ($F(1,25) = .21$, $p > .05$, Eta-squared = .01) variable, nor were any time by group interactions ($F(2,50) = .16$, $p > .05$, Eta-squared = .01). The mean scores of eccentric hamstring strength measurement in non-dominant leg (Nm/kgbw) are presented in Figure 4.2.

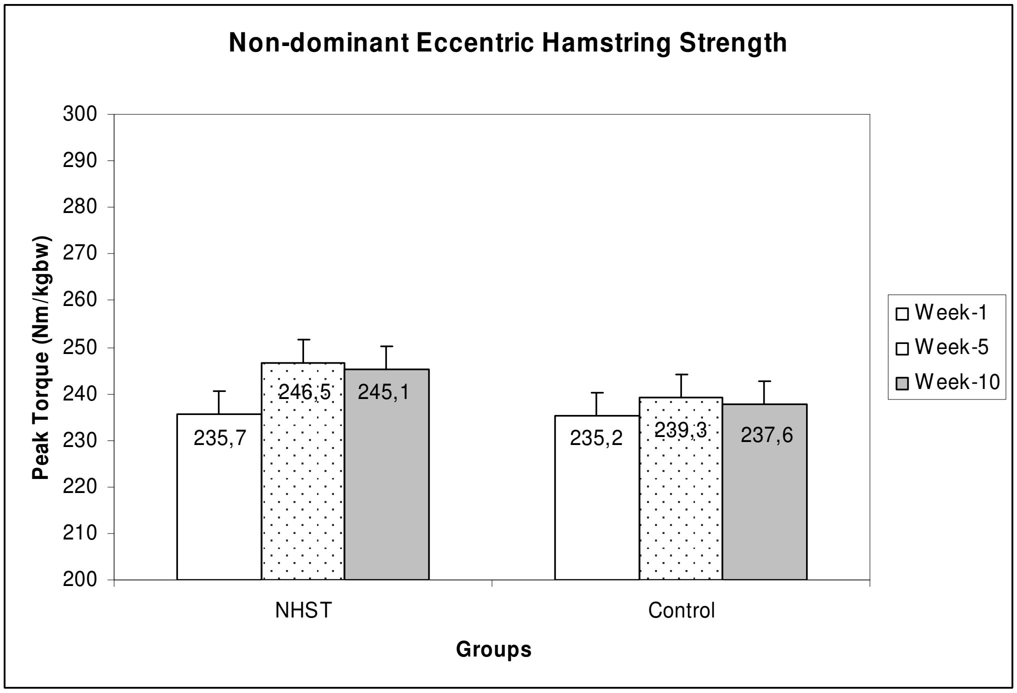


Figure 4.2 Non-dominant Eccentric Hamstring PT/BW Differences.

4.2.1.3 Eccentric Dominant Hamstring AvgPT

Dominant eccentric AvgPT results showed no significant main effect for group (F (1,25) = .53, p > .05, Eta-squared = .02) or time by group interactions (F (2,50) = .06, p > .05, Eta-squared = .00). Meanwhile, significant main effect for Time was obtained, F (2,50) = 5.64, p < .05, (Eta-squared = .18). Dominant eccentric hamstring AvgPT was not changed for both NHST and control group (Table 4.3).

Table 4.3 Simple Effect Analysis of Time for Eccentric Hamstring AvgPT in Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	2.9	.06
Control Group	2	2.7	.07

The mean scores of eccentric hamstring average peak torque (Nm) in dominant leg are presented in Figure 4.3.

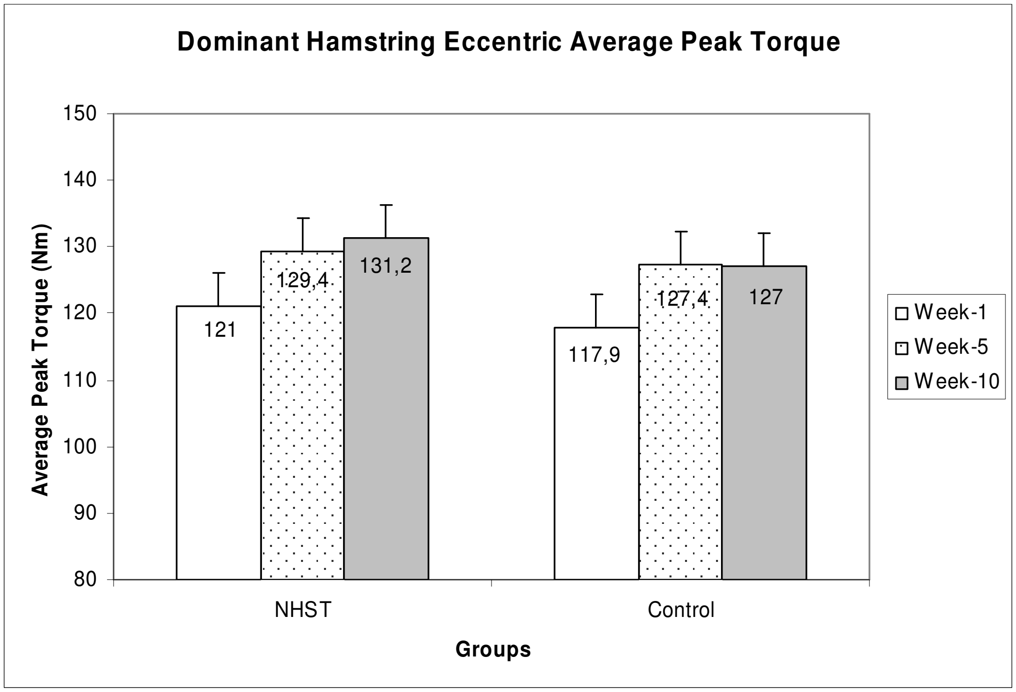


Figure 4.3 Dominant Eccentric Hamstring AvgPT Differences.

4.2.1.4 Eccentric Non-Dominant Hamstring AvgPT

Non-dominant eccentric hamstring AvgPT results showed no significant main effect for time (F (2,50) = .08, p > .05, Eta-squared = .00) or group (F (1,25) = .23, p > .05, Eta-squared = .01) variable, nor were any time by group interactions (F (2,50) = 1.94, p > .05, Eta-squared = .07). The results of eccentric hamstring average peak torque (Nm) in non-dominant leg are presented in Figure 4.4.

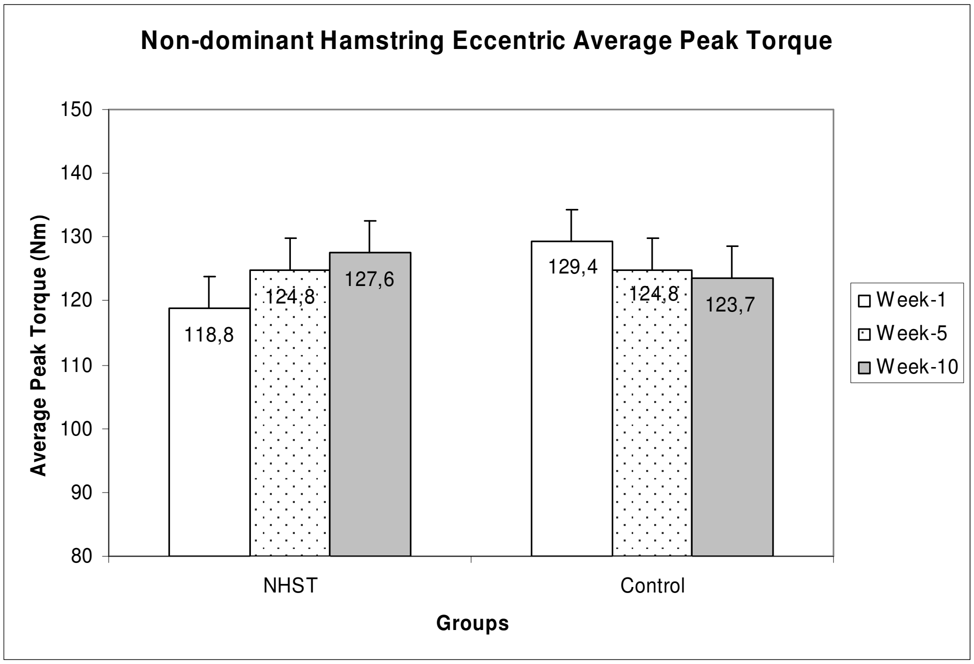


Figure 4.4 Non-dominant Eccentric Hamstring AvgPT Differences.

4.2.1.5 Eccentric Dominant Quadriceps PT/BW

Dominant eccentric quadriceps PT/BW results showed no significant main effect for group variable (F (1,25) = .78, p > .05, Eta-squared = .03) or time by group interaction (F (2,50) = .13, p > .05, Eta-squared = .00). Meanwhile, significant main effect for Time was obtained, F (2,50) = 6.59, p < .05, (Eta-squared = .21). Dominant eccentric quadriceps strength increased significantly with the time due to the NHST program (Table 4.4).

Table 4.4 Simple Effect Analysis of Time for Eccentric Quadriceps Strength in Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	3.9	.02*
Control Group	2	2.8	.07

Pair-wised comparison of test results did not showed any significant differences. The non-significant comparison results for week-1 to week-5, week-1 to week-10, and week-5 to week-10 tests were t (13) = -1.80, p = .09, t (13) = -2.35, p = .03 and t (13) = -.64, p = .53, respectively. The mean scores of eccentric quadriceps peak torque (Nm/kgbw) in dominant leg are presented in Figure 4.5.

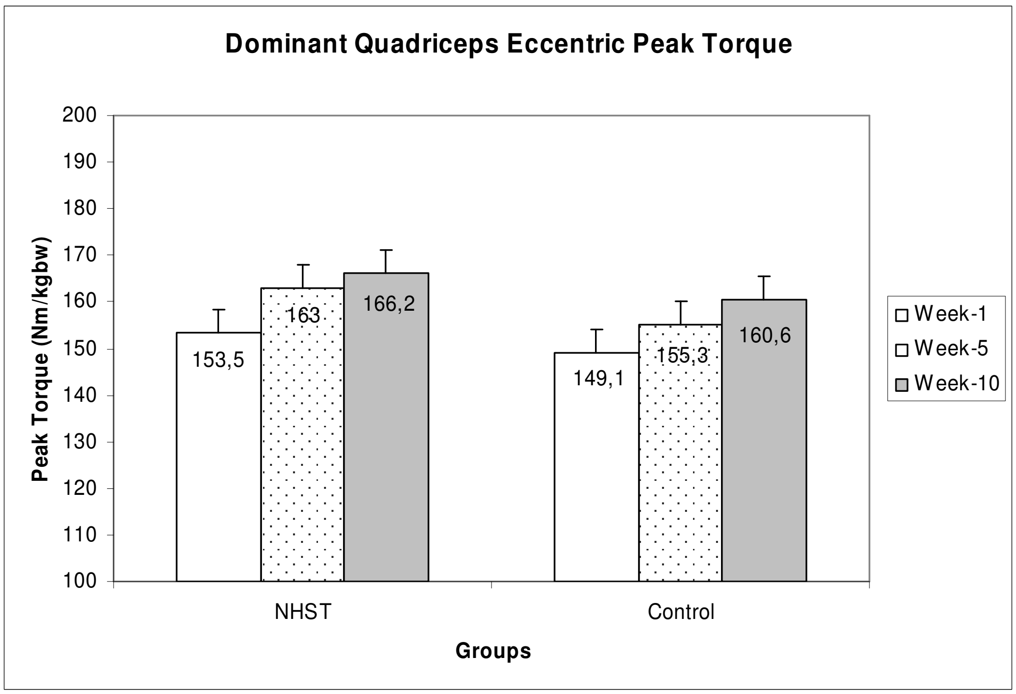


Figure 4.5 Dominant Eccentric Quadriceps PT/BW Differences.

4.2.1.6 Eccentric Non-Dominant Quadriceps PT/BW

Non-dominant eccentric quadriceps Peak torque to BW results showed no significant main effect for time (F (2,50) = .92, p > .05, Eta-squared = .03) or group (F (1,25) = .57, p > .05, Eta-squared = .02) variable, nor were any time by group interactions (F (2,50) = 3.84, p > .05, Eta-squared = .13). The mean scores of eccentric quadriceps peak torque (Nm/kgbw) in non-dominant leg are presented in Figure 4.6.

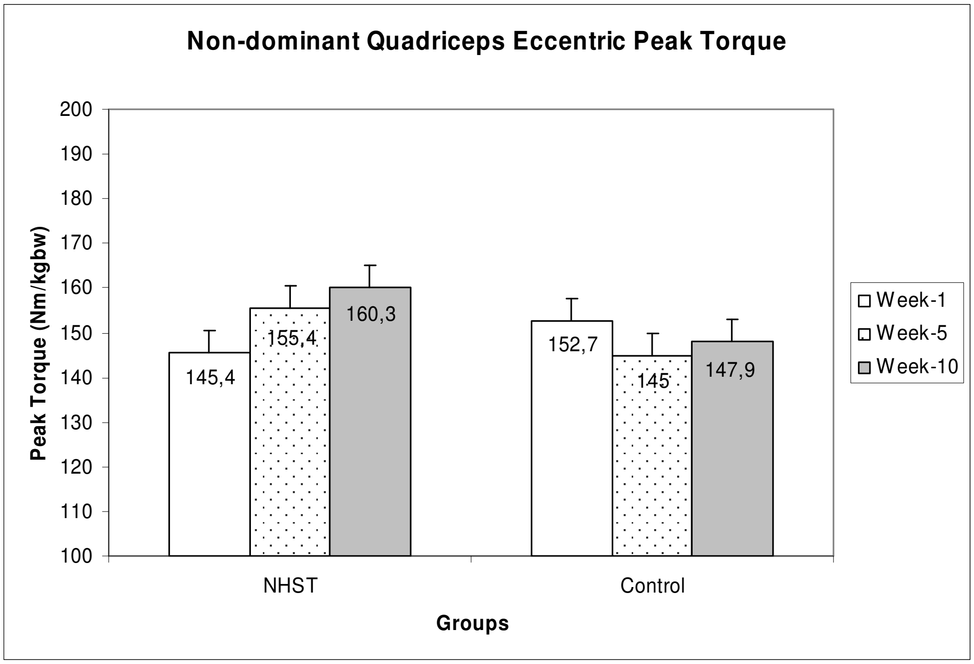


Figure 4.6 Non-dominant Eccentric Quadriceps PT/BW Differences.

4.2.1.7 Eccentric Dominant Quadriceps AvgPT

Dominant eccentric quadriceps AvgPT results showed no significant main effect for group variable ($F (1,25) = .92$, $p > .05$, Eta-squared = .04) or time by group interaction ($F (2,50) = .39$, $p > .05$, Eta-squared = .01). Meanwhile, significant main effect for Time was obtained, $F (2,50) = 12.46$, $p < .05$, and this was a strong effect (Eta-squared = .33).

Dominant eccentric quadriceps AvgPT strength increased with the time due to the NHST program (Table 4.5).

Table 4.5 Simple Effect Analysis of Time for Eccentric Quadriceps AvgPT Strength in the Dominant Leg.

Groups	DF	F	Sig of F
NHST Gr.	2	7.9	.00*
Control Gr.	2	5.1	.01*

The NHST group's results indicated that the mean dominant eccentric quadriceps AvgPT strength in week-10 (M = 87.6, SD = 14.0) was significantly greater than the mean strength for week-1 (M = 78.3, SD = 10.4), t (13) = -3.82, p = .00, and control group's results also demonstrated that the mean dominant eccentric quadriceps AvgPT strength in week-10 (M = 84.0, SD = 10.4) was significantly greater than the mean strength for week-1 (M = 75.9, SD = 12.2), t (13) = -3.38, p = .00. The mean scores of eccentric quadriceps average peak torque (Nm) in dominant leg are presented in Figure 4.7.

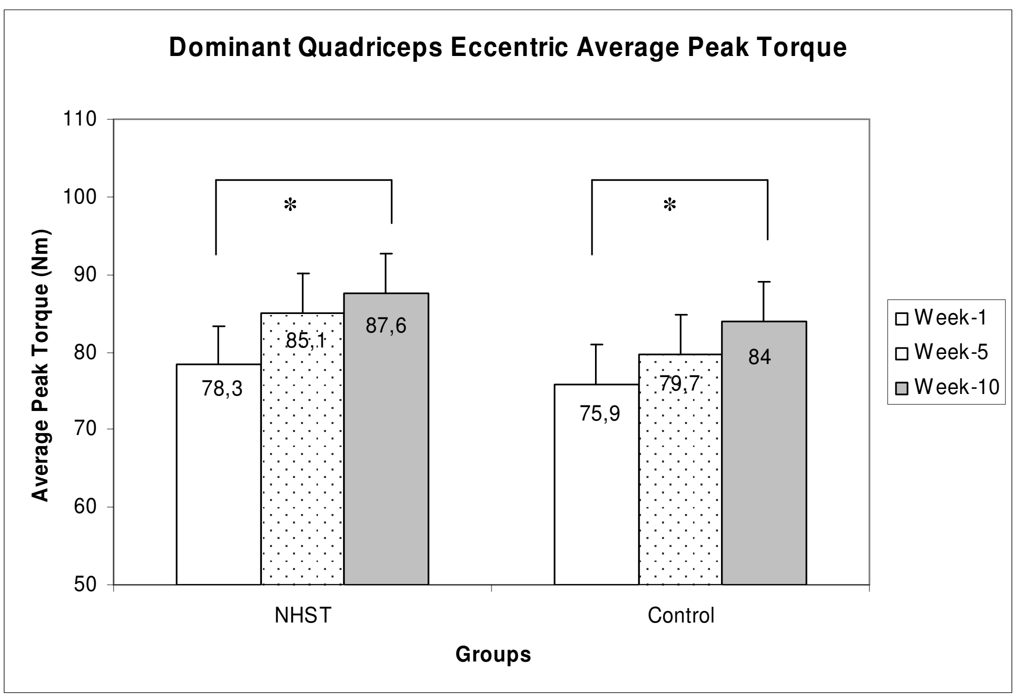


Figure 4.7 Dominant Eccentric Quadriceps AvgPT Differences ($p < .017$).

4.2.1.8 Eccentric Quadriceps Non-Dominant AvgPT

Non-dominant eccentric quadriceps AvgPT results showed no significant main effect for time ($F(2,50) = 2.68$, $p > .05$, Eta-squared = .09) or group ($F(1,25) = .23$, $p > .05$, Eta-squared = .01) variable, nor were any time by group interactions ($F(2,50) = 3.7$, $p > .05$, Eta-squared = .13). The results of eccentric quadriceps average peak torque (Nm) in non-dominant leg are presented in Figure 4.8.

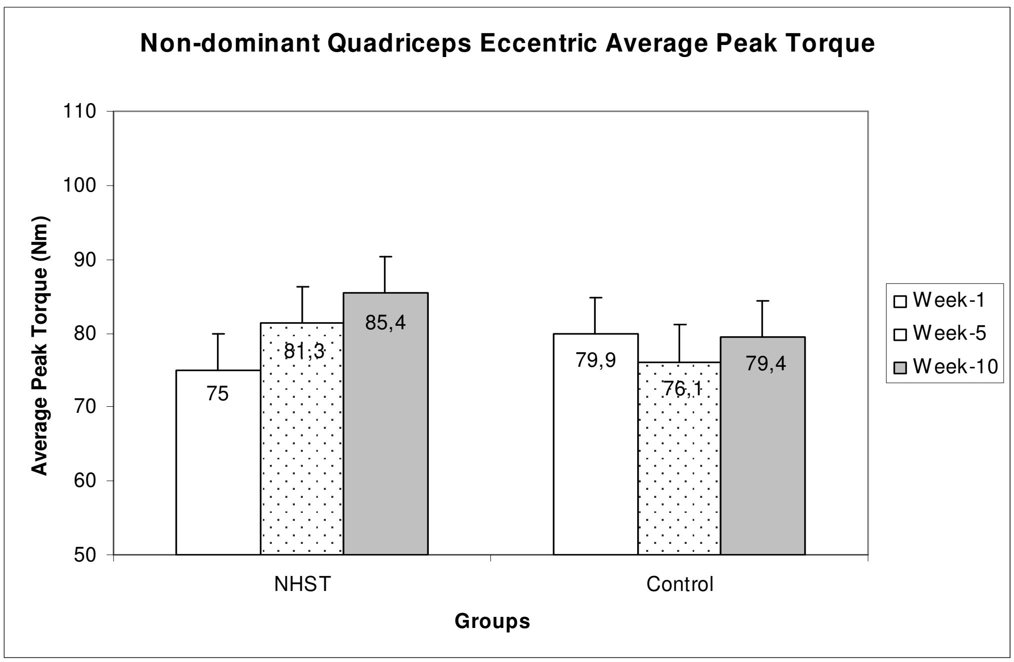


Figure 4.8 Non-dominant Eccentric Quadriceps AvgPT Differences.

4.2.2 Concentric Strength Variables

4.2.2.1 Concentric Hamstring Dominant PT/BW

Dominant concentric hamstring PT/BW results showed no significant main effect for group variable ($F (1,25) = 1.42$, $p > .05$, Eta-squared = .05) or time by group interaction ($F (2,50) = 3.53$, $p > .05$, Eta-squared = .12). Meanwhile, significant main effect for Time was obtained, $F (2,50) = 8.54$, $p < .05$, and this was a strong effect (Eta-squared = .25).

Dominant concentric hamstring strength increased significantly with the time due to the NHST program (Table 4.6).

Table 4.6 Simple Effect Analysis of Time for Concentric Hamstring Strength in the Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	11.8	.00*
Control Group	2	.7	.50

The results indicated that the mean dominant concentric hamstring strength PT/BW in week-10 (M = 109.7, SD = 10.4) was significantly greater than the mean strength for week-1 (M = 91.5, SD = 18.6), $t (13) = -5.42$, $p = .00$. The results of concentric hamstrings peak torque (Nm/kgbw) in dominant leg are presented in Figure 4.9.

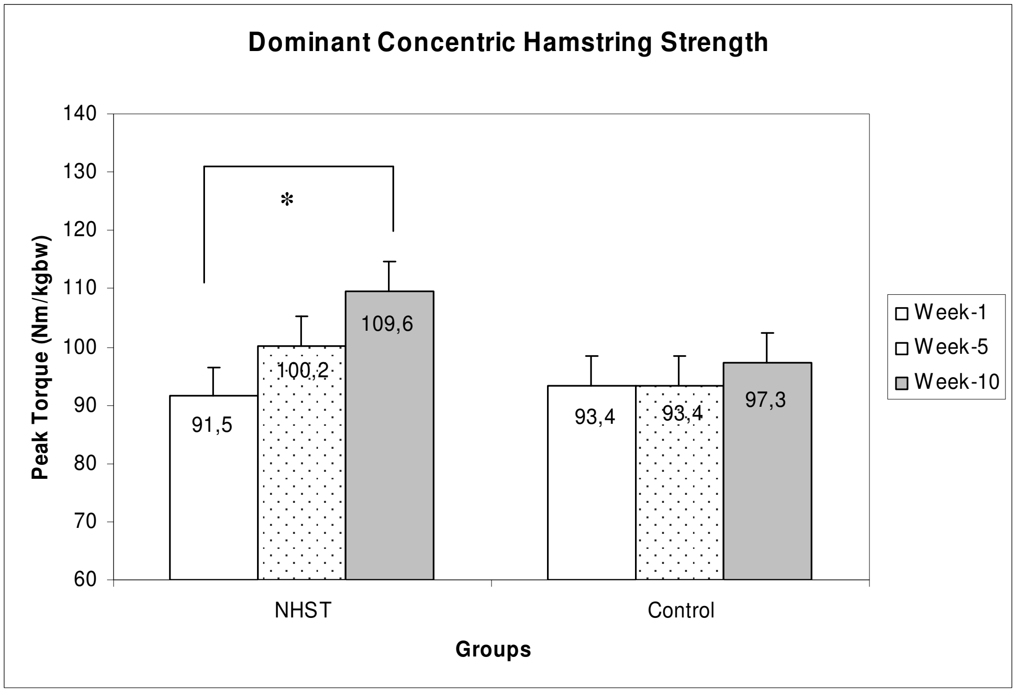


Figure 4.9 Dominant Concentric Hamstring PT/BW Differences (p < .017).

4.2.2.2 Concentric Hamstring Non-Dominant PT/BW

Non-dominant PT/BW results showed no significant main effect for group variable (F (1,25) = 1.36, p > .05, Eta-squared = .05) or time by group interaction (F (2,50) = .01, p > .05, Eta-squared = .01). Meanwhile, significant main effect for Time was obtained, F (2,50) = 26.94, p < .05, and this was a strong effect (Eta-squared = .52). Non-dominant concentric hamstring strength increased significantly by time for both NHST and control group (Table 4.7).

Table 4.7 Simple Effect Analysis of Time for Concentric Hamstring Strength in the Non-dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	14.5	.00*
Control Group	2	12.5	.00*

NHST group's results indicated that the mean non-dominant concentric hamstring PT/BW strength in week-10 (M = 101.3, SD = 9.8) was significantly greater than the mean strength for week-1 (M = 84.1, SD = 17.1), t (13) = -4.96, p = .00, and week-5 (M = 96.5, SD = 15.8) was significantly greater than the mean strength for week-1 (M = 84.1, SD = 17.1), t (13) = -2.98, p = .01, and control group's results also demonstrated that the mean strength in week-10 (M = 94.9, SD = 16.3) was significantly greater than the mean strength for week-1 (M = 78.2, SD = 16.8), t (13) = -5.26, p = .00, and week-5 (M = 89.9, SD = 16.9) was significantly greater than the mean strength for week-1 (M = 78.2, SD = 16.8), t (13) = -3.57, p = .00. The results of concentric hamstrings peak torque (Nm/kgbw) in non-dominant leg are presented in Figure 4.10.

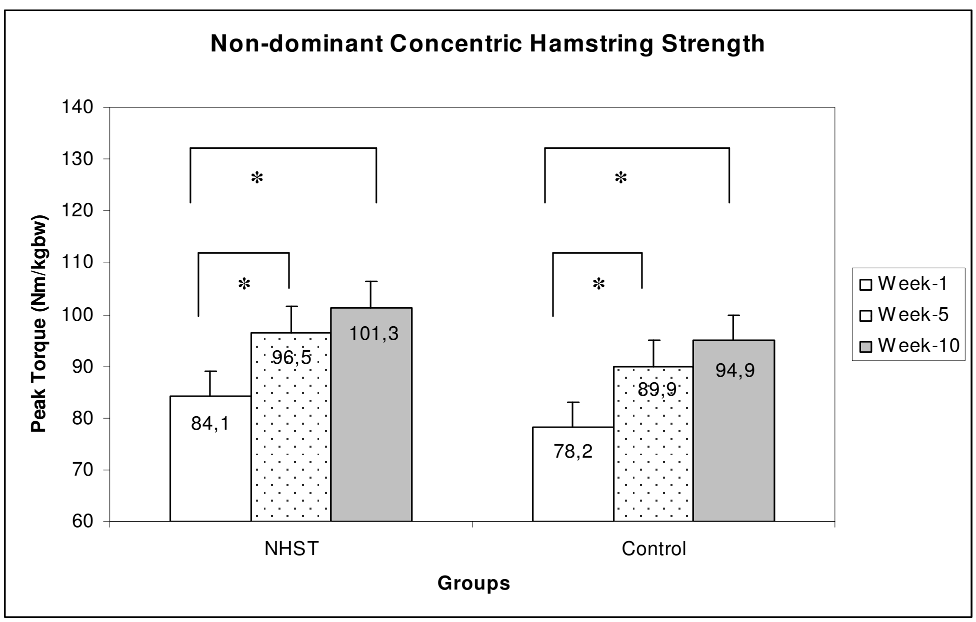


Figure 4.10 Non-dominant Concentric Hamstring PT/BW Differences ($p < .017$).

4.2.2.3 Concentric Hamstring Dominant AvgPT

Dominant concentric hamstring AvgPT results showed no significant main effect for group variable ($F(1,25) = 1.84$, $p > .05$, Eta-squared = .07) or time by group interaction ($F(2,50) = 1.53$, $p > .05$, Eta-squared = .06). Meanwhile, significant main effect for Time was obtained, $F(2,50) = 6.47$, $p < .05$, and this was a strong effect (Eta-squared = .21).

Dominant concentric hamstring AvgPT strength increased significantly with the time due to the NHST program (Table 4.8)

Table 4.8 Simple Effect Analysis of Time for Concentric Hamstring AvgPT Strength in the Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	6.3	.00*
Control Group	2	1.9	.16

Results indicated that the mean dominant concentric hamstring AvgPT strength in week-10 ($\underline{M} = 57.6$, $\underline{SD} = 7.7$) was significantly greater than the mean strength for week-1 ($\underline{M} = 50.7$, $\underline{SD} = 11.8$), $\underline{t}(13) = -4.05$, $p = .00$. The results of concentric hamstrings average peak torque (Nm) in dominant leg are presented in Figure 4.11.

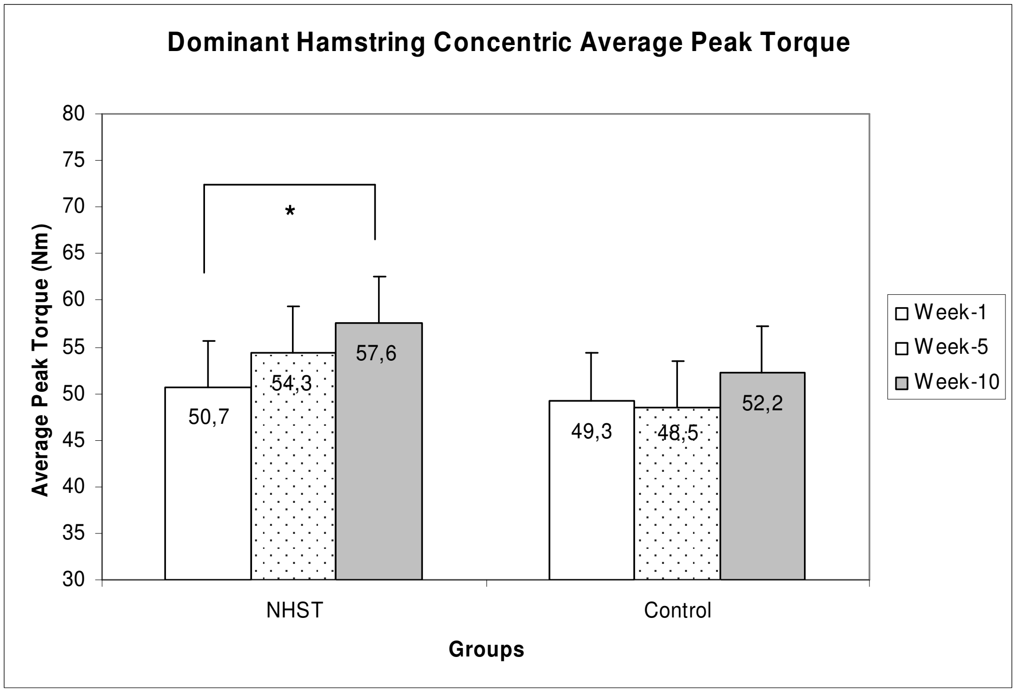


Figure 4.11 Dominant Concentric Hamstring AvgPT Differences ($p < .017$).

4.2.2.4 Concentric Hamstring Non-Dominant AvgPT

Non-dominant concentric hamstring AvgPT results showed no significant main effect for group ($F (1,25) = 2.25$, $p > .05$, Eta-squared = .08) or time by group interactions ($F (2,50) = .29$, $p > .05$, Eta-squared = .01). Meanwhile, significant main effect for Time was obtained, $F (2,50) = 32.34$, $p < .05$, and this was a strong effect (Eta-squared = .56). Non-dominant concentric hamstring AvgPT strength increased significantly for both NHST and control group (Table 4.9).

Table 4.9 Simple Effect Analysis of Time for Concentric Hamstring AvgPT Strength in the Non-dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	13.9	.00*
Control Group	2	18.5	.00*

NHST group's results indicated that the mean non-dominant concentric hamstring AvgPT strength in week-10 (M = 54.9, SD = 8.5) was significantly greater than the mean strength for week-1 (M = 46.2, SD = 8.8), t (13) = -5.89, p = .00, and week-5 (M = 52.2, SD = 10.7) was significantly greater than the mean strength for week-1 (M = 46.2, SD = 8.8), t (13) = -3.16, p = .01, and control group's results also demonstrated that the mean strength in week-10 (M = 51.2, SD = 7.9) was significantly greater than the mean strength for week-1 (M = 40.7, SD = 8.5), t (12) = -6.07, p = .00, and week-5 (M = 47.4, SD = 8.3) was significantly greater than the mean strength for week-1 (M = 40.7, SD = 8.5), t (12) = -2.91, p = .01, and the mean strength week-5 (M = 47.4, SD = 8.3) was significantly greater than the mean strength for week-10 (M = 51.2, SD = 7.9), t (12) = -3.00, p = .01. The mean scores of concentric hamstrings average peak torque (Nm) in non-dominant leg are presented in Figure 4.12.

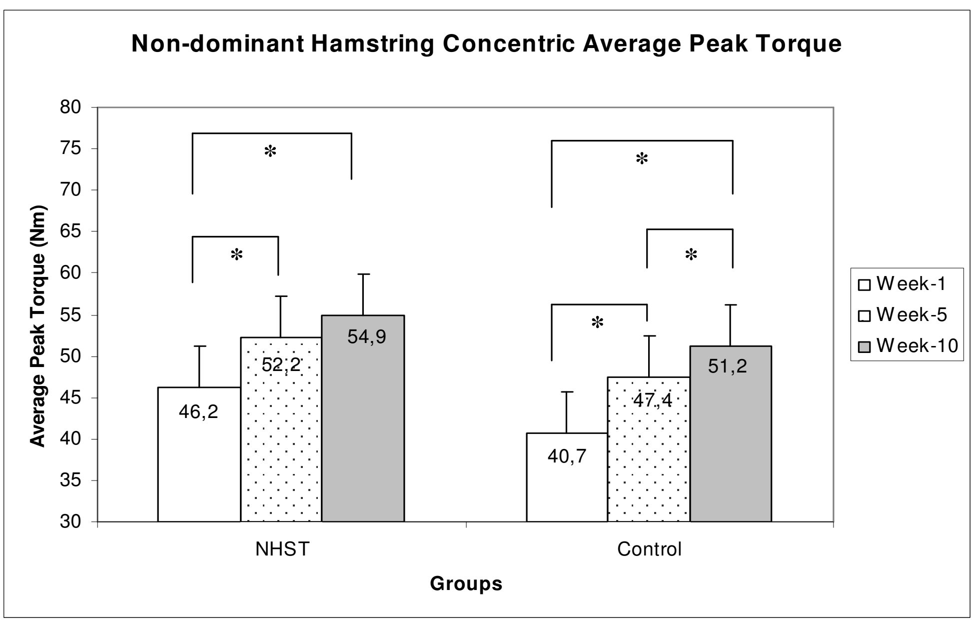


Figure 4.12 Non-dominant Concentric Hamstring AvgPT Differences ($p < .017$).

4.2.2.5 Concentric Quadriceps Dominant PT/BW

Dominant concentric quadriceps PT/BW results showed no significant main effect for group variable (F (1,25) = .02, p > .05, Eta-squared = .00) or time by group interaction (F (2,50) = .19, p > .05, Eta-squared = .01). Meanwhile, significant main effect for Time was obtained, F (2,50) = 4.35, p < .05, and this was a strong effect (Eta-squared = .15). Dominant concentric quadriceps PT/BW strength did not changed significantly for both NHST and control group (Table 4.10).

Table 4.10 Simple Effect Analysis of Time for Concentric Quadriceps PT/BW Strength in Dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	3.1	.06
Control Group	2	1.5	.23

The mean scores of concentric quadriceps peak torque (Nm/kgbw) in dominant leg are presented in Figure 4.13.

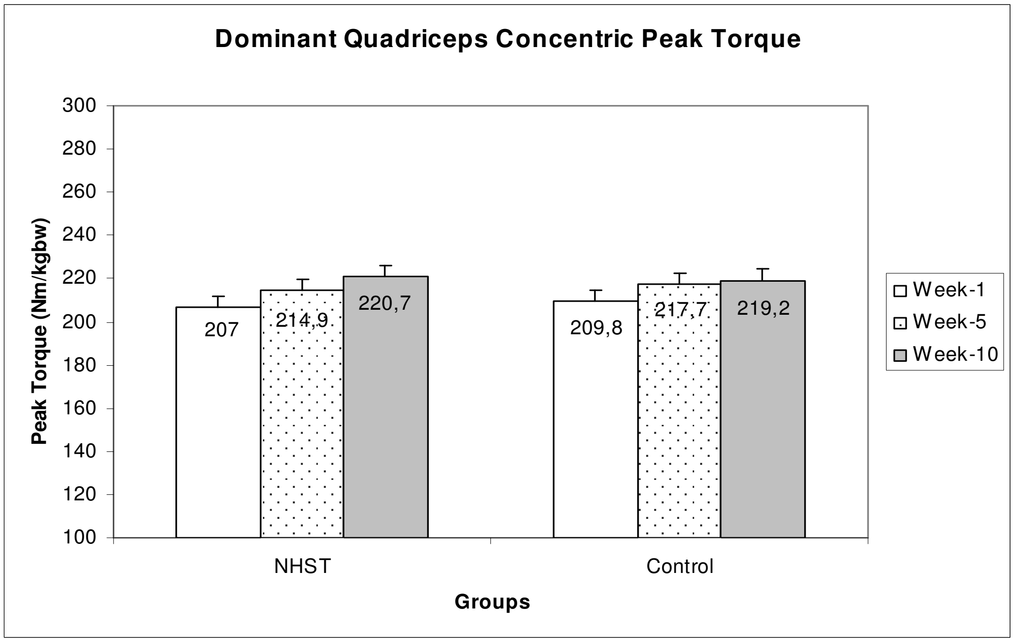


Figure 4.13 Dominant Concentric Quadriceps PT/BW Differences.

4.2.2.6 Concentric Quadriceps Non-Dominant PT/BW

Non-dominant concentric quadriceps PT/BW results showed no significant main effect for group variable ($F(1,25) = .05$, $p > .05$, Eta-squared = .00) or time by group interaction ($F(2,50) = .62$, $p > .05$, Eta-squared = .02). Meanwhile, significant main effect for Time was obtained, $F(2,50) = 7.42$, $p < .05$, and this was a strong effect (Eta-squared = .23). Non-dominant concentric quadriceps PT/BW strength increased significantly for both NHST and control group (Table 4.11).

Table 4.11 Simple Effect Analysis of Time for Concentric Quadriceps PT/BW Strength in Non-dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	3.5	.03*
Control Group	2	4.5	.01*

NHST group's results indicated that the mean non-dominant concentric quadriceps PT/BW strength in week-10 (M = 220.6, SD = 25.3) was significantly greater than the mean strength for week-1 test (M = 205.9, SD = 28.3), t (13) = -2.75, p = .01, and control group's results also demonstrated that the mean strength in week-10 (M = 224.8, SD = 33.9) was significantly greater than the mean strength for week-5 test (M = 208.8, SD = 35.2), t (12) = -3.49, p = .00. The mean scores of concentric quadriceps peak torque (Nm/kgbw) in non-dominant leg are presented in Figure 4.14.

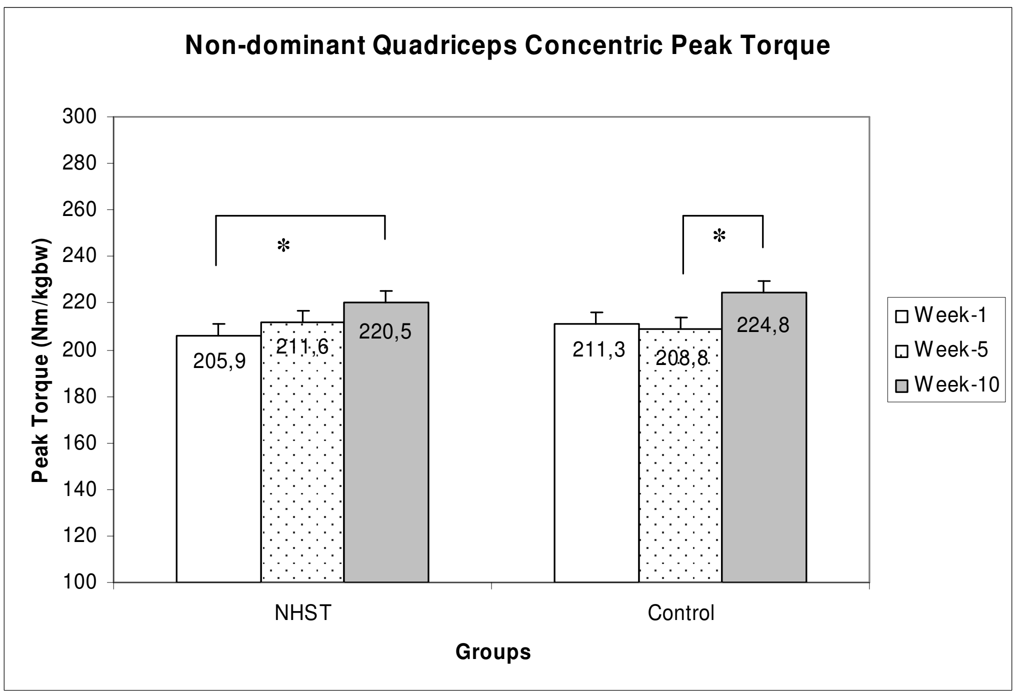


Figure 4.14 Non-dominant Concentric Quadriceps PT/BW Differences ($p < .017$).

4.2.2.7 Concentric Quadriceps Dominant AvgPT

Dominant concentric quadriceps AvgPT results showed no significant main effect for time ($F(2,50) = 1.56$, $p > .05$, Eta-squared = .06) or group ($F(1,25) =$

.00, p > .05, Eta-squared = .00) variable, nor were any time by group interactions (F (2,50) = .01, p > .05, Eta-squared = .00). The mean scores of concentric quadriceps average peak torque (Nm) in dominant leg are presented in Figure 4.15.

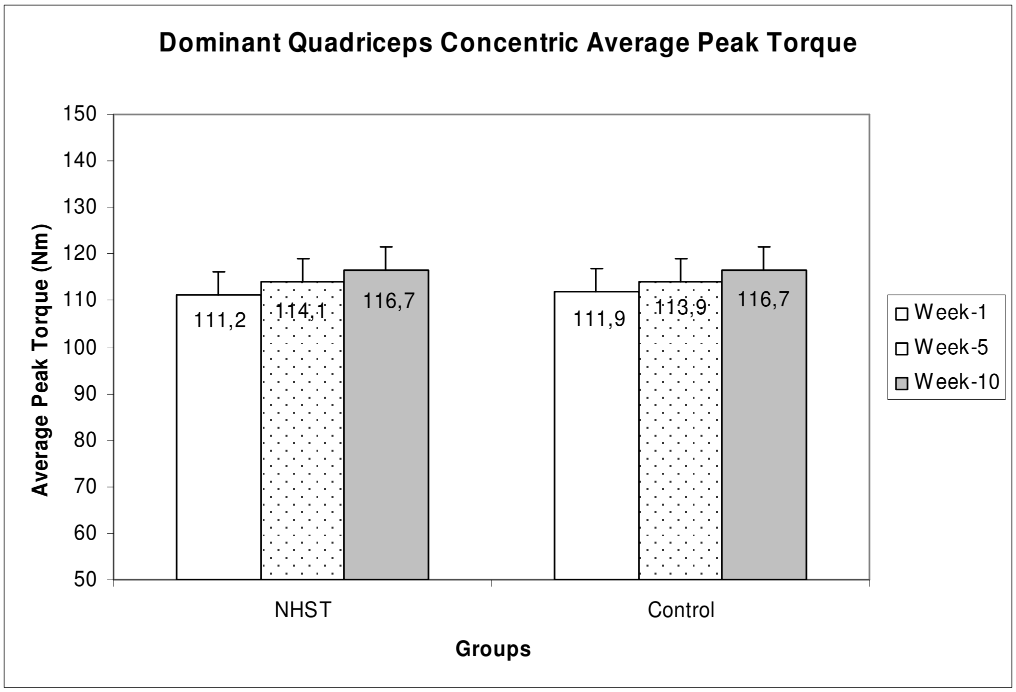


Figure 4.15 Dominant Concentric Quadriceps AvgPT Differences.

4.2.2.8 Concentric Quadriceps Non-Dominant AvgPT

Non-dominant concentric quadriceps AvgPT results showed no significant main effect for group (F (1,25) = .04, p > .05, Eta-squared = .00) or time by group interaction (F (2,50) = 1.98, p > .05, Eta-squared = .07). Meanwhile, significant main effect for Time was obtained, F (2,50) = 8.70, p < .05, and this was a strong effect (Eta-squared = .26). Don-dominant concentric quadriceps AvgPT strength increased significantly with the time for control group (Table 4.12).

Table 4.12 Simple Effect Analysis of Time for Concentric Quadriceps AvgPT Strength in the Non-dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	2.6	.08
Control Group	2	7.9	.00*

The control group's results indicated that the mean non-dominant concentric quadriceps AvgPT strength in week-10 (M = 123.1, SD = 16.4) was significantly greater than the mean strength for week-1 test (M = 111.9, SD = 15.5), t (12) = -3.22, p = .01, and the mean strength in week-10 (M = 123.1, SD = 16.4) was significantly greater than the mean strength for week-5 test (M = 109.6, SD = 17.7), t (12) = -3.78, p = .00. The mean scores of concentric quadriceps average peak torque (Nm) in non-dominant leg are presented in Figure 4.16.

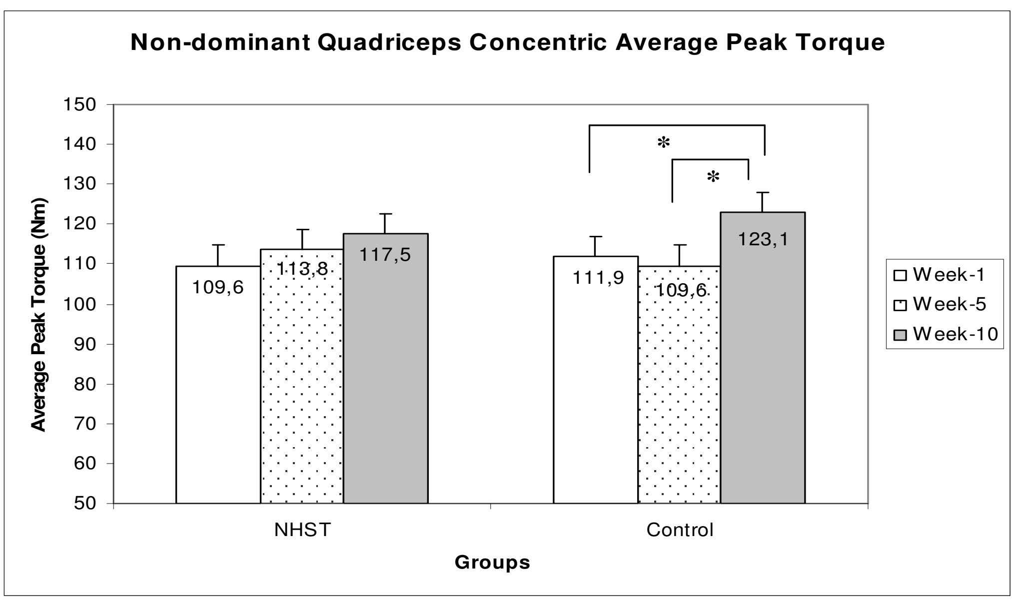


Figure 4.16 Non-dominant Concentric Quadriceps AvgPT Differences ($p < .017$).

4.2.3 Dynamic Control and Conventional Strength Ratio Variables

4.2.3.1 Dominant Leg Dynamic Control Strength Ratio

Dominant leg dynamic control ratio results showed no significant main effect for time ($F(2,50) = .12$, $p > .05$, Eta-squared = .00) or group ($F(1,25) = .96$, $p > .05$, Eta-squared = .04) variable, nor were any time by group interactions ($F(2,50) = .07$, $p > .05$, Eta-squared = .00). The mean scores of dominant dynamic control ratio in dominant leg are presented in Figure 4.17.

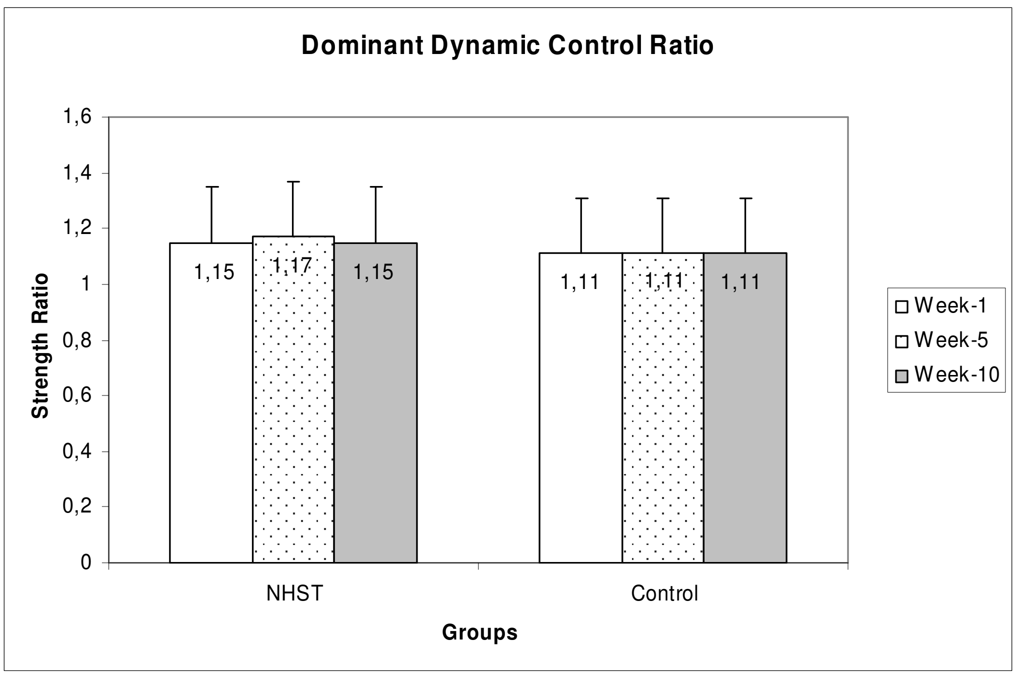


Figure 4.17 Dominant Dynamic Control Ratio Differences.

4.2.3.2 Non-Dominant Leg Dynamic Control Strength Ratio

Non-dominant leg dynamic control ratio results showed no significant main effect for time ($F(2,50) = 2.17$, $p > .05$, Eta-squared = .08) or group ($F(1,25) = .14$, $p > .05$, Eta-squared = .00) variable, nor were any time by group interactions (F (2,50) = .25, p > .05, Eta-squared = .01). The mean scores of non-dominant dynamic control ratio in dominant leg are presented in Figure 4.18.

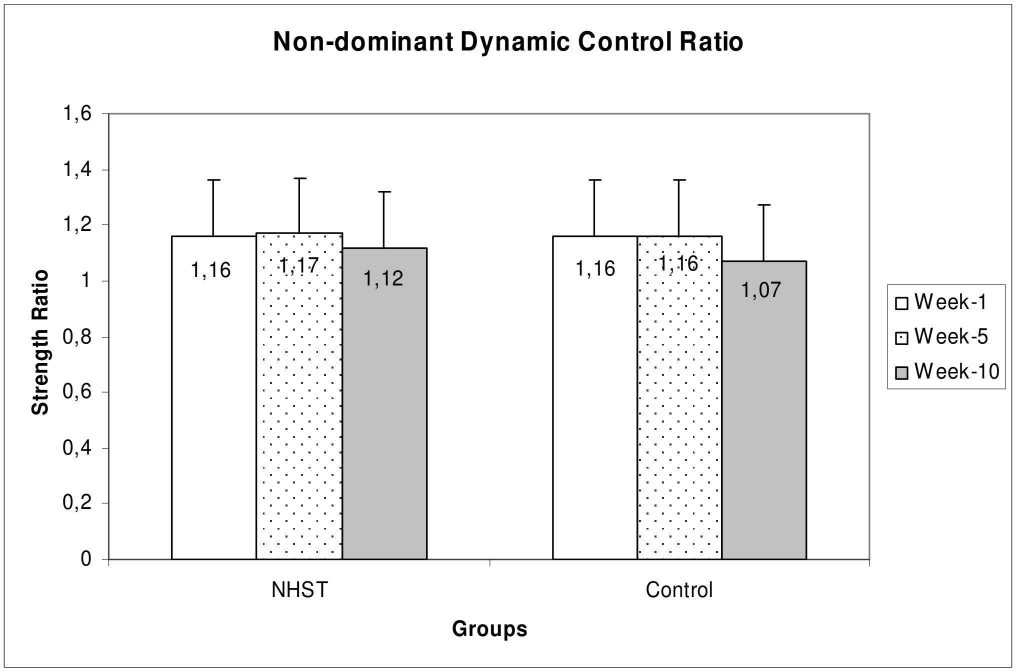


Figure 4.18 Non-dominant Dynamic Control Ratio Differences.

4.2.3.3 Dominant Eccentric Conventional Strength Ratio

Dominant leg eccentric strength ratio results showed no significant main effect for time (F (2,50) = .74, p > .05, Eta-squared = .03) or group (F (1,25) = .17, p > .05, Eta-squared = .00) variable, nor were any time by group interactions (F (2,50) = .03, p > .05, Eta-squared = .00). The mean score of dominant eccentric agonist/antagonist strength ratio in dominant leg are presented in Figure 4.19.

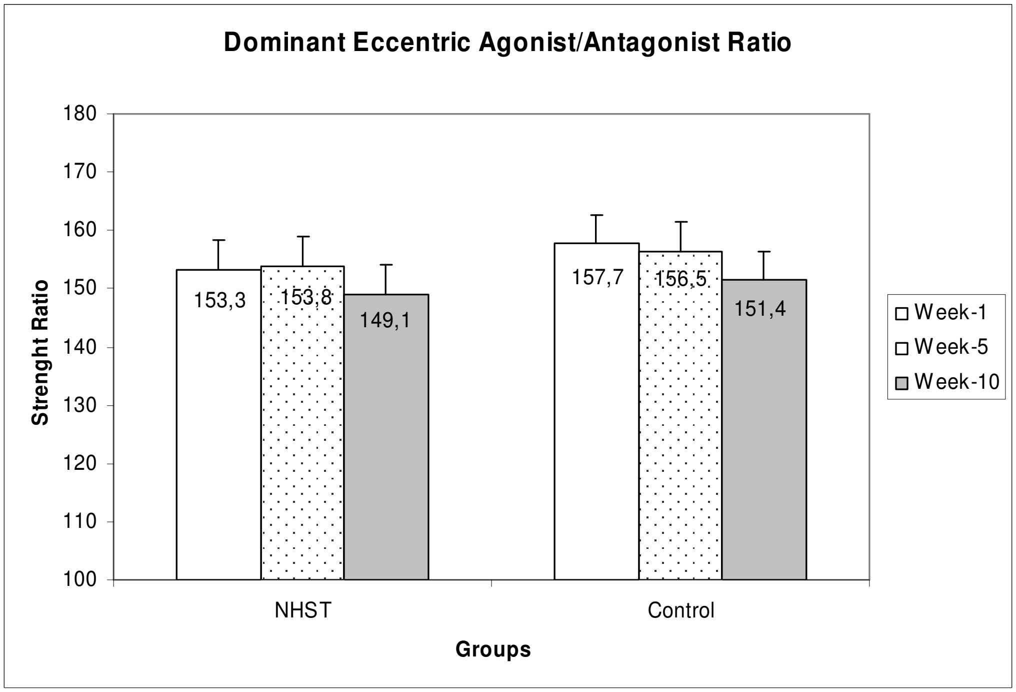


Figure 4.19 Dominant Eccentric Conventional Strength Ratio Differences.

4.2.3.4 Non-Dominant Eccentric Conventional Strength Ratio

Non-dominant leg eccentric strength ratio results showed no significant main effect for time (F (2,50) = 1.23, p > .05, Eta-squared = .05) or group (F (1,25) = .69, p > .05, Eta-squared = .03) variable, nor were any time by group interactions (F (2,50) = 1.15, p > .05, Eta-squared = .04). The mean scores of dominant eccentric agonist/antagonist strength ratio in non-dominant leg are presented in Figure 4.20.

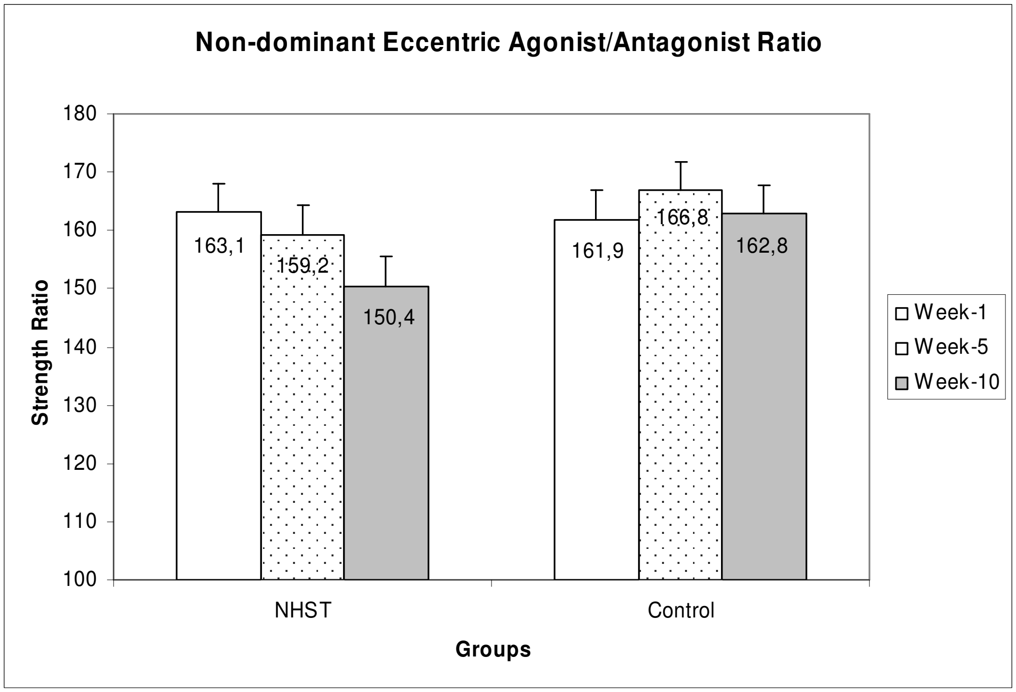


Figure 4.20 Non-dominant Eccentric Conventional Strength Ratio Differences.

4.2.3.5 Dominant Concentric Conventional Strength Ratio

Dominant leg concentric conventional strength ratio results showed no significant main effect for time (F (2,50) = 1.78, p > .05, Eta-squared = .07) or group (F (1,25) = 3.09, p > .05, Eta-squared = .11) variable, nor were any time by group interactions (F (2,50) = 1.24, p > .05, Eta-squared = .05). The mean scores of dominant concentric agonist/antagonist strength ratio in dominant leg are presented in Figure 4.21.

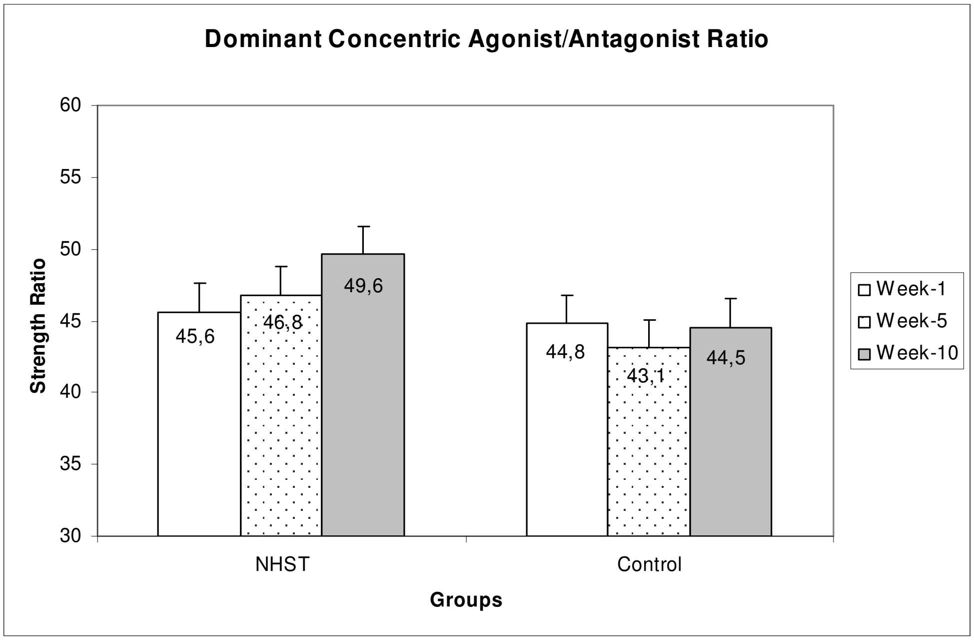


Figure 4.21 Dominant Concentric Conventional Strength Ratio Differences.

4.2.3.6 Non-Dominant Concentric Conventional Strength Ratio

Non-dominant conventional concentric strength ratio results showed no significant main effect for group variable (F (1,25) = 4.17, p > .05, Eta-squared = .14) or time by group interaction (F (2,50) = .83, p > .05, Eta-squared = .03). Meanwhile, significant main effect for Time was obtained, F (2,50) = 14.70, p < .05, and this was a strong effect (Eta-squared = .37). Non-dominant concentric conventional strength ratio increased significantly with the time for both NHST and control group (Table 4.13).

Table 4.13 Simple Effect Analysis of Time for Concentric Conventional Strength Ratio in the Non-dominant Leg.

Groups	DF	F	Sig of F
NHST Group	2	4.9	.01*
Control Group	2	10.4	.00*

NHST group's results indicated that the mean non-dominant concentric conventional strength ratio in week-10 (M = 46.3, SD = 5.9) was significantly greater than the mean strength for week-1 test (M = 42.3, SD = 5.9), t (13) = -2.98, p = .01, in week-5 (M = 45.9, SD = 7.6) was significantly greater than the mean strength for week-1 test (M = 42.3, SD = 5.9), t (13) = -3.18, p = .01, and control group's results also demonstrated that the mean strength ratio in week-10 (M = 42.3, SD = 4.4) was significantly greater than the mean strength for week-1 test (M = 37.0, SD = 6.5), t (12) = -3.02, p = .01, and in week-5 (M = 43.2, SD = 4.6) was significantly greater than the mean strength for week-1 test (M = 37.0, SD = 6.5), t (12) = -3.31, p = .00. The mean scores of dominant concentric agonist/antagonist strength ratio in non-dominant leg are presented in Figure 4.22.

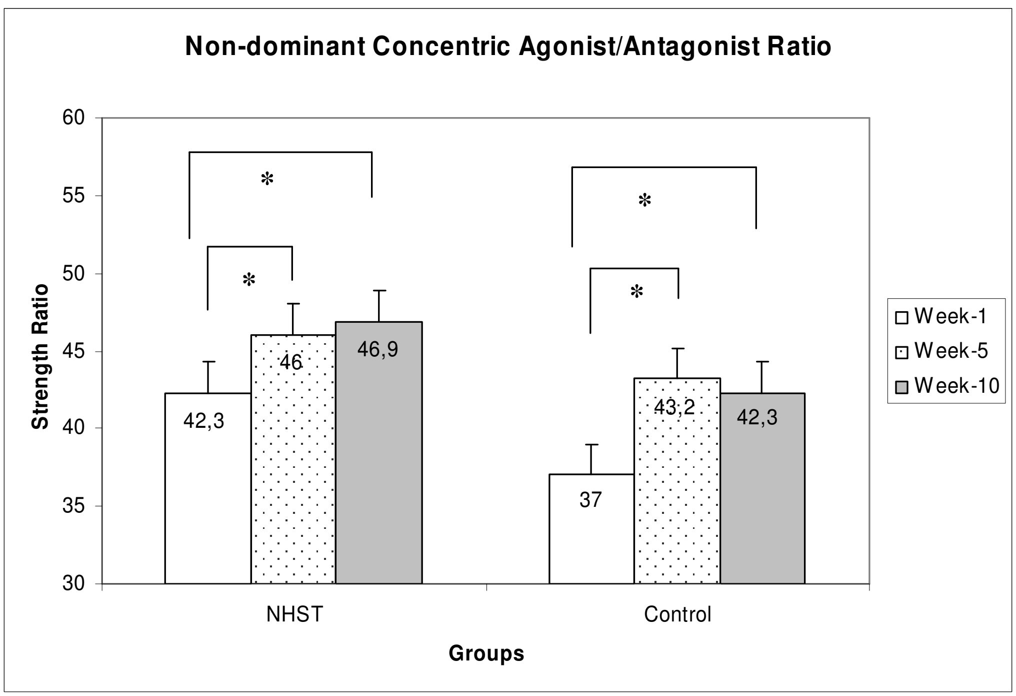


Figure 4.22 Non-dominant Concentric Conventional Strength Ratio Differences ($p < .017$).

4.3 Ground Reaction Force Variables

4.3.1 Peak Vertical Ground Reaction Force

Peak vertical ground reaction force results showed no significant main effect for the group variable (F (1,25) = .46, p > .05, Eta-squared = .02) or time by group interaction (F (2,50) = 2.61, p < .05, Eta-squared = .09). Meanwhile, significant main effect for Time was obtained, F (2,50) = 3.22, p < .05, and this was a moderate effect (Eta-squared = .11).

Peak vertical ground reaction forces decreased significantly with the time due to the NHST program (Table 4.14).

Table 4.14 Simple Effect Analysis of Time for PVGRF.

Groups	DF	F	Sig of F
NHST Group	2	6.0	.00*
Control Group	2	.0	.97

NHST group's results indicated that the PVGRF in week-1 (M = 6.2, SD = .9) was significantly greater than the mean strength for week-5 test (M = 5.3, SD = .9), t (13) = 3.69, p = .00. The mean scores of peak vertical ground reaction force are presented in Figure 4.23.

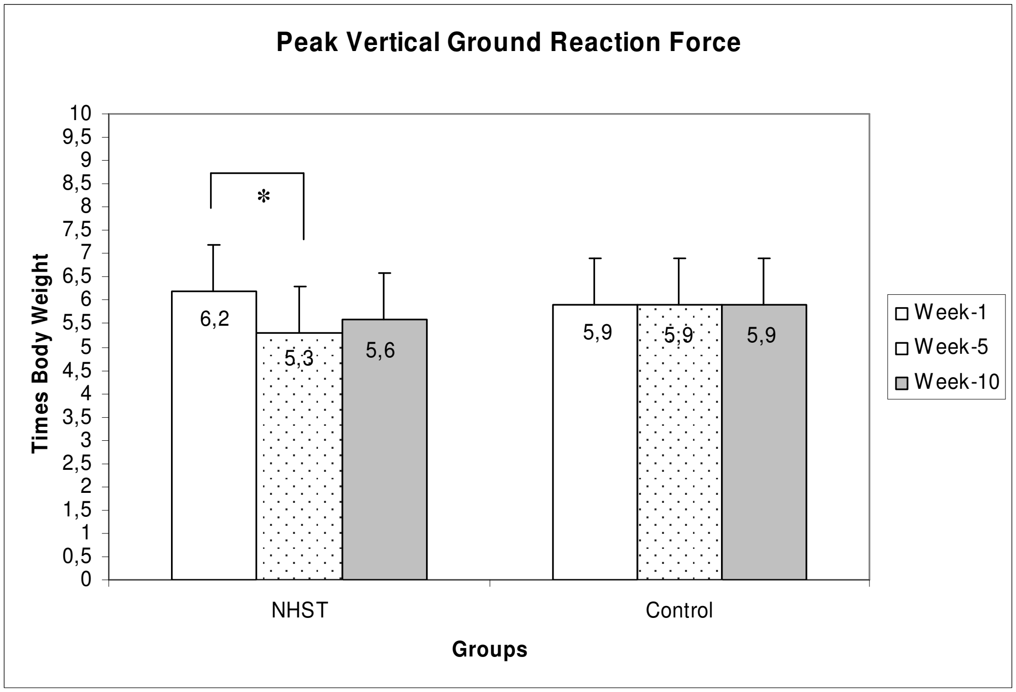


Figure 4.23 Peak Vertical Ground Reaction Force Differences (p < .017).

4.3.2 Peak Anterior/Posterior Ground Reaction Force

Peak anterior/posterior ground reaction force results showed no significant main effect for the group variable (F (1,25) = .00, p > .05, Eta-squared = .00). Meanwhile, significant main effect for Time was obtained, F (2,50) = 9.61, p < .05, and this was a strong effect (Eta-squared = .28) and significant time by group interaction was also obtained (F (2,50) = 4.31, p < .05, Eta-squared = .15). Peak anterior/posterior ground reaction force decreased significantly with the time due to the NHST program (Table 4.15).

Table 4.15 Simple Effect Analysis of Time for PAPGRF.

Groups	DF	F	Sig of F
NHST Group	2	13.8	.00*
Control Group	2	.6	.56

The results indicated that the mean anterior/posterior ground reaction force in week-10 (M = .8, SD = .3) was significantly lower than the mean score for week-1 test (M = 1.1, SD = .2), t (13) = 3.34, p = .00, and week-5 (M = .8, SD = .2) was also significantly lower than the week-1 test results, t (13) = 4.35, p = .00. The mean scores of peak anterior/posterior ground reaction force are presented in Figure 4.24.

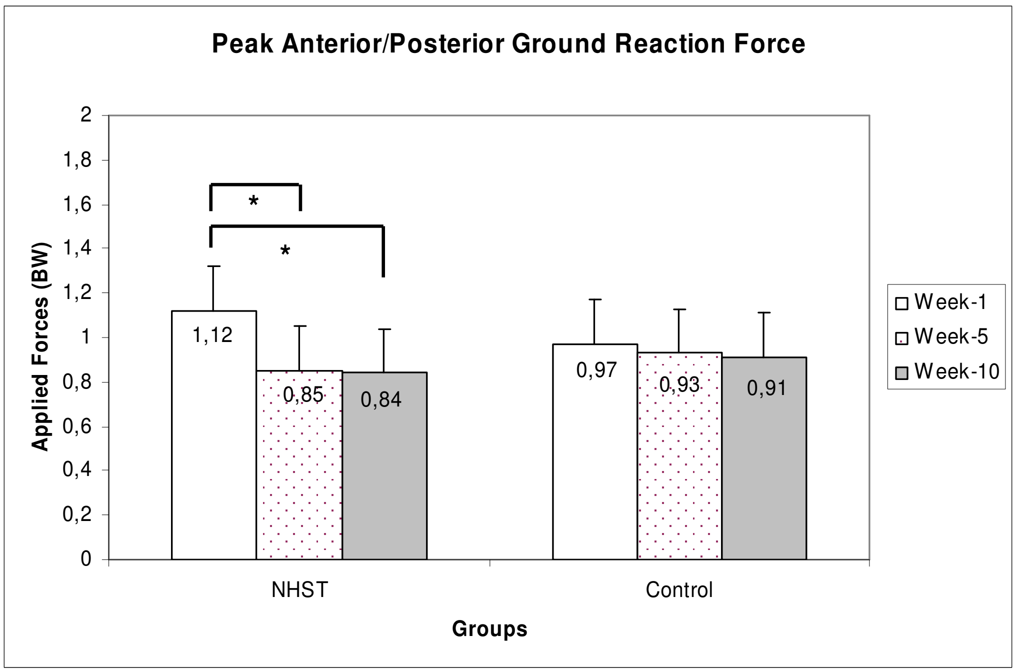


Figure 4.24 Peak Anterior/Posterior Ground Reaction Force Differences ($p < .017$).

4.3.3 Vertical Impulse

Vertical impulse analysis results showed no significant main effect for time (F (2,50) = 1.22, p > .05) or group (F (1,25) = .65, p > .05, Eta-squared = .02) variable, nor were any time by group interactions (F (2,50) = 1.75, p > .05, Eta-squared = .06). The mean scores of peak vertical impulse calculation are presented in Figure 4.25.

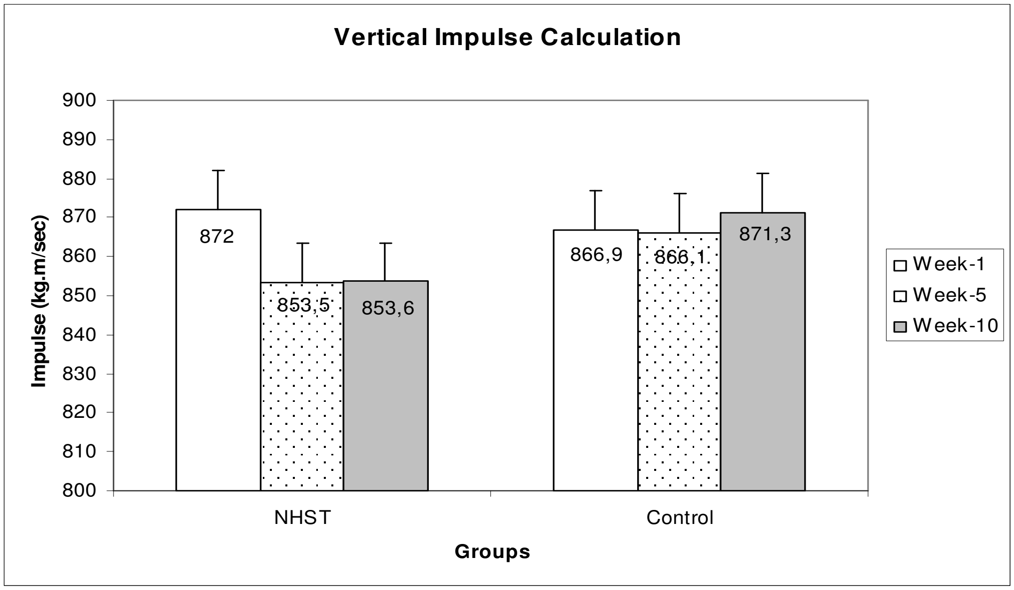


Figure 4.25 Vertical Impulse Differences.

4.3.4 Anterior/Posterior Impulse

Anterior/posterior impulse results showed no significant main effect for the group variable (F (1,25) = 2.06, p > .05, Eta-squared = .07) or time by group interaction (F (1,25) = .26, p > .05, Eta-squared = .01). Meanwhile, significant main effect for Time was obtained, F (1,25) = 5.30, p > .05, and this was a strong effect (Eta-squared = .17). Anterior/posterior impulse scores decreased significantly with the time due to the NHST program (Table 4.16).

Table 4.16 Simple Effect Analysis of Time for APImp.

Groups	DF	F	Sig of F
NHST Group	2	3.9	.02*
Control Group	2	1.7	.20

NHST group's results indicated that the mean anterior/posterior impulse score in week-10 (M = 67.8, SD = 9.2) was significantly lower than the mean score for week-1 test (M = 78.1, SD = 13.6), t (13) = 3.5, p = .00. The mean scores of peak anterior/posterior impulse calculations are presented in Figure 4.26.

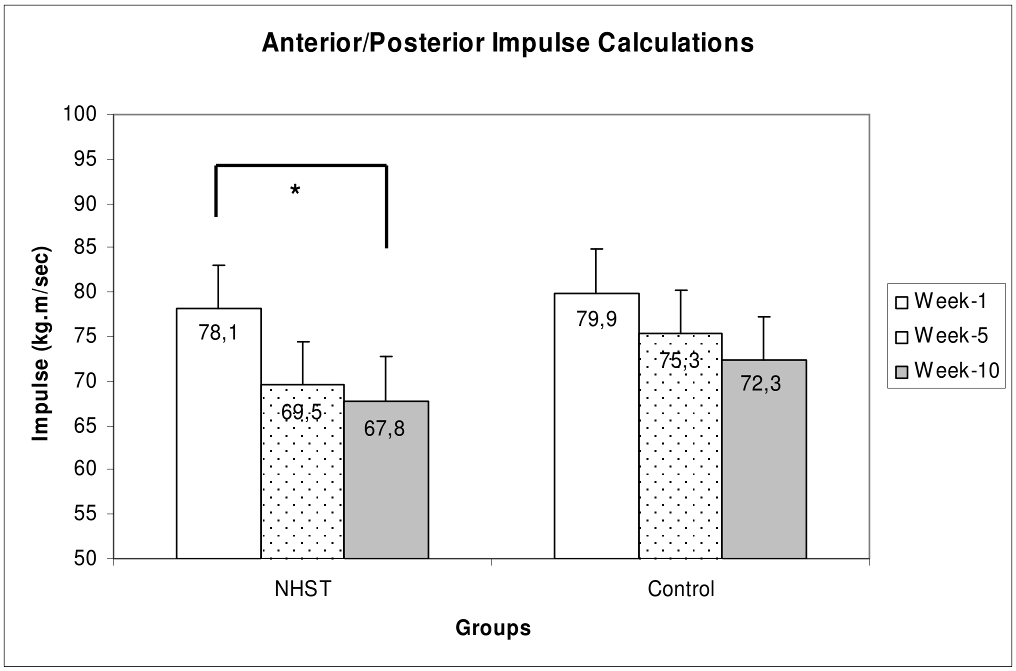


Figure 4.26 Anterior/Posterior Impulse Differences (p < .017).

4.3.5 Time to Peak Force

Time to peak force results showed no significant main effect for the group variable (F (1,25) = .03, p > .05, Eta-squared = .00) or time by group interaction (F (2,25) = .06, p > .05, Eta-squared = .06). Meanwhile, significant main effect for Time was obtained, F (2,25) = 4.52, p < .05, and this was a strong effect (Eta-squared = .15). Time to peak force scores changed significantly with the time due to the NHST program (Table 4.17).

Table 4.17 Simple Effect Analysis of Time for Time to Peak Force.

Groups	DF	F	Sig of F
NHST Group	2	5.9	.00*
Control Group	2	.7	.65

NHST group's results indicated that the mean time to peak force score in week-10 (M = 54.4, SD = 9.5) was significantly lower than the mean score for week-5 test (M = 61.7, SD = 8.3), t (13) = 4.83, p = .00. The mean scores of time to peak force determination are presented in Figure 4.27.

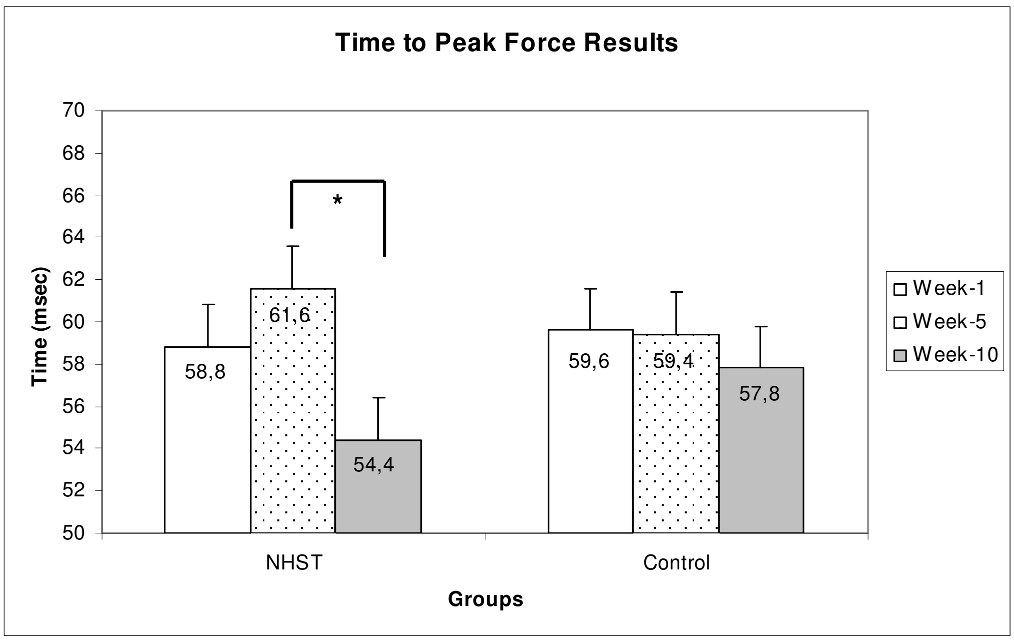


Figure 4.27 Time to Peak Force Differences (p < .017).

4.4 Proprioception Variables

4.4.1 Proprioceptive Sense of Dominant Leg

Dominant leg proprioception measurement results showed no significant main effect for time (F (1,25) = .45, p > .05, Eta-squared = .02) or group (F (1,25) =

.02, p > .05, Eta-squared = .00) variable, nor were any time by group interactions (F (1,25) = 1.08, p > .05, Eta-squared = .04). The mean scores of dominant leg proprioceptive sense are presented in Figure 4.28.

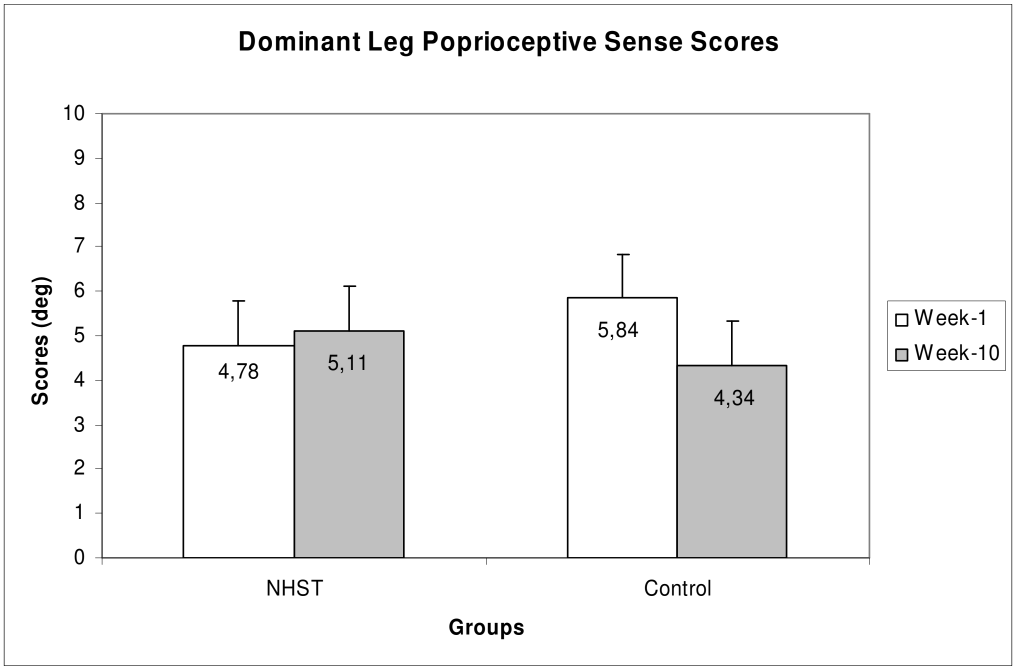


Figure 4.28 Proprioceptive Sense for the Dominant Leg Differences.

4.4.2 Proprioceptive Sense of Non-Dominant Leg

Non-dominant leg proprioception measurement results showed no significant main effect for time (F (1,25) = 1.13, p > .05, Eta-squared = .04) or group (F (1,25) = .58, p > .05, Eta-squared = .02) variable, nor were any time by group interactions (F (1,25) = .72, p > .05, Eta-squared = .00). The mean scores of non-dominant leg proprioceptive sense are presented in Figure 4.29.

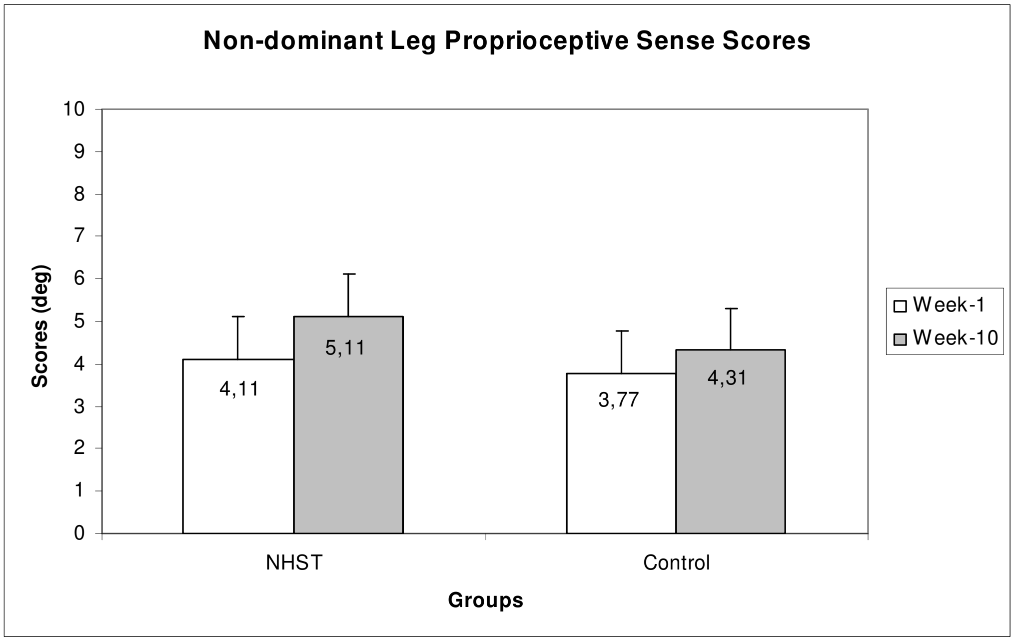


Figure 4.29 Proprioceptive Sense for the Non-dominant Leg Differences.

4.5 Explosive Leg Power

Vertical jumping measurement results showed no significant main effect for the group variable (F (1,25) = .31, p > .05, Eta-squared = .13) or time by group interaction (F (1,25) = 1.69, p > .05, Eta-squared = .06). Meanwhile, significant main effect for Time was obtained, F (1,25) = 5.31, p < .05, and this was a strong effect (Eta-squared = .17). Vertical jumping performance scores increased significantly with the time due to the NHST program (Table 4.18).

Table 4.18 Simple Effect Analysis of Time for Explosive Leg Power (Vertical Jump).

Groups	DF	F	Sig of F
NHST Group	1	6.7	.01*
Control Group	1	.5	.49

Paired-samples t-tests results indicated that the mean vertical jumping performance in week-10 (M = .3, SD = .0) was significantly greater than the mean score for week-1 test (M = .2, SD = .0), t (13) = -2.56, p = .02. The mean scores of vertical jumping performance are presented in Figure 4.30.

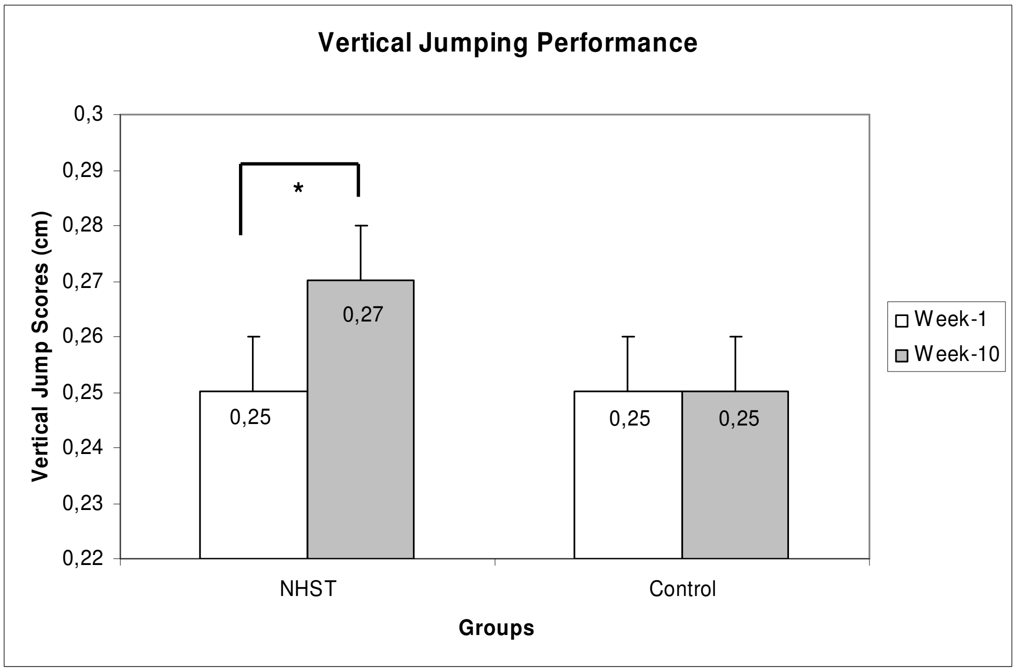


Figure 4.30 Vertical Jumping Performance Differences ($p < .05$).

CHAPTER 5

DISCUSSION

Lower leg muscle strength, bending and stability in female athletes were claimed to be potential risk factors of knee injury (Salci, Kentel, Heycan, Korkusuz & Akin, 2004; Lephart et al., 2002). The purpose of this study was to display increase in hamstring strength after 10-weeks NHST program. Secondly, if such an increase occurred, would this strength change result in altered landing kinetics, knee proprioception, and explosive leg power in recreational female athletes?

5.1 Strength Measurements

The first implication of this study was to determine hamstring strength improvement in the NHST group compared to that of the control group. Lower participant size limited statistical analysis. Based on strength results, it was only possible to examine the main effect for the time variable, a within-subjects factor. So the average score of all three of the test periods could be seen if there is an overall increase in the strength of participants from test to tests. However, overall modifications' ignoring the grouping is not answering our main concerns. For more extensive description of test effects, simple effect analysis was performed for the time within by using syntax command in SPSS, although there were no interactions in the main strength analysis.

Strength data collected via the Biodex isokinetic dynamometer indicated that eccentric dominant hamstring peak torque to body weight results increased significantly from week-1 to 5 and from week-5 to 10 in the NHST group. It was expected that the lower extremity strength training program would improve peak torque in the NHST group with training. Although training improved eccentric dominant hamstring strength significantly, there were no significant group differences in week-5 and week-10 periods.

Mjolsnes et al. (2004) evaluated changes in isokinetic strength after the implementation of 10-weeks Nordic hamstring strength training. Results of that study revealed that eccentric hamstring strength training developed eccentric hamstring strength effectively in well-trained soccer players. The increase in eccentric hamstring strength in the Nordic hamstring strength training group was 11% and researchers attributed their findings to the specificity of the training principle. Our current study results demonstrated that at the end of the 10 week training program the improvement in hamstring eccentric strength in the NHST group was 9%. On the week-5 of the training period, the increase was 7%. Clark et al. (2005) implemented the same training program for four weeks at nine athletic male subjects. In that study eccentric hamstring strength remained almost constant at pre (98.6 Nm) and post-testing (97.3 Nm) in the dominant leg. On the contrary, Tansel et al. (2008) on the exactly same training program reported that NHST program improved eccentric hamstring muscular strength by 12% in young basketball players and this improvement can help athletes to reach their highest potential so they produce greater muscular forces.

Askling and his friends (2003) also studied eccentric training mode. Their participants, male soccer players, presented 19% gain in eccentric strength. Meanwhile, they trained their athletes with a specific hamstring training device (YoYoTM flywheel ergometer). Farthing and Chilibeck (2003) claimed that isokinetic eccentric training would result in greater in strength than the concentric one. Moreover, for the strength development, they concluded that eccentric training was more effective than the concentric isokinetic training.

The researchers also stated that fast-velocity eccentric training was more beneficial than slow eccentric training for the strength improvement. Seger et al. (1998) was also proved the superiority of the eccentric training, but they also implemented this training by a specific isokinetic dynamometer. They reported that the mean eccentric peak torque increased by 18% for their eccentric training group.

Current study and the Clark et al. (2005) demonstrated that NHST program has not significant effect on the non-dominant leg eccentric hamstring strength. The nature of the training can be the reason for this result. It seems that while the athlete lowers her body toward the ground, the dominant leg could get the control of the lowering the body. This potential overload on dominant leg needs further examination. We suppose that the future studies with electromyography evaluation of the NHST exercise may propose logical and concrete examinations.

Dominant eccentric quadriceps average peak torque increased significantly ($p < .05$) in the NHST and control groups due to the training. Actually, this finding was not surprising us because both group they attended volleyball course for an hour and three times a week through the ten-week period. So they performed variety of movements which activates or contracts the quadriceps muscle group.

Dominant concentric hamstrings strength improved significantly ($p < .05$) in the NHST but not in the control group. Askling et al. (2003) reported parallel results that their eccentric training group increased concentric hamstring strength after 10-weeks. Furthermore, present study results revealed that both group improved concentric hamstring strength in non-dominant leg and the parallel results were also gathered in average peak torque scores. Increase in non-dominant quadriceps peak toque was observed between week-1 and week-

10 in the NHST, and week-5 and week-10 in the control group. The explanation for these increases could be being physically active during the 10 week period for both groups. As mentioned in the methods part during 10 week period except for the eccentric exercise both group completed the volleyball course with the same lesson plan.

Dynamic and conventional hamstring to quadriceps strength ratios was significantly different in the non-dominant legs but not in the dominant extremities in both groups. Similar findings in terms of the conventional ratio changes were reported by Tansel et al. (2008). The reason for nonsignificant differences in dynamic control strength ratio may be understood by; as the eccentric hamstring and the concentric quadriceps strengths increased concomitantly their ratios remained unchanged. In other words, increase in the concentric quadriceps strength surpassed the main expected implication of this study and the increase in the eccentric hamstring strength diminished under the strength ratio perspective. It is assumed that even there were no differences in strength ratios, the practical benefits of improved knee stability can help athletes to reach their highest potential as they produce greater muscular forces (Tansel et al., 2008).

5.2 Ground Reaction Force Measurements

Extensive neuromuscular training may enhance sport performance and movement biomechanics in female athletes (Hewett et al., 2005; Myer, Ford & Hewett, 2005). One of our primer hypotheses was that the NHST group would demonstrate decreased vertical ground reaction force during the landing maneuver when compared to the control groups. Based on the findings of the present study, NHST group decreased their PVGRF score 17% from week-1 to week-10. This was not observed in the control group after 10 weeks period.

These findings suggest that eccentric hamstring strength training may have a significant effect on knee stabilization and by means of this exercise athletes were better equipped to absorb the load at impact in landing. Actually, The decrease (33%) in the Peak anterior/posterior ground reaction force was approximately two times higher at the end of the training period in the NHST group. Therefore, it can be claimed that the eccentric hamstring training can decrease the deceleration or breaking force of landing maneuver. Steele (1986) reported that the high anterior/posterior forces generated at landing would play a major contributor role to the high rate of occurrence of ankle and knee injuries.

Cowling, Steele & McNair (2003) studied the effect of verbal instructions on muscle control and preventing risk of ACL injury during landing. They had four groups with “normal landing”, “repeat normal landing”, “landing after instruction to increase knee flexion”, and “landing after instruction to recruit hamstring muscles earlier”. They reported that their “landing after instruction to increase knee flexion” group consistently resulted in lower landing forces than the other groups. They also noted that the peak anterior/posterior forces were significantly lower in landing after “instruction to increase knee flexion group”. The major function of the ACL is to restrain anterior tibial translation, a decrease in these anteriorly directed breaking forces would result in a smaller load for the ACL to endure (Cowling et al., 2003). Therefore, our findings (lower APGRF in trained group for week-1 to week-10 test) may support that trained group had greater knee joint flexion after NHST program. Due to the equipment failure during data acquisition through the whole data collection, the kinematic data analyses could not be performed, if we could be able collect the kinematic data, we would be able to realize these differences. In addition at the present study, the mean APGRF score for the control group changed only 0.2% for the control group after the 10 weeks period.

Plyometric training is one of the jump-training programs that have decreasing effects on landing forces (Hewett et al., 1996; Myer et al., 2005). Hewett and his colleagues (1996) reported that after plyometric training their subjects' peak landing force decreased 22%. Irmischer et al. (2004) also presented the superiority of 9 weeks simple jump-landing-jump tasks on reducing the peak vertical forces. Findings of the current study were in line with these studies. Trowbridge et al. (2005) and McGinn, Mattacola, Malone, Johnson & Shapiro (2006) on the other hand, stated that their strength-training intervention did not affect landing kinetics. They implied that neuromuscular training, specifically focused on motor control patterns, may be necessary for improvements in landing biomechanics.

Our findings indicated that NHST group demonstrated different force dissipation in landing in terms of the time to peak ground reaction force scores for week-5 to week-10 test. Otago (2004) stated that longer time to peak ground reaction force in landing maneuver exhibit less stressful effects on body. However, beside the time component the force distribution through the landing maneuver should be considered as force attenuation strategies may differ through the force-time graph. The difference between week-5 to week-10 may be a compensatory mechanism that may explain NHST effects on landing kinetics. However, this result is questionable because there is no such a study which searches such an effect. Future studies on the effects of NHST program on force dissipation in landing in terms of the time to peak ground reaction force may support better understanding of it effects.

The area under the APGRF curve (APImp) comparisons revealed that NHST group was significantly decreased the APImp score for week-1 to week-10 test duration. The impulse analyses support the information on impact absorption and downward deceleration of the body while landing (Lees, 1981). Therefore, it appears that eccentric hamstring training can modify the landing technique and provide additional support for the knee stability in trained athletes.

Landing forces and knee muscle strength & stability observations from our study supported these implications; we believe one of the most benefits of the NHST program was improvement in functional joint stability. Therefore, our subjects may be able to endure future muscle forces that could potentially causes injury at the knee joint muscles. Actually, quadriceps muscles were strongly activated throughout the landing maneuver as it contracts to absorb the impact of landing. Similarly to quadriceps, as an antagonist, the hamstrings (medial and lateral) activated gradually (Pappas, 2005) throughout the landing maneuver. The importance of the strengthening hamstrings for knee stabilization was implied by Solomonow et al. (1987) and Shultz & Perrin (1999). Solomonow et al. (1987) demonstrated both direct and secondary reflex arcs between ACL and hamstrings, additionally claimed that the hamstrings may be force and load controller, he also stated that muscle strengthening exercises might have potential to enhance hamstring co-activation and help maximize functional joint stability.

5.3 Explosive Leg Power

One of the main implications of this study was significant improvement by 8% in vertical jumping performance. Regarding the vertical jump test, previous research indicated similar trends. Clark et al. (2005) and Tansel et al. (2008) indicated significant 7% and 10% pre-post improvement in vertical jumping height after a four week NHST program, respectively. Lindstedt, Reich, Keim & LaStayo (2002) worked with a group of basketball players assessing the effects of a 6-week high intensity eccentric training on vertical jumping. Training resulted in an 8% (5cm) increase in vertical jump height. Clark et al. (2005) reported that changing position of hamstring peak torque with eccentric training may contribute to higher performance in vertical jump. Furthermore, extended knee joint angle in position of hamstring peak torque may provide higher knee joint stability by increasing the efficiency of force transfer at the final take off phase of jumping (Baratta et al. 1988) Findings of the current study were in line with Clark et al. (2005) and Baratta et al. (1988).

5.4 Proprioceptive Sense

Proprioceptive sense did not change with NHST program. This finding was similar to previous studies (Proske & Morgan, 2001). Due to the method of control in an eccentric contraction the resultant cellular disruption has an acute impact on strength, if this is only because of the disruption at the cell or at the neural interface is yet to be determined, but it is clear that there are accompanying neural and strength decrease as an immediate response to eccentric exercise. Although not widely studied there is initial evidence of a reduction in the proprioceptive sense (Proske & Morgan, 2001), following exposure to eccentrically induced muscle damage. Maximal forced exercises with repetitive exercise can also be a strong adapter of central and peripheral fatigue during subsequent maximal voluntary contractions (Endoh, Nakajima, Sakamoto & Komiyama, 2005).

Muscles are vulnerable to injury during eccentric muscle activity (Garrett, 1990). Weakness of the hamstring muscles is a prominent risk factor for injury (Jonhagen et al., 1994; Yamamoto, 1993; Orchard et al., 1997). Previous studies indicated that players who used NHST had lesser risk of injury (Arnason et al., 2008; Askling et al., 2003; Brooks, Fuller & Kemp, 2006). Nevertheless, exercise training needs to resemble the actual game conditions for achieving the desired physiological adaptation which is also crucial for optimization of performance and injury prevention. Therefore, it is obvious that exercise training which simulates possible injury conditions may help prevent such injury. Hamstring injuries mostly occur during the eccentric muscle action (Garrett, 1990; Kaminski et al., 1998) while the Nordic exercise resembles the typical hamstring injury situation (Mjolsnes et al., 2004). Therefore, adaptation of eccentric exercises, which requires low energy cost and is associated with high torque production (Lindstedt et al, 2001) may encourage significant variation in hamstring strength and hence reduction in muscle damage.

CHAPTER 6

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

6.1 Summary

The answer to our first question was to display increase in hamstring strength after 10-weeks NHST program. Secondly, if such an increase occurred, landing kinetics and improved jumping performance were assumed to improve?

Mechanical load at landing should be reduced to prevent injury. Strength training may improve landing strategies and prevent lower extremity injures.

The results of the study indicated a significant increase in eccentric hamstring strength in the NHST group at week-1 and week-10 when compared to the control group. However, prevalent strength increases exhibited by the NHST group were not sufficient to elicit group differences in strength at the tests of week-10. This would indicate that although the NHST program significantly increased lower extremity strength for the trained group, the increases were not large enough to elicit differences between the trained and control group. Another and the most effective clarification for that case would be the small sample size, even your treatment has some effects on measured parameters you may not find any differences in your comparison due to the lack of sample size.

Since the training group achieved significant increases in strength, the second objective of the study could be investigated; does an increase in lower extremity strength results in alterations in landing kinetics?

The results demonstrated that there were significant differences in landing strategies for the NHST group. Particularly, eccentric strength training elicited improvement in landing kinetics. PVGRF, PAPGRF, and APImp results showed significant decreases in NHST group. So it can be assumed that eccentric hamstring strength training has positive implications on decreasing landing forces.

Finally, we also tested the effectiveness of the NHST program on developing the vertical jumping performance and results demonstrated that NHST group increased their performance but no parallel improvements were noted in control group. Furthermore, proprioceptive sense of knee joint did not change with NHST program.

6.2 Conclusions

This study supports the following points: 1) increases in the eccentric hamstring strength were evident after 10-weeks of NHST program, 2) the increases in isokinetic strength were sufficient to cause alterations in landing kinetics to decrease the GRFs, so the NHST program would be an influential factor in decreasing the lower extremity injuries, and 3) the increase in the efficiency of force transfer at the final take off phase of jumping contributed to a higher performance in vertical jump.

6.3 Recommendations

Future study on the effects of NHST program on lower extremity kinematics is needed. Beside the landing forces the joint kinematics is going to supply better understanding of the training effects.

Further research is encouraged in the area of the combined training (concentric & eccentric strength, plyometric and agility) programs and their transferability to all sport-like movements.

The present study, in landing kinetics evaluations, focused on only 40cm height drop landings, therefore further research is needed for landing from different heights.

Because of the low population size, a further study is needed to test the strength and biomechanical parameters that we found were significant in present study. There might be some variables that are more important then ones we found, but because of the low sample size these variables might not have been discovered.

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Appendix A: Informed Consent Form

GÖNÜLLÜ KATILIM FORMU

Arka bacak kas grubunun kuvvetlendirilmesine yönelik yeni bir egzersiz programı (Nordic hamstring kuvvet programı) ile ilgili yeni bir araştırma yapmaktayız. Araştırmanın ismi "Rekreasyonel Bayan Sporcularda Eksantrik Hamstring Antrenmaninin Alt Ekstremite Kuvveti ve Yere Düşüş Kinetiğine Etkileri"dir.

Sizin de bu araştırmaya katılmanızı öneriyoruz. Ancak hemen söyleyelim ki bu araştırmaya katılıp katılmamakta serbestsiniz. Çalışmaya katılım gönüllülük esasına dayalıdır. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuyup anladıktan sonra araştırmaya katılmak isterseniz formu imzalayınız.

Bu araştırmayı yapmak istememizin nedeni, *sporcuların bir partner yardımıyla ve kendi vücut ağırlıklarıyla yapabilecekleri bu egzersizle (Nordic hamstring kuvvet programı) hem alt ekstremite yaralanmalarına maruz kalma oranlarının azaltılacağı hem de performans arttırımı (patlayıcı kuvvet) açısından faydalı olacağı beklenmektedir*.

Bu çalışmaya katılmanız için sizden herhangi bir ücret istenmeyecektir. Çalışmaya katıldığınız için size ek bir ödeme de yapılmayacaktır.

Bu çalışmaya katılmayı reddedebilirsiniz. Bu araştırmaya katılmak tamamen isteğe bağlıdır ve reddettiğiniz takdirde size uygulanan tedavide herhangi bir değişiklik olmayacaktır. Yine çalışmanın herhangi bir aşamasında onayınızı çekmek hakkına da sahipsiniz.

(Katılımcının Beyanı)
Sayın Araştırmacı Yaşar SALCI tarafından Orta Doğu Teknik Üniversitesi'nde bir araştırma yapılacağı belirtilerek bu araştırma ile ilgili yukarıdaki bilgiler bana aktarıldı. Bu bilgilerden sonra böyle bir araştırmaya katılımcı olarak davet edildim.

Eğer bu araştırmaya katılırsam araştırmacı ile aramda kalması gereken bana ait bilgilerin gizliliğine bu araştırma sırasında da büyük özen ve saygı ile yaklaşılacağına inanıyorum. Araştırma sonuçlarının eğitim ve bilimsel amaçlarla kullanımı sırasında kişisel bilgilerimin ihtimamla korunacağı konusunda bana yeterli güven verildi.

Projenin yürütülmesi sırasında herhangi bir sebep göstermeden araştırmadan çekilebilirim. (*Ancak araştırmacıları zor durumda bırakmamak için araştırmadan çekileceğimi önceden bildirmemim uygun olacağının bilincindeyim)* Ayrıca tıbbi durumuma herhangi bir zarar verilmemesi koşuluyla araştırmacı tarafından araştırma dışı tutulabilirim.

Araştırma için yapılacak harcamalarla ilgili herhangi bir parasal sorumluluk altına girmiyorum. Bana da bir ödeme yapılmayacaktır.

İster doğrudan, ister dolaylı olsun araştırma uygulamasından kaynaklanan nedenlerle meydana gelebilecek herhangi bir sağlık sorunumun ortaya çıkması halinde, her türlü tıbbi müdahalenin sağlanacağı konusunda gerekli güvence verildi. (Bu tıbbi müdahalelerle ilgili olarak da parasal bir yük altına girmeyeceğim).

Araştırma sırasında bir sağlık sorunu ile karşılaştığımda; herhangi bir saatte, Dr. Feza Korkusuz'u 210 49 51 (iş) veya 0535 947 98 68 (cep) no'lu telefonlardan ve ODTÜ Beden Eğitimi ve Spor Bölümü Anabilim Dalı adresinden arayabileceğimi biliyorum.

Bu araştırmaya katılmak zorunda değilim ve katılmayabilirim. Araştırmaya katılmam konusunda zorlayıcı bir davranışla karşılaşmış değilim. Eğer katılmayı reddedersem, bu durumun tıbbi bakımıma ve hekim ile olan ilişkime herhangi bir zarar getirmeyeceğini de biliyorum.

Bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Kendi başıma belli bir düşünme süresi sonunda adı geçen bu araştırma projesinde katılımcı olarak yer alma kararını aldım. Bu konuda yapılan daveti büyük bir memnuniyet ve gönüllülük içerisinde kabul ediyorum.

İmzalı bu form kağıdının bir kopyası bana verilecektir.

Katılımcı
Adı, soyadı:
Adres:
Tel.
İmza   Tarih: .... / ..... / 2007

Görüşme tanığı
Adı, soyadı: Özgür Çelik
Adres: ODTÜ, Eğitim Fakültesi No: 409 06531 ANKARA
Tel. 312 210 40 22
İmza:

Katılımcı ile görüşen araştırmacı
Adı soyadı, unvanı: Yaşar Salcı, Araştırma Görevlisi
Adres: ODTÜ, Eğitim Fakültesi No: 423 06531 ANKARA
Tel. 312 210 40 21
İmza:

Appendix B: Approval of Research Procedures

Orta Doğu Teknik Üniversitesi İnsan Araştırmaları Etik Kurulu Başvuru Formu

Orta Doğu Teknik Üniversitesi (ODTÜ) bünyesinde yapılan ve/ya ODTÜ çalışanları/öğrencileri tarafından yürütülen ve insan katılımcılardan bilgi toplamayı gerektiren tüm çalışmalar, ODTÜ İnsan Araştırmaları Etik Kurulu incelemesine tabidir. Bu başvuru formu doldurulduktan sonra diğer gerekli belgelerle birlikte ODTÜ İnsan Araştırmaları Etik Kuruluna başvuru yapılmalıdır. Çalışmalar, Etik Kurulun onayının alınmasından sonra aktif olarak başlatılmalıdır.

1. Araştırmanın başlığı: *Rekreasyonel Bayan Sporcularda Eksantrik Hamstring Antrenmanının Alt Ekstremite Kuvveti ve Yere Düşüş Kinetiğine Etkileri'dir.*

2. Araştırmanın niteliği:

□ Öğretim Üyesi Araştırması ■ Doktora Tezi

□ Yüksek Lisans Tezi □ Diğer (belirtiniz) ___________________

3. Araştırmacının/Araştırmacıların:

Adı-Soyadı: *Yaşar SALCI* Bölümü: *BES* Telefonu: *210 40 21*

Adresi: *ODTÜ Eğitim Fakültesi 4. Kat No: 423 Eskişehir Yolu / Ankara* E-posta adresi: *ysalci@metu.edu.tr*

4. Danışmanın: Adı-Soyadı *Prof.Dr. Feza Korkusuz Telefonu 210 49 51*

5. Proje Dönemi: Başlangıç *15 Ekim 2007* Bitiş *30 Ocak 2007*

6. Projenin desteklenip desteklenmediği: ■ Desteksiz □ Destekli

Desteklenen bir proje ise, destekleyen kurum: □ Üniversite □ TUBİTAK

☐ Uluslararası (belirtiniz) ______________________ ☐ Diğer (belirtiniz)

7. Başvurunun statüsü: ☒ Yeni başvuru ☐ Revize edilmiş başvuru ☐ Bir önceki projenin devamı

Bir önceki projenin devamı ise, yürütülen çalışma önceden onaylanan çalışmadan herhangi bir farklılık gösteriyor mu? ☐ Evet ☐ Hayır

8. Çalışma katılımcılara, herhangi bir şekilde yanlı/yanlış bilgi vermeyi, çalışmanın amacını tamamen gizli tutmayı
gerektiriyor mu? ☐ Evet ☒ Hayır

Evet ise açıklayınız:____

9. Çalışma katılımcıların fiziksel veya ruhsal sağlıklarını tehdit edici sorular/maddeler, prosedürler ya da manipülasyonlar/uygulamalar içeriyor mu?

☒ Evet ☐ Hayır

Evet ise açıklayınız: On haftalık, haftada 3 günlük fiziksel aktivite söz konusu ve spor yapan herkesin maruz kalabileceği riskleri içeriyor.

10. Katılımcı sayısı: *27*

11. Kontrol grup kullanılacak mı?: ☒ Evet ☐ Hayır

12. Aşağıda sunulan listeden, çalışmanın katılımcılarını en iyi tanımlayan seçenekleri işaretleyiniz.

- ☒ Üniversite Öğrencileri
- ☐ Çalışan Yetişkinler
- ☐ Halihazırda İş Sahibi Olmayan Yetişkinler
- ☐ Okul Öncesi Çocuklar
- ☐ İlköğretim Öğrencileri
- ☐ Lise Öğrencileri
- ☐ Çocuk İşçiler
- ☐ Yaşlılar
- ☐ Zihinsel Engelli Bireyler

☐ Fiziksel Engelli Bireyler

☐ Tutuklular

☐ Diğer (belirtiniz) ___________________

13. Aşağıda yer alan uygulamalardan, çalışma kapsamında yer alacak olanları işaretleyiniz.

☐ Anket

☐ Mülakat

☐ Gözlem

☐ Bilgisayar ortamında test uygulamak

☐ Video/film kaydı

☐ Ses kaydı

☐ Alkol, uyuşturucu ya da diğer herhangi bir kimyasal maddenin katılımcılara kullandırılması

☐ Yüksek düzeyde uyarıma (ışık, ses gibi) maruz bırakma

☐ Radyoaktif materyale maruz bırakma

☒ Diğer (belirtiniz):

Seçmeli voleybol dersi kapsamında rutin voleybol dersi ile birlikte on dakikalık katılımcıların kendi vücut ağırlıkları ile yapılacağı arka bacak kaslarını kuvvetlendirici egzersiz. Bacak kuvveti testi (Sağlık Rehberlik Merkezi, Biodex Kuvvet Dinamometresi). 40 cm'lik yükseklikte olan platformdan yere inişte alt ekstremite de oluşan kinetik ve kinematik parametrelerin takibi (ODTÜ, Biyomekanik Araştırma Laboratuarı).

Bu bölüm ilgili bölümleri temsil eden İA Etik Alt Kurulu tarafından doldurulacaktır.

Proje No: XXXX – XX – XXX (Yıl – Etik Alt Kurul No. – Proje Sıra No.)

Değerlendirme Tarihi: İmza:

Appendix C: Data Collection Sheet

Group **E** ☐ **C** ☐

Name, Surname :

Weight :
Height :
Age :
Dom Leg :

Lower Extremity Injury : Yes ☐ No ☐

If Yes, History :

....

....

....

Proprioception:

Dominant Leg .... /.......

NonDom Leg .... /.......

Jumping Performance :

VJ : ..../...........

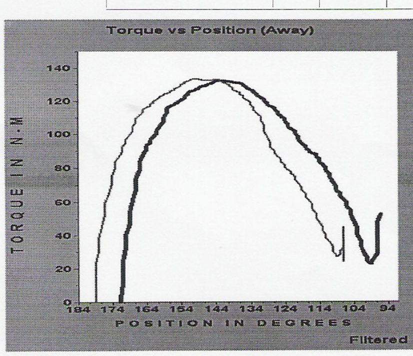
Date : .... /.... / 2007

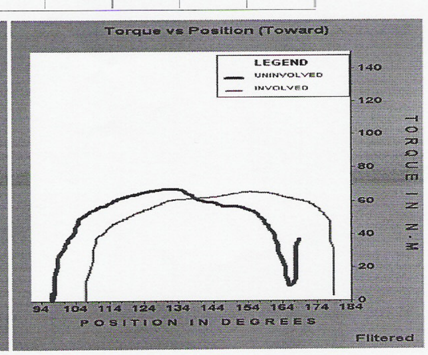
Appendix D: Isokinetic Strength Evaluation Sheet

Comprehensive Evaluation

Name:	FATMA CEKER	Session:	19.10.2007 18:02:42	Windowing:	None
ID:	YASAR-17	Involved:	None	Protocol:	Isokinetic Bilateral
Birth Date:	(dd.MM.yyyy)	Clinician:		Pattern:	Extension/Flexion
Ht:		Referral:		Mode:	Isokinetic
Wt:	64.4	Joint:	Knee	Contraction:	CON/CON
Gender:	Female	Diagnosis:		GET:	18 N-M at 90 Degrees

		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC		
# OF REPS: Right 3		UNINVOLVED	INVOLVED	DEFICIT	UNINVOLVED	INVOLVED	DEFICIT
# OF REPS: Left 3		RIGHT	LEFT		RIGHT	LEFT	
PEAK TORQUE	N-M	132.3	133.3	-0.7	67.3	65.7	2.3
PEAK TQ/BW	%	206.7	208.2		105.1	102.6	
TIME TO PK TQ	MSEC	510.0	510.0		580.0	810.0	
ANGLE OF PK TQ	DEG	142.0	150.0		130.0	155.0	
TORQ @ 30.0 DEG	N-M	0.0	0.0	0.0	0.0	0.0	0.0
TORQ @ 0.18 SEC	N-M	98.4	97.3	1.2	51.7	48.2	6.8
COEFF. OF VAR.	%	4.7	4.4		5.9	9.2	
MAX REP TOT WORK	J	128.8	125.0	3.0	81.0	71.7	11.5
MAX WORK REP #	#	3	2		3	1	
WRK/BODYWEIGHT	%	201.2	195.2		126.5	112.0	
TOTAL WORK	J	366.3	364.1	0.6	215.9	203.9	5.6
WORK FIRST THIRD	J	126.8	122.6		72.2	71.8	
WORK LAST THIRD	J	109.2	116.6		70.2	60.8	
WORK FATIGUE	%	13.9	4.9		2.7	15.4	
AVG. POWER	WATTS	93.9	95.6	-1.7	52.1	49.1	5.8
ACCELERATION TIME	MSEC	50.0	50.0		40.0	40.0	
DECELERATION TIME	MSEC	40.0	50.0		40.0	200.0	
ROM	DEG	87.3	75.1		87.3	75.1	
AVG PEAK TQ	N-M	127.1	128.2		63.8	61.1	
AGON/ANTAG RATIO	%	50.8	49.3	G: 62.0			





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Appendix E: Curriculum Vitae

PERSONAL DETAILS

Name:	Yaşar Salcı
Date of Birth:	30/01/1975
Place Of Birth:	İstanbul
Current Occupation:	Research Assistant

CONTACT DETAILS

Telephone:	+90 536 637 94 32
Post:	Middle East Technical University - Department of Physical Education & Sports 06531 Ankara / Turkey
Electronic Mail:	ysalci@yahoo.com

EDUCATIONAL DETAILS

Secondary Education:	Ankara Bahçelievler Deneme Lisesi, 1993
Tertiary Education:	B.S. 1995-1999 METU - Physical Education & Sports Department
	M.Sc. 1999-2002 METU - Physical Education & Sports Department

EMPLOYEMENT AND EXPERIENCE

1999 (December) - Present	METU, Research Assistant
1999 (August – December)	Mustafa Kemal University, Research Assistant
1999 (June – August)	Arı College - Summer School, Swimming Teacher
1999 (September – December)	Arı College - Winter School, Swimming Teacher
2002-2003	Çankaya University - Men Volleyball Team Coach
2003 (June)	Arı College - Summer School, Swimming Teacher

RELEVANT SKILLS

- Life Saving Certificate Turkish Under Water Sports, Life-Saving, Water Ski and Fin Swimming Federation - Silver Sportsman

RESEARCH INTERESTS

- Physiology of exercise
- Human movement analysis
- Isokinetic strength measurements

PUBLICATIONS

International Publications*:*

Tansel, R.B., **Salci, Y,** Yildirim, A., Kocak, S., Korkusuz, F. (2008). Effects of eccentric hamstring strength training on lower extremity strength of 10-12 years old male basketball players. **Isokinetic and Exercise Science.** 16(2): 81-85.

Boyar, A., **Salci, Y.**, Kocak, S., Korkusuz, F. (2007). Shoulder proprioception in male adolescenttennis players and controls: The effect of shoulder position and dominance. **Isokinetic and Exercise Science**. 15(2): 111-116.

Salci, Y., Kentel, B.B., Heycan, C., Korkusuz, F., Akin, S. (2004). Comparison of landing maneuvers between male and female college volleyball players. **Clinical Biomechanics**. 19: 622-628.

National Publications:

Salcı, Y., Tansel, B., Çelik, Ö., Karakaya, H., Sarıoğlu, T., Korkusuz, F. (2001). 19 – 40 Yaş Arasındaki Sedanter ve Düzenli Spor Yapan Bayanların Kemik Mineral Yoğunlukları ile Fiziksel Aktivite Seviyeleri Arasındaki İlişki. **Spor Bilimleri Dergisi**. 12(2): 3 – 8.

Salcı, Y., Koçak, S. (2001). Fiziksel Aktivite Düzeyini Belirlemede Yaygın Olarak Kullanılan Anketler. **Gazi Beden Eğitimi ve Spor Bilimleri Dergisi**. 6(4): 19 – 28.

International Congress and Presentations:

Oral Presentations.

Salci, Y., Coskun, O.O., Ozberk, Z.N., Yildirim, A., Akin, S., Korkusuz, F. Physical Features of American Football Players in Post and Pre-Season Period. VI. World Congress on Science & Football, Journal of Sports Science and Medicine, **(Suppl. 10),** 76-79, 2007.

Altunsoz, O.S., **Salci, Y.,** Korkusuz, F. Determination of Bone Mineral Density and Trunk Muscle Strength in Active Soccer Players and Veterans. VI. World Congress on Science & Football, Journal of Sports Science and Medicine, **(Suppl. 10),** 30-34, 2007

Altunsoz, O.S., **Salci, Y.,** Korkusuz, F. Effects of Long Term Playing Soccer on Lumbar Spine Degeneration. VI. World Congress on Science & Football, Journal of Sports Science and Medicine, **(Suppl. 10),** 22-25, 2007.

Salcı, Y., Tansel, B., Çelik, Ö., Karakaya, H., Sarıoğlu, T., Korkusuz, F. Relationship between bone mineral density and physical activity level of active and sedentary women between 19-40 yr. old. **VI. International Sports Sciences Congress**. Ankara, Turkey, 3 – 5 Nov 2000.

Poster Presentations:

Salci, Y., Altunsoz, O.S., Korkusuz, F. Effect of Long Term Soccer on Spinal Mobility and Lumbar Spine Degeneration. **VI. World Congress on Science & Football.** Antalya, Turkey, 16 – 20 Jan 2007.

Coşkun Ö, Özberk N, **Salci Y**, Çelik Ö, Altun Ö, Akın S, Bayramoğlu A, Korkusuz F, Evaluation of physiological characteristics of elite basketball players**. 46th. "ICHPER.SD Aniversary World Congress"**, (2005), p.437-438.

National Congress and Presentations:

Oral Presentations:

Salcı, Y., Kentel, B.B., Heycan, C., Korkusuz, F., Akın, S. Erkek ve Bayan Voleybolcularda Yere Düşüş Hareketinin Karşılaştırılması. **IX. Spor Hekimliği**

Kongresi (9th National Sports Medicine Congress) 23 – 26 Ekim 2003, Kapadokya, Türkiye.

Books:

Salci, Y., Yilmaz, L., Ak, E., & Korkusuz, F. Sık Karşılaşılan Spor Yaralanmaları ve İlk Müdahale. ODTU Yayıncılık. Ankara, 2007. ISBN:9944-344-44-9.

Altunsoz, O.S., **Salci, Y.** Korkusuz, F. (2008). Acute and chronic spinal injuries in soccer. In T. Reilly & F. Korkusuz (Ed.), Science and Football VI: Sports Medicine (pp. 69-74). Taylor & Francis Group. ISBN: 0415429099

Appendix E: Türkçe Özet

REKREASYONEL BAYAN SPORCULARDA EKSANTRİK HAMSTRİNG ANTRENMANININ ALT EKSTREMİTE KUVVETİ VE YERE DÜŞÜŞ KİNETİĞİNE ETKİLERİ

Giriş

İyi planlanmış egzersiz programları insanların yaşam kalitesini arttıran önemli etmenlerdir. Hastalıklardan korunmak açısından ise herkes için en kaliteli ve en ucuz yoldur. Düzenli egzersizin kolesterol seviyesinin düşmesine, ev ve iş yaşamında maruz kalınan stresin azaltılmasına ve ruhsal sağlığın arttırılmasına olumlu etkileri vardır. Bu faydalardan yararlanabilmek için de egzersiz yapanların spor hocalarından yani işin uzmanlarından yardım almaları önerilir. Egzersiz yaparak sağlıklı bir bedene sahip olmak hoş gözükse de egzersiz yapanlar yaralanmalarla da karşı karşıya gelebilirler.

Sıçrama, sprint ve çeviklik gerektiren hareketler pek çok spor branşının ayrılmaz parçasıdır ve alt ekstremite (bacak) kuvveti bu noktada önemli bir belirleyicidir. Kuvvet ve kondisyon programları sadece sporcunun performansını arttırmakla kalmaz bunun yanında yaralanmalardan da uzak kalabilmek içinde faydalıdır.

Hamstring yaralanmaları bu yaralanmaların içinde iyi bilinen ve iyi tanımlanmış olanlardan biridir. Maruz kalındığında spordan uzak kalma süresi azımsanmayan (Garrett ve ark., 1989) ve iyileşmesi yavaş gelişen ve her yaralanma gibi özel ilgi gerektiren bir yaralanmadır (Burkett, 1970). Hamstring yaralanmalarının nedenlerini sıralarsak; hamstring ve kuadriseps kas kuvveti oranı dengesizliği (Kujala ve ark., 1997), kuvvet eksikliği (Orchard ve ark., 1997), yetersiz esneklik (Hartig & Henderson, 1999), yorgunluk (Kujala ve ark., 1997) ve daha önce meydana gelen hamstring yaralanmaları (Bennell ve ark., 1998) hamstring problemlerinin ana sebepleridir.

Çoğunlukla spor yaralanmalarından kaçınmak mümkün olmamakla birlikte sporcu fiziksel aktiviteye zihinsel ve fiziksel olarak hazır ise yaralanmalardan korunmak mümkündür. Spor yaparken dikkat edilmesi gereken bazı önemli ayrıntılar mevcut. Bu ayrıntılara gösterilen hassasiyet yaralanma riskinin azaltılmasında faydalı olacaktır. Bu önemli ayrıntıları sıralarsak, öncelikle egzersiz olarak orta seviyede bir aktivite ile egzersize başlayabiliriz, aktiviteden önce yeteri kadar ısınma ve esneme-germe hareketleri yapılmalıdır, egzersiz sonrası soğuma yapmak vücudu durağan hale geçme aşamasına alışması için ve vücutta biriken laktik asidin atılımı için gereklidir. Yapılacak egzersize uygun kıyafet seçilmeli ve egzersiz yükü kademeli olarak arttırılmalıdır. Bu hususlardaki hassasiyet bireyi yaralanmalardan mümkün olduğu kadar uzak tutar ve fiziksel olarak yüklenmeye (kardiyovaskular veya kuvvet antrenmanlarına) hazır hale getirir (NIH, 2004).

Alt ekstremiteye odaklanmış olan kuvvet antrenmanları örneğin hamstring ve kuadriseps kas gruplarının ko-kontraksiyonlarının arttırılması faydalı olacaktır. Koşuda hamstring ve kuadriseps kas gruplarının kasılma mekanizmalarını açıklarsak bu kas gruplarının ne çeşit antrenmana ihtiyacı olduğunu da belirleyebiliriz. Koşu hareketinde kuadriseps kas grubu hızlanma fazında konsantrik olarak etkin durumda iken hamstring grubu eksantrik olarak kasılarak yavaşlama fazını domine eder. Koşu aktivitesinin hemen her spor branşının içinde olduğu düşünülürse kuvvet antrenmanlarının hem konsantrik hem de eksantrik modda planlanması gerekmektedir.

Daha önceki çalışmalarla, eksantrik olarak planlanmış antrenman programının diğer konsantrik ve izometrik olarak planlanan antrenman programlarına olan üstünlüğü kanıtlanmıştır (Aagard ve ark., 1996; Arnason ve ark., 2008; Askling ve ark., 2003; Brockett ve ark., 2001; Clark ve ark., 2005; Mjolsnes ve ark., 2004; Olsen ve ark., 2005). Fakat kuvvet artışlarının yanında egzersizle kuvvetlenen alt eksremitenin biyomekaniksel olarak gösterebileceği farklılıklar çok fazla irdelenmemiştir. Bu bağlamda planlanan bu çalışmanın amacı 10 haftalık eksantrik hamstring kuvvet antrenmanı sonrasında kuvvette meydana gelecek artışı göstermektir. İkinci olarak da eğer kuvvette artış olursa bu artış yere düşüş kinetiğini ve dikey sıçrama performansını etkiliyor mu sorusuna cevap vermektir.

Materyal ve Metot

Çalışmada 27 sağlıklı rekreasyonel bayan sporcu iki gruba ayrılarak Nordic Hamstring Strength Training (NHST) (n = 14, yaş = 20.4 ± 1.1, boy = 1.7 ± .0 m, kilo = 56.2 ± 6.3 kg) ve kontrol (n = 13, yaş = 21.0 ± 1.5, boy = 1.7 ± .1 m, kilo = 56.8 ± 6.1 kg) gruplarını meydana getirdi. Ölçümler 10 haftalık egzersiz programının başında, ortasında ve sonunda yapıldı. Katılımcıların bu dönemlerde yere düşüş kinetiği parametreleri kuvvet platformunda, alt ekstremite kuvveti ve propriyosepsiyonu kuvvet dinamometresiyle ve dikey sıçrama performansları sıçrama minderi ile değerlendirilmiştir. NHST grubu voleybol dersine ek olarak 10 haftalık eksantrik hamstring antrenmanı aldı. Kontrol grubu ise sadece aynı voleybol dersine katıldı.

Katılımcıların izokinetik kuvvet değerlendirmeleri Biodex izokinetik dinamometresinde yapıldı. Eksantrik ve konsantrik modlarda 60°/sn açısal hızlarda test edilen hamstring ve kuadriseps kas gruplarının ulaştıkları en yüksek torklar (PT/BW), ortalama torkları (AvgPT), hamstring'in kuadriseps kas kuvvetine oranı ve dinamik kontrol kuvvet oranları kaydedildi.

Katılımcılar yere düşüş kinetiğinin incelenmesi için 40 cm'lik bir platformdan yere serbest düşüş gerçekleştirdiler. Yere düşüş manevrasında kuvvet platformundan Fz yönünde ortaya çıkan en yüksek kuvvet (PVGRF), Fy yönünde ortaya çıkan en yüksek kuvvet (PAPGRF), aynı yönlerin içtepileri ve kuvvet-zaman grafiğinde en yüksek kuvvete ulaşma zamanları kaydedildi.

Katılımcıların diz eklemi pozisyon algılama becerileri ise yine Biodex izokinetik kuvvet dinamometresi ile ölçüldü. Dikey sıçrama performansları da Bosco Timing matında değerlendirildi (Sıçrama yüksekliği = 4.9 x (0.5 x Zaman)^2).

NHST grubuna uygulanan eksantrik hamstring kuvvet programı Nordic Hamstring Kuvvet Antrenmanı olarak bilinmektedir (Mjolsnes ve ark., 2004). Yapılan egzersizi kısaca tanımalarsak; NHST bir partner ile yapılması gereken bir egzersizdir. Yerdeki mindere diz üstü dik olarak pozisyonlanan katılımcının ayak bileklerinden bastırılarak sabit pozisyonda tutulmaya çalışılır. Sonrasında ise kollarını gövdesinin yanlarına alan katılımcı üst gövde de özellikle belden her hangi bir bükülme yapmadan gövdesini yere doğru yaklaştırır. Yer çekimine karşı direnmeye çalışarak gövdesinin ellerle birlikte yerle temasını sağlar ve hareketi sonlandırır.

Bu egzersizin etkileri değerlendirilirken SPSS programı kullanıldı. Her bir parametre ayrı 2x3 (grup ve zaman) "mixed repeated measures ANOVA" dizaynı ile test edildi. Post hoc testler için de Bonferroni düzeltmeli eşleştirilmiş *t* testi uygulandı.

Sonuçlar

Sonuçlar NHST grubunun antrenman programı sonunda eksantrik hamstring kuvvetlerini arttırdıklarını gösterdi (hafta-1 = 233.6 ± 27.5, hafta-10 = 253.8 ± 28.4 Nm/kgbw; $p < .05$). Anlamlı farklılıklar NHST grubunun yere düşüş mekaniği ölçüm değerlendirmelerinde de gözlendi. PVGRF (hafta-1 = 6.2 ± 0.9, hafta-5 = 5.3 ± 0.9; $p < .05$), PAPGRF (hafta-1 = 1.1 ± 0.2 & hafta-10 = 0.8 ± 0.3; $p < .05$), ve APImp (hafta-1 = 78.1 ± 13.6 & hafta-10 = 67.8 ± 9.2; $p < .05$) sonuçlarında anlamlı azalmalar belirlendi. Bunların yanında NHST grubunun dikey sıçrama performansında da anlamlı artış görüldü (hafta-1 = 0.25 ± 0.0 & hafta-10 = 0.27 ± 0.0 cm; $p < .01$), fakat kontrol grubunun değerlendirmeleri artış yönünde olmadı.

Tartışma ve Öneriler

Bu çalışmanın ilk önemli yansıması olarak NHST grubunun egzersiz sonunda eksantrik hamstring kuvvetini anlamlı olarak arttırdığı bulunmuştur ($p < 0.05$). Mjolsnes ve ark. (2004) aynı egzersiz programını kullanarak benzer sonuçlara ulaşmışlar ve egzersiz grubunun kuvvet artışı yüzde 11 olarak rapor etmişler. Bizim çalışmamızda ulaşılan kuvvet artışı 10 haftalık egzersiz sonunda yüzde 9 olarak bulundu. Fakat aynı gelişme dominant olmayan bacakta maalesef gözlenemedi. Orijinal çalışmada sadece dominant bacağın değerlendirildiği rapor edilmiş ve diğer bacak ile ilgili herhangi bir bilgiye ulaşılamıyor. Bu sonuçlar egzersizin pozitif etkisi dominant olmayan bacağa yansımıyor mu? sorusunu ortaya atıyor. Tansel ve ark. (2008) aynı egzersizi 5 hafta uygulayarak yüzde 12 oranında bir artış elde etmişler ve çalışmada yine sadece dominant bacağın değerleri mevcut.

Dominant olmayan bacakta kuvvet artışının eksikliği şöyle açıklanabilir. Egzersiz yapılırken öne doğru olan eğilmede dominant bacak kontrolü ele alır ve zorlanmanın büyük bir kısmını üstlenir. Doğal olarak da kuvvet artışı daha fazla olur. Bu eksikliğin giderilmesi için egzersiz esnasında sıra ile sağa ve sola yapılabilecek hafif gövde eğimleri kontrolün bir sağ bacağa bir sol bacağa geçmesini sağlayacaktır. Daha sonra ki çalışmalar için dikkat edilmesi gereken bir etken olarak düşünülmelidir.

Hamstring kas grubuna eksantrik antrenman vererek kuvvet artışı sağlayan başka çalışmalarda vardır (Askling ve ark., 2003; Seger ve ark., 1998). Askling ve ark. (2003) çalışmalarında hamstring kas grubunda yüzde 19 oranında bir kuvvet artışı rapor etmişlerdir. Seger ve ark. (1998) yine aynı egzersiz modunda yüzde 18 oranında artış bulmuşlar. Seger ve arkadaşları (1998) çalışmalarında izokinetik dinamometre ile sporcularını antrene ederken, Askling ve arkadaşları (2003) da bir diğer özel ekipman olan "YoYoTM flywheel ergometer" kullanmışlardır. Her iki çalışmada da kuvvet artış oranları yüksek olmakla birlikte egzersizin uygulanabilirliği ya da antrenmanın verilebilirliği çok yüksek değildir. Özel ekipman gerektiren çalışmalar hem zaman alabilen hem de her çalışma grubuna uygulamaya uygun olmayan yapılara sahip olabilirler. Bizim çalışmamızda kullandığımız egzersizin uygulanabilirliği oldukça yüksektir, daha önce de bahsettiğimiz gibi ihtiyaç olan bir partner bir de yer minderdir.

Çalışmanın başlangıcında, arka bacak kas grubunun kuvvetinde meydana gelecek artış sonrasında, katılımcıların dinamik kontrol kuvvet oranlarında (H_{ecc}/Q_{con}) artış beklenmekteydi. Çalışmanın sonunda bu değerlerde anlamlı farklılıklar gözlenemedi. Sonuçlar dikkatlice incelendiğinde eksantrik hamstring kuvvetinde anlamlı bir artış mevcut fakat bunun yanında konsantrik kuadriseps kuvveti de bu paralellikte artmış. Bu eş zamanlı kuvvet artışı dinamik kontrol kuvvet oranında beklenen artışı gizlediği görülmektedir. Bununla beraber her iki kas grubunda görülen kuvvet artışı, diz eklemi stabilitesini arttırır ve spor performansında daha fazla kuvvet üretme potansiyelini ortaya çıkarır.

Kuvvet antrenmanının spor performansını arttırdığı ve hareket biyomekaniğini geliştirdiği daha önce ortaya konmuştur (Hewett ve ark., 2005; Myer ve ark., 2005). Bu çalışmada, bizim ana hipotezlerimizden biri de uygulanan kuvvet antrenmanı ile NHST grubunda yere düşüş kinetiğinde farlılıklar beklenmekteydi. Uygulanan NHST sonrasında sporcuların yere uyguladığı dikey kuvvet (PVGRF) yüzde 17 oranında azalma gösterdi ($p < 0.05$). Bu sonuç ile ortaya çıkan NHST ile diz eklemi stabilitesi artıyor ve bu artış, yere düşüşle maruz kalınan kuvvetlerin alt ekstremite tarafından daha etkin olarak emildiğini göstermektedir. Aslında NHST grubunun PAPGRF değerlerinde görülen azalma yaklaşık PVGRF da görülen azalmanın iki katı kadar fazladır. Yüzde 33 oranında azalmanın anlamı, yapılan egzersizle yere düşüş manevrasında frenleme kuvveti “breaking force” geliştirilmiştir. Bu da yere düşüşte meydana gelebilecek ayak bileği ve diz eklemi yaralanmalarının meydana gelme olasılıklarının düşürülmesine yardımcı olacaktır (Steele, 1986).

Cowling ve ark. (2003) çalışmalarında farklı geribildirim etkilerini incelerken dört grup üzerinde yoğunlaştılar. Amaçları değişik geribildirim metotlarının yere düşüş kuvvetini azaltılması yönündeki etkilerini incelemekti. Rapor ettikleri sonuçta yere uygulanan kuvvetin azalmasını en çok “diz bükülmesini irdeledikleri” grupta sağlamışlar. Aynı grupta PAPGRF sonuçları da anlamlı azalma göstermiş. Bizim çalışmamızda da deney grubumuzda PVGRF ve PAPGRF parametreleri azalma gösterdi, bunun olası nedenleri diz eklemi kas gruplarının kuvvetlenmesi ile yere düşüşte diz eklemindeki açılanmanın artmış olabileceğidir. Bu durumu destekleyecek sonuçları laboratuarımızda meydana gelen kamera problemi nedeni ile belgeleyemediğimiz için yorumlarımız spekülatif kalacak ama Cowling ve arkadaşlarının (2003) çalışması göz önüne alındığında bu spekülatif yorumların çok da yanlış olmayacağı görüşündeyiz.

NHST grubunun dikey sıçramalarının ön ve son test karşılaştırmalarında yüzde 8 oranında anlamlı bir artış bulundu ($p < 0.05$). Clark ve ark. (2005) ve Tansel ve ark. (2008) aynı antrenman programının yarı yarıya kısaltılmış şekli ile benzer artışları çalışmalarında rapor ettiler. Hamstring kas grubunun eksantrik olarak kuvvetlendirilerek dikey sıçrama performansını olumlu yönde etkilemesi şu şekilde açıklanabilir; eksantrik hamstring antrenmanı ile değişen hamstring kas grubunun ulaşılabildiği en yüksek torku üretme açısı değişebilmekte ve gelişebilmekte (Clark ve ark., 2005). Bu değişim ile sıçrama hareketinde ayağın yerle temasının kesildiği anda meydana gelen kuvvet transferinin dikey sıçrama performansını arttırdığı belirtilmektedir (Baratta ve ark., 1988).

Çalışmanın sonunda; 1) antrenmanının NHST grubunda kuvvet artırımı etkisi, 2) bu artışın aynı grupta yere düşüş biyomekaniğini etkilediği ve eklemlere binen yükü azaltarak yaralanma riskini azaltabileceği, ve son olarak ta 3) sıçrama hareketinde “take off phase” olarak adlandırılan ayağın yerle temasının kesildiği anda ki kuvvet transferinin etkinliğinin bu tip egzersizle arttırıldığı ve dikey sıçrama performansının ilerlemesine katkıda bulunduğu gözlenmiştir.