EFFECTS OF A 5-WEEK NORDIC HAMSTRING STRENGTH TRAINING ON 10-12 YEARS OLD MALE BASKETBALL PLAYERS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF PHYSICAL EDUCATION AND SPORTS

DECEMBER 2006

Approval of the Graduate School of Social Sciences

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

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ABSTRACT

EFFECTS OF A 5-WEEK NORDIC HAMSTRING STRENGTH TRAINING ON 10-12 YEARS OLD MALE BASKETBALL PLAYERS

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December 2006, 50 pages

The purpose of this study was to investigate the effects of Nordic hamstring strength training (NHST) program on (1) leg power, (2) vertical jump, (3) and knee proprioception measurements of 10-12 years old male basketball players. Nordic Hamstring Strength Training (NHST) group (N=16), participated in basketball training plus in Nordic hamstring strength training, while the control group (N=11) participated in basketball training only. Subjects were tested before and after 5-week training program for, vertical jump, isokinetic leg strength and knee proprioception. Each subject who agreed to participate in this investigation signed a consent form along their parent. Pre and post test differences between experimental and control group was investigated by MANOVA and paired sample t-test was used to evaluate the differences between pre and post tests of both groups. There was no significant difference in pre and post test results of NHST and control group.

There were statistically significant increase in concentric quadriceps and hamstring strength, eccentric quadriceps strength, conventional H:Q strength ratio, and vertical jumping measurements in experimental group between the pre and post tests.

It can be concluded that NHST program combine with basketball training has beneficial effects on the leg strength and H:Q strength ratio. These findings also suggest that hamstring exercise may be beneficial or helpful for preventing the hamstring injury occurrence and improving the physical performances such as jumping ability.

Key words: Nordic hamstring strength training, isokinetic leg strength, vertical jump, standing long jump, knee proprioception

ÖZ

5 HAFTALIK NORDİC HAMSTRİNG KUVVET ANTRENMANININ 10-12 YAŞ ARASI ERKEK BASKETBOLCULARA ETKİSİ

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Aralık 2006, 50 sayfa

Bu çalışmanın amacı 10-12 yaş arası erkek basketbol oyuncularında Nordic hamstring kuvvet antrenmanının (1) bacak kuvveti, (2) dikey sıçrama, (3) propriyosepsiyon değerleri üzerine etkisini araştırmaktır. Egzersiz grubuna (N=16) rutin basketbol antrenmanlarına ek olarak Nordic hamstring kuvvet antrenman programı verilirken, kontrol grubuna (N=11) sadece rutin basketbol antrenmanı yaptırılmıştır. Katılımcıların 5 haftalık egzersiz öncesi ve sonrasında, dikey sıçramaları, bacak kuvvetleri ve diz propriyosepsiyonları ölçülmüştür. Çalışmaya gönüllü olarak katılan her bireyin ebeveynlerinden imzalı onam formu alınmıştır. Egzersiz ve kontrol grubunun ön ve son test sonuç karşılaştırmaları MANOVA, grupların ön test ve son test farklılıkları ise eşleştirilmiş t testleriyle yapılmıştır. MANOVA sonuçlarına göre grupların ön ve son test karşılaştırılmalarında anlamlı bir farklılık gözlenmemiştir.

Egzersiz grubunun ön ve son test sonuçlarına göre konsentrik hamstring ve quadriseps kuvvetlerinde, egzantrik quadriceps kuvvetinde, hamstring-quadriseps kuvvet oranlarında ve dikey sıçrama değerlerinde anlamlı farklılık gözlenmiştir. Fakat, durarark yatay sıçrama ve diz propriyosepsiyonu sonuçlarında anlamlı bir fark bulunmamıştır. Sonuç olarak basketbol antrenmanlarına entegre edillen Nordic hamstring kuvvet çalışmaları bacak kuvveti ve hamstring-quadriseps kuvvet oranlarının gelişimine katkıda bulunabilmektedir. Buna ek olarak, hamstring kuvvet çalışmaları bacak arkasındaki kaslarda meydana gelebilecek muhtemel sakatlıklardan korunulmasında faydalı olabilecek ve sıçrama performansına katkı sağlayabilecektir.

Anahtar Kelimeler: Nordic hamstring kuvvet antrenmanı, izokinetik bacak kuvveti, dikey sıçrama, diz propriyosepsiyonu

To My Family

ACKNOWLEDGMENTS

I would like to gratefully acknowledge the support of, Prof. Dr. Feza Korkusuz, for support and encouragement, which made this study possible. I would also like to thank the members of examining committee, Prof. Dr Ömer Geban, Assoc. Prof. Settar Koçak for their guidance and discussing me for the different aspects of the study.

My special thanks go to Yaşar Salcı and Ahmet Yıldırım for their help and friendship and guiding in the test applications. Many thanks to Medical Center Physiotherapy for their allowance and implementation of performance tests.

And finally, I would like to thank many times to my family.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Basketball has a great popularity as it is a well-known sport in all around the world. This popularity induces a very challenging environment and requires high quality in technical, tactical, physiological, psychological, and physical readiness. Physical readiness is important to prepare the basketball players for extended time of competitions. The nature of the game requires aggressive play and concentrated struggle for desired performance. Today's basketball has many matches in a year with high intensity. Also they have two or even three training sessions in a day.

Basketball has become very complex game of accuracy, timing and agility. The improved nature of the game, as well as the quality of the players, has necessitated the maximization of player preparation. Jumping, sprinting, quick changes of direction, sudden stop-and-go actions, and leg power are important keys to successful performance in many athletic activities, especially basketball.

Basketball players were discouraged from weight training or any sport-specific pertaining to resistance work in near past times. Experts once thought that these activities were detrimental to the athlete. But it has changed recently. Trainers, coaches and conditioners now understand the importance of weight training, conditioning and specialized drills and their role in the advanced of the game of basketball. They are also aware of that sport-specific strength and conditioning programs directly affect the athletes. In the most challenging basketball league, NBA, for example, basketball is a different game than it was 10 or 15 years ago. Players are robust, stronger, quicker, and more explosive. Because players know how beneficial physical conditioning is for basketball, how it improves their game (Sigmon, 2003). It is well known that when a muscle is subjected to a high intensity training program, it responds to these loads by increasing the cross sectional area of the muscle (Tesch & Larson, 1982).

Strength and conditioning programs are also important for injury prevention. Hamstring injury is a common problem in sports which involve sudden actions, acceleration and deceleration movements. Inadequate hamstring strength, strength imbalance between hamstring and quadriceps and bilateral hamstring deficits may cause injuries (Morgan-Jones, T Cross, MJ Cross, 2000). All these factors can be improved with a proper training. One of the newest hamstring training is Nordic exercise which is concentrated on eccentric hamstring strength.

Quadriceps muscle group is especially used in athletic activities rather than hamstring muscle group. So there should be an accepted strength ratio between hamstring and quadriceps muscle groups in order not to have injury. It may be advantageous to consider the continuation of lower extremity strength training as a method of injury prevention; specifically a strength training program that targets the hamstring and quadriceps and focuses on improving the co-contractibility of these two muscle groups. Since the hamstring and quadriceps function during landing and cutting, and provide joint stability during rapid contractions such as jumping and kicking. It may prove invaluable to evaluate changes in the isokinetic peak torque, time to peak torque, and the agonist-antagonist relationship of the hamstring and quadriceps muscle groups after implementing such a program (Lephart, Ferris, Riemann, & Myers 2002; Barata et al, 1988). 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).

Strength training has beneficial effects on neuromuscular coordination and it may be contribute to improve proprioception performance of player. Proprioception has many definitions, the most general one is the ability to sense limb and body position in space (Prentice, 1999). Proprioception is ascribed to neuromuscular control during fine motor movements, muscle reflex, and dynamic joint stability (Lephart, Pinciver, Giraldo, & Fu, 1997). Proprioception also supports the ability to maintain a stable base of support throughout dynamic and static activities (Palmieri, Ingersoll, Stone, & Krause, 2002). These are indispensable components of movement during sport participation because they give the athlete a self-assessment of extremity position and movement throughout activity.

Proprioception is also inevitable for optimum joint function in sports. Because sport activities are not static normally, the dynamic component of proprioception is extremely important. The static and dynamic components of proprioception provide an ability to adapt body position to the activity for athletes (Palmieri, Ingersoll, Stone, 2002). Efficient proprioceptive abilities are important in athletics because of the reduced risk of injury during sport participation (Konradsen, 2002). Lephart et al. (1997) emphasized that the combination of mechanical imbalance and lacking in proprioceptive abilities contribute to functional instability within a joint, and could be resulted in further injuries.

Strict proprioception training is not the main target but it can be considered as important secondary focus in specific sport area. The focus is specific and relative to the particular sport in which the athlete is involved. Because the training background of an athlete varies depending on the sport that the athlete participates. Proprioceptive abilities of a particular athlete will likely be different than those of an athlete from a different sport. For example, basketball training and soccer training are not similar. Basketball events take place on a firm and flat surface, while soccer events generally take place on the fairly flat, yet forgiving surface of natural or artificial grass. So differences in sport training background may result in the athletes in a particular sport having greater overall proprioceptive ability than athletes who participate in another sport.

Jumping is a fundamental human movement that requires the complex coordination of both upper and lower limbs. Vertical jump tests are used to measure the explosive power of the legs

The vertical jump has been considered an integral part of many sport skills. Many basketball skills contain vertical jumps which are performed with bilateral symmetry of the lower extremity joints and are executed from a two-footed takeoff. Therefore, improved vertical jump performance is believed to enhance the overall capabilities of the athlete in the specific sport skill. In order to improve vertical jump ability, most training programs for basketball players include jumping exercise or plyometric drills which are based on the stretch-shortening cycle of muscle contraction.

The vertical jump has been studied to identify the lower extremity joint sequence that produced the superior jump performance. Winter, (1979) suggested that the vertical jump projected the body by developing the explosive power from a sequential pattern of joint actions which progressed from proximal to distal in the lower extremity joints.

Jumping activities have received much attention by coaches, conditioners and investigators who are interested in improving athletic performance. The question being addressed are how technique, ground forces, stresses to the body, and individual body segments affect and contribute to activities requiring jumping skills. The vertical jump is one of the most studied movements in athletics. The reason for this is that vertical jump is one of the most commonly applied movements in many athletics (Harmon, M.T. Rosenstein, Frykman, R.M. Rosenstein 1990). Coaches and physical educators use the vertical jump to assess an athlete's leg strength, overall power and athletic ability (Shetty, Spooner, Barnum, & Lightsey, 1985). For this reason the vertical jump has been considered a valid contributor to one's success in sport activities (Shetty & Etnyre, 1989).

Strength, Jumping ability and proprioception are three important elements for desired performance. The purpose of this study was to investigate the Nordic hamstring strength training (NHST) program on (1) leg power, (2) vertical jump, (3) and proprioception measurements of 10-12 years old male basketball players. The findings of this study could possibly be benefited in trainings of basketball players

1.1 Hypotheses

- NHST program will increase the PT:BW score.
- NHST program will increase the H/Q strength ratio.
- NHST program will increase the explosive strength.
- NHST program will increase the proprioceptive sense at the knee joint.

1.2 Purpose of the Study

1. To compare extension and flexion PT:BW scores for control and NHST groups.
2. To compare H/Q strength ratio for pre and post tests between control and NHST group
3. To compare jumping measurements for pre and post tests between control and NHST group
4. To compare proprioceptive sense between control and NHST group.

1.3 Limitations

1. The subject population was limited to 10-12 years old male basketball players.
2. The investigation is was limited to absence of sedentary group.
3. The subject is limited by number of subjects.
4. The subject is limited by sex of subjects.
5. The precision of the torque readings was limited to the recording accuracy of the BIODEX isokinetic apparatus, the BIODEX software, the computer and manual calibration process.

1.4 Assumptions

1. Subjects received enough rest between trials that fatigue is not a confounding variable.

2. It was assumed that each participant understood directions and were able to perform maximally in regards to the jumping and isokinetic strength tests.
3. Both groups were equally motivated in completing the tests.

1.5 Significance of the Study

Hamstring muscle strains are common injuries when sprinting, the deceleration phase shortens, requiring a higher eccentric activation of the hamstrings to compensate the forward momentum, and the forces that influence the hamstrings may then cause tearing in the muscle–tendon unit in sports with high demands such as basketball (Garrett, 1990).

Muscle strength deficiency has been proposed as one of several risk factors for hamstring injury. Strength training advocated as a preventive measure in order to avoid hamstring muscle injuries. If strength is a predictor hamstring strains, the next question is how to build eccentric hamstring strength most effectively. In general, muscles adapt to training in a very specific manner. However, studies on the specificity of hamstring strengthening are few, and with conflicting results (Ryan et al., 1991; Kaminski et al., 1998). Moreover, to make it easier to include such training in the regular training programs, e.g., for basketball teams, there is a need to develop hamstring strength exercises that are simple and can be performed in the field without special equipment.

Therefore the aim of study was to determine whether the Nordic hamstring strength exercise results in favorable adaptations. By means of these newly adapted eccentric exercises athletes could be prevented from hamstring injuries and also it might be helpful to increase sport specific performance.

CHAPTER II

REVIEW OF LITERATURE

The examination of the relevant literature revealed a limited amount of research on the effects of Nordic hamstring strength exercise on selected physiological and fitness parameters. The related studies are represented according to their relevance in the following part.

Mjolsnes and his colleagues (2004) worked on comparing the effects of a 10-week training program with two different exercises – traditional hamstring curl (HC) and Nordic hamstrings (NH), a partner exercise focusing the eccentric phase – on muscle strength among male soccer players. Subjects were 21 well trained players who were randomized to NH training (N=11) or HC training (N=10). The programs were similar, with a gradual increase in the number of repetitions from two sets of six reps to three sets of eight to 12 reps over 4 weeks, and then increasing load during the final 6 weeks of training. Strength was measured as maximal torque on a Cybex dynamometer before and after the training period. In the NH group, there was an 11% increase in eccentric hamstring torque measured at 601 s_1, as well as a 7% increase in isometric hamstring strength at 901, 601 and 301 of knee flexion. Since there was no effect on concentric quadriceps strength, there was a significant increase in the hamstrings:quadriceps ratio from 0.89 _ 0.12 to 0.98 _ 0.17 (11%) in the NH group. No changes were observed in the HC group. NH training for 10 weeks more effectively develops maximal eccentric hamstring strength in well-trained soccer players than a comparable program based on traditional HC.

Askling et al (2005) examined the whether a preseason strength training program for the hamstring muscle group – emphasizing eccentric overloading could affect the occurrence and severity of hamstring injuries during the subsequent competition season in elite male soccer players. Thirty players from two of the best premier-league division teams in Sweden were divided into two groups; one group received additional specific hamstring training, whereas the other did not. The extra training was performed 1-2 times a week fro 10 weeks by using a special device aiming at specific eccentric overloading of the hamstrings. Isokinetic hamstring strength and maximal running speed were measured in both groups before and after the training period and all hamstring injuries were registered during the total observational period of 10 months. The results showed that the occurrence of hamstring strain injuries was clearly lower in the training group (3/15) than in the control group (10/15). In addition, there were significant increases in strength and speed in the training group. However, there were no obvious coupling between performance parameters and injury occurrence. These results indicate that addition of specific preseason strength training for the hamstring – including eccentric overloading – would be beneficial for elite soccer players, both from injury prevention and from performance enhancement point of view.

Ayed (1990) in his study tried to examine the effects of a six week plyometric training program on selected physiological and physical fitness parameters, twenty four basketball players (14-18 yrs) were utilized to perform anaerobic power and anaerobic capacity tests. In addition subjects performed a vertical jump, standing long jump, 40 yard dash and one repetition maximum squat. The subjects were randomly placed in an experimental group or control group, and the groups were randomly designated as experimental or control group. Before the treatment was given, a pre-test was conducted fro both groups. Following the six week treatment the vertical jump (cm) and standing long jump of the plyometric training group increased ($p<.05$). Also, after treatment the vertical jump in kilograms meter/seconds was higher for the plyometric group when compared to the control group (130.3 vs. 120.0 kgm/s). A significant chance was seen in the 1 RM squat for both groups ($p<.05$), with the experimental group increasing from 75.3 to 96.3 kg, while the control group increased from 81.1 to 96.0 kg. No significant effect of plyometric training on 1 RM squat was seen. The experimental group decreased in the 40 yard dash time from 5.3 to 5.1 seconds. However, these changes were not statistically significant. Post-treatment anaerobic power (watts) for both groups was significantly different ($p < .01$). The experimental group increased from 559.3 to 619 watts and the control group increased from 516.9 to 579.7 watts. Also, a significant change was seen in the mean anaerobic power (watts/kg) for both groups after treatment ($p < .01$) with the experimental group increasing from 7.65 to 8.37 w/kg while the control group increased from 6.97 to 7.79 w/kg. no significant effect of plyometrics on anaerobic power was observed. Post-treatment anaerobic capacity (watts) for both groups was significantly different ($p < .01$). After treatment, post anaerobic capacity (watts) increased in the experimental group from 466.6 to 501.5 watts and for the control group from 414.3 to 456.2 watts. Also, following treatment there was a significant chance in the mean anaerobic capacity (w/kg) for both groups ($p<.05$) with the experimental group increasing from 6.4 to 6.8 w/kg, while the control group increased from 5.6 to 6.2 w/kg. No significant plyometric training administered in this investigation can significantly improve the vertical jump and standing long jump abilities. Furthermore, the findings of this study suggest that plyometric training does not elicit alterations either improving leg muscle strength or in improving power output as measured by the want compared to the control group.

One of the other researchers (Buchanan, 2003) studied on the gender differences in anterior cruicate ligament (ACL) injury rates, the purpose of this study was to assess the leg strength of female and male basketball players ages 9-10, 12-13 yr old, corresponding to preubescence, periupbescence and post pubescence. Composite relative torques for hip, knee and ankle perarticular muscles and antigravity muscles were used to test hypotheses that 1) strength would increase with age, 2) prebescente and peripubescent female and male players would have similar strength, and 3) postbubescent male players would be stronger than female players. Fifty basketball players (9-10 yr old:7 F, 6 M; 12-13 yr old:10 F, 11 M; 16-22 yr old: 9 F, 7 M) with intact knee ligaments and menisci consented to concentric isokinetic strength testing of hip, knee and ankle musculature, Following gravity correction and body mass normalization peak torques within legs were summed to determine strength dominance. Ankle, knee and hip composite variables were sums of periarticular muscle torques; antigravity composites were sums of ankle plantar flexor, knee extensor and hip extensor torques. For 9-10 vs. 12-13 yr olds, small differences among all measures favoring older players and boys were not significant. Among 12-13 and 16-22 yr olds, older players were significantly stronger on all measures except ankle, and male player were consistently significantly stronger than female players. After puberty, female basketball players are weaker then male players, which may contribute to greater risk of ACL injury. Strength differences are not isolated to knee periarticular muscles. These findings suggest female basketball players should begin strength training that targets the entire lower extremity musculature before high school.

Hamstring injuries are the most common injury sustained by elite Australian football players and result in substantial costs because of missed training time, unavailability for matches and lost player payments (Gabbe et al., 2006). Evidence to support proposed risk factors for hamstring injury is generally lacking, limiting the development of appropriate prevention strategies. To identify intrinsic risk factors for hamstring injury at the elite level of Australian football. A prospective cohort of 222 players underwent baseline measurement in the form of a self-report questionnaire and a musculo-skeletal screen during the preseason period of the 2002 Australian football season. Injury surveillance and exposure data were collected for the full season. Logistic regression analyses were used to identify independent predictors of hamstring injury in this group of players. Thirty-one players sustained a hamstring injury. A past history (previous 12 months) of hamstring injury and increasing age were found to be independent predictors of hamstring injury. Older players and those with a previous history of hamstring injury are target groups for further research and implementation of injury prevention strategies. Restricted ankle dorsiflexion range of movement warrants consideration in the development of prevention programs for hamstring injury.

Ghanima, (1986) was studied on the effects of a six-week exercise and rope jump program on AAHPERD Health Related Physical Fitness Test scores of high school females in Jordan. Sixty-two students, aged 15 to 16 years, enrolled in the 10th grade physical education classes in the National Orthodox School in Amman, Jordan, during the spring semester of 1986, were subjects. Pre- and post-tests (administered according to directions outlined in the AAHPERD Test Manual) were given to two groups. One group, composed of 31 students, participated in a designed exercise and rope jump program. The exercise and rope jump program consisted of warm-up, conditioning exercise, rope jump, and cool-down periods. The other group of 31 students participated in a regular physical education class. These students chose to participate in one or more sport activities: basketball, volleyball, team handball, and ping pong. All subjects participated in 18 sessions, three times each week for 30 minutes, in a six-week period. Pre-and post-test scores were recorded for the one-mile jog/walk, body composition, sit-ups, and flexibility tests. The results showed that subjects in the exercise and rope jump program scored significantly higher in all four components. Subjects who participated in the exercise and rope jump program scored significantly better in all four components than subjects who participated in the regular physical education classes. Subjects who participated in the regular physical education class did not score significantly higher in any of the four components.

Canavan (2003) in his study worked on rate of knee injuries, while playing the sport of basketball. Many females injure their anterior cruciate ligament, while landing from a jump. The three purposes of this study were: (1) to evaluate the kinetic and kinematic effects of two different arm positions, (Overhead and Anterior), while holding a basketball, during bilateral (BO, BA) and unilateral leg landing (UO, UA), from a.30 meter box; (2) to test the effect of a jump training program on landing characteristics and on lower extremity strength and vertical jump (3). Twenty female college aged recreational basketball players, (10 intervention, 10 control), participated in the study. A Qualisys four camera system, Biodex dynamometer, AMTI and Kistler force plates were used for analysis. Three way mixed procedure repeated measure ANOVA's (2 x 2 x 4) (group x time x condition), were used to determine the differences between the landing conditions and between the control and intervention groups for the landing test over time. Paired t-tests were used to analyze the vertical jump and lower extremity strength for the intervention group. The UA landing condition produced longer time to peak moment z (Mz) positive (P = .010) and negative (P = .008), compared to BO. The intervention group demonstrated decreased peak landing force (Fz), following participation in the program ($P < .0001$) and a slower rate to peak Fz/body weight. There were no significant improvements in the vertical jump (p = .6044) and average power (p = .6778) in the post test for the intervention group. Right knee peak extension torque increased at 180 degrees/sec (p = .0033) for the intervention group. Single leg landing with arms held anterior may be less safe than landing with both legs with arms overhead. Participation in the jump training program resulted in increased in decreased landing forces, decreased rate to peak Fz, and improved right quadriceps strength.

The incidence of hamstring muscle injuries in professional rugby union is high, but evidence-based information on risk factors and injury-prevention strategies in this sport is limited (Brooks et al., 2006). To define the incidence, severity, and risk factors associated with hamstring muscle injuries in professional rugby union and to determine whether the use of hamstring strengthening and stretching exercises reduces the incidence and severity of these injuries. Team clinicians reported all hamstring muscle injuries on a weekly basis and provided details of the location, diagnosis, severity, and mechanism of each injury; loss of time from training and match play was used as the definition of an injury. Players' match and training exposures were recorded on a weekly basis. The incidence of hamstring muscle injuries was 0.27 per 1000 player training hours and 5.6 per 1000 player match hours. Injuries, on average, resulted in 17 days of lost time, with recurrent injuries (23%) significantly more severe (25 days lost) than new injuries (14 days lost). Second-row forwards sustained the fewest (2.4 injuries/1000 player hours) and the least severe (7 days lost) match injuries. Running activities accounted for 68% of hamstring muscle injuries, but injuries resulting from kicking were the most severe (36 days lost). Players undertaking Nordic hamstring exercises in addition to conventional stretching and strengthening exercises had lower incidences and severities of injury during training and competition. The Nordic hamstring strengthening exercise may reduce the incidence and severity of hamstring muscle injuries sustained during training and competition.

Iossifidou and his friends (2005) tried to examine joint power generation during a concentric knee extension isokinetic test and a squat vertical jump. The isokinetic test joint power was calculated using four different methods. Five participants performed concentric knee extensions at 0.52, 1.57, 3.14 and 5.23 rad · s −1 on a Lido isokinetic dynamometer. The squat vertical jump was performed on a Kistler force plate. Kinematic data from both tests were collected and analyzed using an ELITE optoelectronic system. An inverse dynamics model was applied to measure knee joint moment in the vertical jump. Knee angular position data from the kinematic analysis in the isokinetic test were used to derive the actual knee angular velocity and acceleration, which, in turn, was used to correct the dynamometer moment for inertial effects. Power was measured as the product of angular velocity and moment at the knee joint in both tests. Significant differences ($p < 0.05$) were found between mean peak knee joint power in the two tests (squat vertical jump: 2255 ± 434W; isokinetic knee extension: 771 ± 81W). Correlation analysis revealed that there is no relationship between the peak knee joint power during the vertical jump and the slow velocity isokinetic tests. Higher isokinetic velocity tests show better relationships with the vertical jump but only if the correct method for joint power calculation is used in the isokinetic test. These findings suggest that there are important differences in muscle activation and knee joint power development that must be taken into consideration when isokinetic tests are used to predict jumping performance.

Conventionally, the H:Q strength ratio is calculated by dividing the maximal knee flexor (hamstring) moment by the maximal knee extensor (quadriceps) moment measured at identical angular velocity and contraction mode (Aagaard et al., 1998). The agonist-antagonist strength relationship for knee extension and flexion may, however, be better described by the more functional ratios of eccentric hamstring to concentric quadriceps moments (extension), and concentric hamstring to eccentric quadriceps moments (flexion). We compared functional and conventional isokinetic H:Q strength ratios and examined their relation to knee joint angle and joint angular velocity. Peak and angle-specific (50°, 40°, and 30° of knee flexion) moments were determined during maximal concentric and eccentric muscle contractions (10° to 90°

of motion; 30 and 240 deg/sec). Across movement speeds and contraction modes the functional ratios for different moments varied between 0.3 and 1.0 (peak and 50°), 0.4 and 1.1 (40°), and 0.4 and 1.4 (30°). In contrast, conventional H:Q ratios were 0.5 to 0.6 based on peak and 50° moments, 0.6 to 0.7 based on 40° moment, and 0.6 to 0.8 based on 30° moment. The functional H:Q ratio for fast knee extension yielded a 1:1 relationship, which increased with extended knee joint position, indicating a significant capacity of the hamstring muscles to provide dynamic knee joint stability in these conditions. The evaluation of knee joint function by use of isokinetic dynamometry should comprise data on functional and conventional H:Q ratios as well as data on absolute muscle strength. The ratio of maximal isokinetic hamstring muscle strength relative to maximal isokinetic quadriceps muscle strength (H:Q ratio) is a parameter commonly used to describe the muscle strength properties about the knee joint.[3, 12,19] The H:Q ratio has conventionally been calculated as maximal knee flexion strength divided by maximal knee extension strength obtained at a given knee angular velocity and contraction mode (isometric, concentric, eccentric). For example, the conventional concentric H:Q strength ratio is calculated by dividing maximal concentric knee flexor (hamstring) moment by the maximal concentric knee extensor (quadriceps) moment obtained at a given joint angular velocity. It has recently been suggested that the agonist-antagonist strength relationship for knee extension and flexion may be better described by a functional H:Q ratio of eccentric hamstring to concentric quadriceps muscle strength (Hecc:Qcon, representative of knee extension) or concentric hamstring to eccentric quadriceps muscle strength (Hcon:Qecc, representative of knee flexion).[2] As an example, the functional H:Q ratio for knee extension is calculated by expressing maximal eccentric hamstring moment relative to maximal concentric quadriceps moment obtained at given angular velocity. In conceptual terms, the conventional H:Q ratio implies that concentric (or eccentric) contraction would take place for the knee extensors and flexors simultaneously. However, true knee joint movement only allows eccentric hamstring muscle contraction to be combined with concentric quadriceps muscle contraction (during extension) or vice versa (during flexion). As such, the conventional H:Q ratio has been suggested to merely indicate whether a qualitative similarity exists between the moment-velocity patterns of the hamstring and quadriceps muscles, as suggested by a constancy in conventional H:Q ratios across contraction modes and speeds.2 While addressing the use of isokinetic dynamometry in the assessment of human muscle function, several authors have focused on the aspect of conventional isokinetic H:Q strength ratios.3, 7, 12,19 Various terms have been used for this H:Q ratio: reciprocal muscle group ratio,3,12 agonist: antagonist muscle ratio,19 and torque ratio.7 The relevance of this strength variable has appeared just as diverse.

One review reported it to be arguably more important than the maximal moment for the assessment of human muscle function, whereas another review concluded the H:Q strength ratio to be an idiosyncratic parameter when used as a measure for successful rehabilitation in individual subjects. Even though the presence of non-optimal (i.e., lowered) H:Q strength ratios has been suggested to be associated with an increased risk of musculoskeletal injury, such a relationship has not yet actually been demonstrated.8 Active quadriceps muscle contraction may create significant anterior tibial translation or shear, particularly at high contraction forces and with the knee toward full extension. It may also produce substantial internal rotation of the tibia relative to the femur. In addition to ligamentous constraints (the ACL), the amount of active co-activation of the hamstring muscles will significantly contribute to counterbalance this tibial shear or rotation. The functional Hecc:Qcon ratio introduced earlier may be used to indicate the extent to which the hamstring muscles are capable of counteracting the anterior tibial shear induced by maximal quadriceps muscle contraction. Values for conventional H:Q strength ratios of 0.40 to 0.50 have been reported based on peak moments, independent of contraction mode and velocity. In contrast, a functional Hecc:Qcon ratio of about 1.00 was found for fast isokinetic knee extension, indicating a significant capacity of the hamstring muscles to provide dynamic joint stabilization during active knee extension. This capacity for dynamic joint stabilization was enhanced after high-resistance strength training but unchanged after fast low resistance types of strength training.1 Low values (0.30) have been reported for functional H:Q ratios representative of fast isokinetic knee flexion (Hcon:Qecc), which suggests that the hamstring muscles have a reduced capacity for dynamic knee joint stabilization during forceful knee flexion movements with simultaneous eccentric quadriceps muscle contraction. Recent studies have proposed that combining data on conventional H:Q ratios with data on functional H:Q ratios and values of absolute strength will result in a more thorough description of the muscular strength properties at the knee joint than that revealed by the conventional H:Q ratio alone. More information may thereby be gained on the evaluation of eccentric hamstring muscle function, including its potential for providing dynamic knee joint stability during fast forceful knee extension movements and its possible enhancement in response to specific types of physical training. The purpose of the present study was to examine and compare the conventional and functional H:Q strength ratios obtained during concentric and eccentric muscle contraction in maximal isokinetic knee extension and flexion movements. This comprised an analysis of the influence from movement velocity as well as knee joint position on the calculation of the different H:Q strength ratios.

An other study (Lee, 2003) was performed to examine the H/Q ratios of female soccer athletes, and to test the effects of a six week strength training program on these ratios. Twelve NCAA Division I female soccer athletes volunteered for this study. Subjects completed two practice sessions, a pretest, six weeks of strength training, and a posttest. The isokinetic pre and post testing was performed on KIN-COM dynamometer, with the trials in a set order (concentric 240,180,60/s and eccentric 60,180,240/s) Gravity correction was used on all trials. The H:Q strength ratio was examined conventionally (concentric hamstring: concentric quadriceps) and functionally (eccentric hamstring: concentric quadriceps). Both conventional and functional ratios showed significant differences in the non-dominant and dominant legs, and angular velocities (60,180,240/s.) Functionally, there was a significant difference in the pre to posttest strength ratios. Conventionally, there was no significant difference in the pre to posttest strength ratios. These findings show that the six week strength training program elicited significant functional improvements in the H:Q strength ratio.

Rosene and his colleagues (2001) examined the differences in the concentric H:Q ratio among athletes in different sports at 3 velocities. We measured the H:Q ratio of both knees using the Biodex Pro Isokinetic Device. Eighty one male and female collegiate athletes were participated in this study. We performed analyses for sport, velocity, and side of body for each sex. To compare the means of the concentric H:Q ratios for mean peak torque and mean total work, a 2 x 3 x 4 mixed factorial analysis of variance was computed for women and a 2 x 2 x 3 mixed factorial analysis of variance was computed for men. We observed no significant interactions for men and women fro the concentric H:Q ratio for mean peak torque. There was a significant mean difference among velocity conditions and a significant difference for men with respect to velocity. No significant differences were found for side of body or sport. The H:Q ratio increased as velocity increased. No differences existed for the H:Q ratio for sport or side of body.

Liu-Ambrose et al. (2003) examined the effects of a proprioceptive training program (PT) vs. a strength training (ST) program on neuromuscular function after anterior cruciate ligament (ACL) reconstruction. The second purpose was to establish the determinants of functional ability for the operated limb. Ten participants with unilateral ACL reconstructions were randomly assigned to one of the following 12-week training protocols: (1) isotonic ST, and (2) PT. The outcome measures were: (1) peak torque time of the hamstring muscles (PeakTT), (2) average concentric and eccentric torques of the quadriceps and hamstring muscles, (3) one-legged single hop for distance (SLHD), (4) one-legged time hop (TH), and (5) subjective scores. There was a significant group by time interaction effect for PeakTT ($P=0.017$). The PT group demonstrated greater percent chance in isokinetic torques than the ST group at the end of the 12 week ($P\leq0.05$). Participants in both group demonstrated similar significant gains in functional ability and subjective scores ($P\leq0.014$). Quadriceps strength is a determinant of functional ability for the operated limb (R2=0.72). Both training protocols influenced PeakTT. The beneficial effects of ST on PeakTT appear to be load-dependent, while sufficient practice may be crucial in maintaining PeakTT improvements induced by PT. Proprioceptive training alone can induce isokinetic strength gains. Restoring and increasing quadriceps strength is essential to maximize functional ability of the operated knee joint.

Older adulthood is accompanied by declines in muscular strength, coordination, function, and increased risk of falling (Thompson, 2001). Resistance training increases muscular strength in this population but its effect on proprioception and function is unknown. To evaluate the effect of resistance training on proprioception and function, community dwelling older women (n=34) completed a three month exercise study. A resistance training (RT) group (n=18) underwent supervised weight training three times per week while a non-strength trained control (NSTC) group (n=16) attended twice weekly of supervised, plus once on their own, range-of-motion classes that mimicked the movements of the RT group but without the benefit of muscle loading. Subjects were evaluated at baseline, 6, and 12 weeks for strength, proprioception, and functional performance. Proprioception significantly improved in both groups by 6 weeks. There was no significant difference between groups at any point. Both groups also significantly improved their functional performance measures by 6 weeks and continued to improve significantly by 12 weeks, without significant differences between groups. The RT group made significant strength improvements. The NSTC group made modest improvements in strength in two of the four tests. The percentage of improvement in strength of the RT group was significantly greater than the NSTC group for all strength tests. Our findings suggest proprioception, and not muscle loading, is a key factor in improving functional performance. This challenges current wisdom regarding the unique benefits of resistance training to improve functional ability and broadens the spectrum of exercise options for older adults.

William (2004) set the purpose of his study as to examine the effect of incremental levels of isokinetic concentric muscle exertion on passive reproduction of passive positioning (PRPP) and active reproduction of passive positioning (ARPP) at the knee joint in male and female collegiate soccer and basketball players. Subjects for this study included 20 (10 males and 10 females) volunteers. Subjects performed knee extension and flexion concentric isokinetic exercise until torque output fell below the 10%, 30%, or 50% of maximum hamstring torque for three consecutive repetitions. Subjects were then tested on either PRPP or ARPP following the isokinetic exercise session. Following testing of the first independent measure, subjects were given a 20 minute rest period. Following the rest period, the procedure was repeated for two more exercise sessions. Testing of PRPP and ARRP was counterbalanced between trials and sessions in order to decrease the chance of a learning effect on the results of each testing session. The major findings of this study indicate that increasing levels of exertion do not have a significant effect on either active reproduction ability [ARPP-45° ($F_{2,38} = 0.88$, $p = 0.42$), ARPP- 30° ($F_{2,38} = 0.69$, $p = .51$), and ARPP-15° ($F_{2,38} = .23$, $p = 0.80$) or passive reproduction ability [PRPP-60°·s^{-1} ($F_{2,38} = 0.25$, $p = .78$) , PRPP-90°·s^{-1} ($F_{2,38} = 0.31$, $p = 0.73$), and PRPP120°·s^{-1} ($F_{2,38} = 1.58$, $p = 0.22$)]. However, the reliability of all PRPP and ARPP measures at 15° demonstrated poor reliability. Fatigue has long been theorized to be a contributing factor in decreased proprioceptive acuity, and therefore a contributing factor to joint injury. The lack of significant findings may be explained by the idea that as the level of muscle fatigue increases muscle spindle discharge increases. Poor reliability for all PRPP and ARPP at 15° draws into question the meaningfulness of the results for these measures.

A collegiate-level soccer player was instructed by her coach to incorporate a proprioceptive component into her training program (Owen et al.,2006). He suggested that she purchase a balance board and immediately begin a program that he designed. She approached her physical therapist (SJF) for more information. I immediately recognized that, because of her sex and sport of choice, she would be at high risk for an anterior cruciate ligament (ACL) injury. It is estimated that as many as 2,200 ACL ruptures per year occur in female collegiate athletes in both the recreational and competitive ranks. Treatment and rehabilitation costs are estimated at $17,000 per ACL injury, which do not take into account the potential loss of long-term participation, loss of scholarship funding, and future disability from arthritic changes in a reconstructed knee, for these reasons, a shift toward injury prevention is warranted.

Injury prevention for the ACL can take many forms, including a variety of training protocols, athlete education, and bracing. Current studies focus on neuromuscular training as a preventive measure, with programs that include strength, flexibility, plyometrics, sport-specific agility drills, speed enhancement, balance, and athlete education. A clinician who understands the individual components of these programs could optimize injury prevention and aid athletes in appropriate program design and equipment purchases. In the case of this athlete, my colleagues and I focused on the use of proprioception or balance training and its effect on incidence of ACL injury.

They searched the literature to answer our clinical question "Is there evidence that proprioception or balance training can prevent ACL injuries in athletes without previous ACL insufficiencies?" and our secondary question "What balance training protocols are used in ACL injury prevention programs?"

CHAPTER III

MATERIALS AND METHODS

Isokinetic (quadriceps and hamstring muscle peak torque to body weight) and proprioceptive parameters were measured at the Medical Center Physiotherapy Laboratories of the Middle East Technical University.

3.1 Subjects:

The subjects for this investigation were utilized from Middle East Technical University Sports Club basketball teams. All subjects in this investigation were healthy male volunteers, (N = 16 for experimental group, N = 11 for the control group) between age of 10 -12 years, and they were fully informed of the risks and discomfort associated with the investigation before giving their written consent to participate. Prior to participation in the investigation each subject was informed of the risks, discomfort and procedures involved in participating in this investigation. Each subject who agreed to participate in this investigation signed a consent form along their parent.

3.2 Experimental Design:

Subjects were divided into two groups of Nordic Hamstring Strength Training (NHST) group, participated in basketball training and in addition performed Nordic Hamstring Strength Training (Figure 1), and the control group, participated in basketball training only.

Subjects were pre-tested 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. At the conclusion of the 5 week training program all subjects were again participated for the all test measurements. During the testing procedures, each subject appeared on two separate occasions. The first meeting was used to determine vertical jump, and free jump. Each test was administered before training program began. Post-test were administered at the termination of the five week training protocol (Figure 5).

3.3 Treatment

Subjects, who were engaged in NHSTG, participate in basketball activities which involved the fundamental skills of passing dribbling and shooting practice drills and competition plus Nordic Hamstring Training program (Figure 2). Control group were only participated basketball trainings.

3.3.1 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.

Figure 1. Nordic Hamstring Training Exercise (Adapted from Oslo Sports Trauma Research Center 2004)

Week	Sessions per week	Sets-Reps	Technical notes
1	1	2/5	The subjects is encouraged to resist falling as long as possible
2	2	2/6	Subject tries to reduce lowering speed
3	3	3/6	Subject can resist falling even longer, and for an increased number of repetitions
4-5	3	3/8-12	Load on the subject increases by allowing more speed in the start phase as well as another gradual increase in repetitions

Figure 2. Nordic Hamstring Training Protocol

3.4 Isokinetic Testing

An isokinetic dynamometer (Biodex®, Medical System, New York, U.S.A.) was used as a measure of muscle strength. All tests were performed according to the isokinetic protocol suggested by the manufacturer in order to ensure the quality and validity of testing. The dynamometer was calibrated prior to the study. Participants were placed in a comfortable upright-seated position on the chair of the dynamometer and their thigh, pelvis and torso were secured using straps in order to minimize extraneous body movements. The lateral femoral condyle was used as the bony landmark by matching the axis of rotation of the knee joint and dynamometer. The axis of rotation of the participants was aligned, stabilized and the ranges of motion stops were set at 90 degrees flexion and full extension. Values for the isokinetic variables measured were automatically compensated for gravity using the Biodex Advantage Software Rev. 3.27.

Figure 3. Isokinetic Measurements with Biodex®, (Medical System, New York, U.S.A)

Tests were performed at angular velocities of 60º/sec and all subjects were tested (Figure 3) for both concentric and eccentric knee extension and flexion strength on the dominant and non-dominant leg. Prior to each testing session, the subjects warmed-up and stretched their body with the aid of an assistant coach and then subjects performed three submaximal trial contractions of knee extension and flexion. The main testing protocol consisted of five maximum concentric and eccentric efforts for 60°/sec of angular velocity. A three minute rest was provided for each test.

3.5 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 45 degrees of knee flexion by the examiner at an angular velocity of 5º/s (Figure 4). Subjects concentrated on the sensation of the presented angle (45 degrees of knee flexion) for 3 seconds. The subject's leg was then returned passively to the starting position by the examiner.

Figure 4. Proprioception Measurement with Biodex®, (Medical System, New York, U.S.A)

Following a three second rest period the dynamometer passively moved the subject's leg at one of the test velocity 45 degrees of knee flexion for 10 seconds. The subject attempted to stop the dynamometer movement at the presented joint angle (45 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 AAD was used for statistical analysis.

3.6 Jumping Measurements

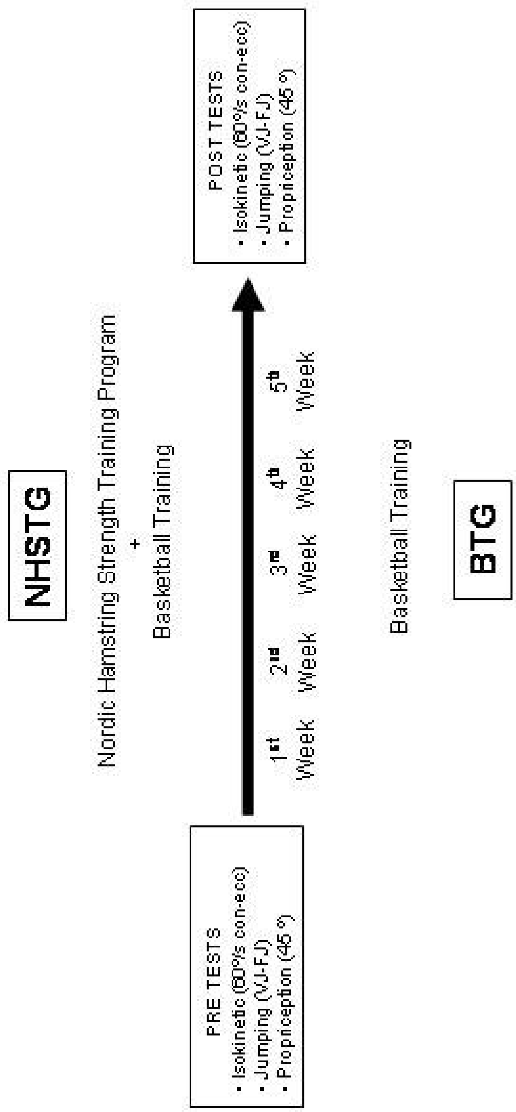
The vertical jump (VJ), and Free Jump (FJ) test was used to measure each subject's ability to raise his center of gravity. Jumping height was measured by Boscow Timing Mat. The subjects were given instruction on correct jumping. A minute rest was given to subjects between the tests. VJ test performed with no arm movement (two hands on hip). FJ test performed with allowed using their arms.

Subjects place on a Boscow Timing Mat and jumps as high as possible and landed on mat nearly fully extended legs. Subjects performed three trials for each tests. A record of all trials was recorded and the average jump used in calculations.

3.7 Analysis of Data

The SPSS for Windows (11.5) software was used for statistical analysis. Pre and Post test differences between experimental and control group was investigated by MANOVA. Paired t test was used to evaluate the differences between pre and post tests of both groups. The level of statistical significance was $p < 0.05$.

Figure 5. Study Design



CHAPTER IV

RESULTS

4.1 Subject Characteristics

In this study, 16 of the subjects were located in the experimental group (Nordic Hamstring Strength Training Group) and 11 were defined as the control group. Both groups were the teams of the METU sports club and performing the generally same training program. Physical characteristics can be seen from table 1. The mean age of the experimental group players was 10.6 ± .5 years (ranging from 10 to 11 years) and 11.7 ± .5 (ranging from 11 to 12 years) for control group. The mean body weight for the experimental group and control group were 42.8 ± 7.2 kg (ranging from 32 to 58 kg) and 46.6 ± 5.6 kg (ranging from 37 to 55 kg), respectively. The mean heights for the experimental group and control group were 1.56 ± .07 m (ranging from 1.47 to 1.67 m) and 159 ± .05 m (ranging from 1.54 to 1.68 m).

Table 4.1 Physical characteristics of the subjects.

	N	Age (yrs)	Height (m)	Weight (kg)	BMI (kg/m^2)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Experimental G.	16	10.6 ± .5	1.56 ± .07	42.8 ± 7.2	17.5 ± 2.7
Control G.	11	11.7 ± .5	1.59 ± .05	46.6 ± 5.6	18.2 ± 1.4

Table 4.2.1 Multivariate Analysis of Variance Pre-Test Results[#]

Effect	Value	F	Hypothesis df	Error df	Sig.	Eta Sq.	Observed power[a]
Group	.558	.561	18	8	.853	.558	.152
	.442	.561	18	8	.853	.558	.152
	1.261	.561	18	8	.853	.558	.152
	1.261	.561	18	8	.853	.558	.152

[#] All values in the MANOVA above were given according to Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root.

[a] Computed using alpha = .05

According to the results of the MANOVA, Table 4.2.1 displays the results of MANOVA. Table 4.2.1 indicates, there were no any significant differences between Nordic Hamstring Strength Training Group and control group in pre test scores. Therefore, it can be said that both group was equal at the beginning of the study.

Table 4.2.2 Multivariate Analysis of Variance Post-Test Results[#]

Effect	Value	F	Hypothesis df	Error df	Sig.	Eta Sq.	Observed power[a]
Group	.778	1.560	18	8	.266	.778	.398
	.222	1.560	18	8	.266	.778	.398
	3.510	1.560	18	8	.266	.778	.398
	3.510	1.560	18	8	.266	.778	.398

[#] All values in the MANOVA above were given according to Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root.

[a] Computed using alpha = .05

According to the results of the MANOVA, Table 4.2.2 displays the results of MANOVA. Table 4.2.2 indicates, there were no any significant differences between Nordic Hamstring Strength Training Group and control group in post test scores.

Table 4.3 Comparison of pre and post concentric strength measurements scores (peak torque to body weight) of Nordic Hamstring Strength Training Group.

N= 16		Mean ± SD	t	p
Quadriceps D-L (%)				
	Pre	230.7 ± 24.1	-1.45	.16
	Post	237.4 ± 25.6		
Quadriceps N-L (%)				
	Pre	221.5 ± 33.2	-2.50	.02
	Post	241.4 ± 39.2		
Hamstring D-L (%)				
	Pre	112.1 ± 22.1	-4.44	.00
	Post	129.2 ± 15.9		
Hamstring N-L (%)				
	Pre	107.5 ± 18.7	-4.62	.00
	Post	120.9 ± 18.5		

A paired-samples t test was conducted to compare the pre and post strength measurement scores of Nordic Hamstring Strength Training group. The results indicated that the mean non-dominant quadriceps, dominant hamstring and non-dominant hamstring post strength measurements (M = 241.4, SD = 39.2; M = 129.2, SD = 15.9; M = 120.9, SD = 18.5, respectively) were significantly greater then their mean pre-test scores (M = 221.5, SD = 33.2), t (15) = 2.50, p = .02; (M = 112.1, SD = 22.1), t (15) = 4.44, p = .00; (M = 107.5, SD = 18.7), t (15) = 4.62, p = .00.

Table 4.4 Comparison of pre and post eccentric strength measurements scores (peak torque to body weight) of Nordic Hamstring Strength Training Group.

N= 16		Mean ± SD	t	p
Quadriceps D-L (%)				
	Pre	201.1 ± 34.1	-1.35	.20
	Post	211.9 ± 28.7		
Quadriceps N-L (%)				
	Pre	197.4 ± 28.7	-2.67	.02

Table Continues 4.4

Post	216.9 ± 36.5		
Hamstring D-L (%)			
Pre	244.5 ± 58.6	-1.75	.10
Post	269.5 ± 41.3		
Hamstring N-L (%)			
Pre	252.7 ± 37.9	-1.14	.27
Post	266.0 ± 42.7		

A paired-samples t test was conducted to compare the pre and post eccentric strength measurement scores of Nordic Hamstring Strength Training group. The results indicated that the mean non-dominant quadriceps post strength measurement (M = 216.9, SD = 36.5) was significantly greater then the mean pre-test score (M = 197.4, SD = 28.7), t (15) = 2.67, p = .02.

Table 4.5 Comparison of pre and post both concentric and eccentric strength ratios measurements scores of Nordic Hamstring Strength Training Group.

N= 16	Mean ± SD	t	p
Hcon/Qcon D.L			
Pre	48.8 ± 9.9	-3.20	.01
Post	54.7 ± 7.1		
Hcon/Qcon N.L			
Pre	49.1 ± 8.9	-1.06	.30
Post	50.7 ± 8.6		
Hecc/Qecc D.L			
Pre	121.6 ± 17.5	-1.01	.32
Post	127.9 ± 17.0		
Hecc/Qecc N.L			
Pre	125.0 ± 13.2	.45	.65
Post	123.0 ± 13.8		

A paired-samples t test was conducted to compare the pre and post both concentric and eccentric strength ratios measurement scores of Nordic Hamstring Strength Training group. The results indicated that the mean dominant Hcon/Qcon post strength ratio (M = 54.7, SD = 7.1) was significantly greater then the mean pre-test strength ratio (M = 48.8, SD = 9.9), t (15) = 3.20, p = .01.

Table 4.6 Comparison of pre and post jumping performances of Nordic Hamstring Strength Training Group.

N= 16	Mean ± SD	t	p
Vertical Jump (m)			
Pre	.17 ± .04	-2.87	.01
Post	.20 ± .02		
Free Jump (m)			
Pre	.29 ± .04	-3.12	.01
Post	.32 ± .05		

A paired-samples t test was conducted to compare the pre and post jumping performances of Nordic Hamstring Strength Training group. The results indicated that the mean post vertical, and free jump performances (M = .20, SD = .02; M = .32, SD = .05) were significantly greater then the mean pre-test scores (M = .17, SD = .04), t (15) =2.87, p = .01; M = .29, SD = .04), t (15) =3.12, p = .01.

Table 4.7 Comparison of pre and post proprioceptive sense scores of Nordic Hamstring Strength Training Group.

N= 16	Mean ± SD	t	p
Proprioception D.L (deg)			
Pre	29.8 ± 12.1	.96	.35
Post	26.2 ± 6.6		
Proprioception N.L (deg)			
Pre	25.1 ± 9.2	-.22	.82
Post	25.6 ± 5.7		

A paired-samples t test was conducted to compare the pre and post knee proprioceptive sense scores of Nordic Hamstring Strength Training group. The results indicated no significant difference.

Table 4.8 Comparison of pre and post concentric strength measurements scores (peak torque to body weight) of control group.

N= 11	Mean ± SD	t	p
Quadriceps D-L (%)			
Pre	217.6 ± 27.8	.07	.94
Post	217.2 ± 19.5		
Quadriceps N-L (%)			
Pre	225.7 ± 33.8	.05	.95
Post	225.3 ± 25.3		
Hamstring D-L (%)			
Pre	110.5 ± 20.7	-1.25	.23
Post	117.2 ± 15.6		
Hamstring N-L (%)			
Pre	100.2 ± 25.0	-.56	.58
Post	104.1 ± 14.6		

A paired-samples t test was conducted to compare the pre and post strength measurement scores of control group. The results indicated that there were no differences in pre and post strength measurement scores of control group.

Table 4.9 Comparison of pre and post eccentric strength measurements scores (peak torque to body weight) of control group.

N= 11	Mean ± SD	t	p
Quadriceps D-L (%)			
Pre	196.4 ± 39.4	1.29	.22
Post	180.1 ± 33.8		

Table Continues 4.9

Quadriceps N-L (%)			
Pre	178.6 ± 32.9	-.27	.79
Post	181.1 ± 34.2		
Hamstring D-L (%)			
Pre	247.4 ± 49.0	1.06	.31
Post	232.6 ± 31.9		
Hamstring N-L (%)			
Pre	250.6 ± 42.1	1.71	.11
Post	234.1 ± 46.2		

A paired-samples t test was conducted to compare the pre and post eccentric strength measurement scores of control group. The results indicated that there were no significant differences in pre and post eccentric strength measurement scores of control group.

Table 4.10 Comparison of pre and post both concentric and eccentric strength ratios measurements scores of control group.

N= 11	Mean ± SD	t	p
Hcon/Qcon D.L			
Pre	51.0 ± 7.8	-1.61	.13
Post	53.8 ± 4.6		
Hcon/Qcon N.L			
Pre	44.1 ± 8.7	-1.20	.25
Post	46.8 ± 9.2		
Hecc/Qecc D.L			
Pre	128.3 ± 22.7	-.11	.91
Post	129.2 ± 20.9		
Hecc/Qecc N.L			
Pre	141.8 ± 18.7	1.41	.18
Post	130.2 ± 20.6		

A paired-samples t test was conducted to compare the pre and post both concentric and eccentric strength ratios measurement scores of control group. The results indicated that there were no significant differences in pre and post both concentric and eccentric strength ratios measurement scores of control group.

Table 4.11 Comparison of pre and post jumping performances of control group.

N= 11	Mean ± SD	t	p
Vertical Jump (m)			
Pre	.19 ± .02	-.06	.95
Post	.19 ± .02		
Free Jump (m)			
Pre	.28 ± .03	2.04	.06
Post	.27 ± .03		

A paired-samples t test was conducted to compare the pre and post jumping performances of control group. The results indicated that there were no significant differences in pre and post jumping measurement scores of control group.

Table 4.12 Comparison of pre and post proprioceptive sense scores of control group.

N= 11	Mean ± SD	t	p
Proprioception D.L (deg)			
Pre	26.4 ± 8.2	-.64	.53
Post	28.4 ± 7.6		
Proprioception N.L (deg)			
Pre	28.2 ± 6.2	.85	.41
Post	25.8 ± 7.9		

A paired-samples t test was conducted to compare the pre and post knee proprioceptive sense scores of control group. The results indicated that there were no significant differences in the pre and post knee proprioceptive sense scores of control group.

CHAPTER V

DISCUSSION

The primary purpose of this investigation was to examine the effects of Nordic Hamstring Strength Training on selected physiological and physical fitness parameters. Sixteen experimental and eleven control subjects were utilized in this investigation. The subjects ranged in age from 10 to 12 years. Each of the twenty seven subjects performed jumps (vertical, squat, free and standing long) proprioception and isokinetic measurements in two separate meetings. After the five-week Nordic Hamstring Strength Training Program treatment, a post-test was conducted on the same variables.

The proposed differences that might be seen in the physiological and physical fitness parameters between the experimental (Nordic Hamstring Strength Training plus basketball training) and the control group (basketball training only).

5.1 Isokinetic Strength Measurements

The one of the purpose of this study was to assess the effect of the Nordic hamstring training program on isokinetic variables. As mentioned before there were two groups, experimental and the control one. At the beginning of the study, in pre test measurements, both groups' isokinetic strength scores were not significantly different ($p>.05$). Therefore, about the both groups' physical characteristics, it might be said that they had similar physical characteristics.

In the five weeks of Nordic hamstring strength training, for the experimental group, the quadriceps and hamstrings peak torque to body weight increased at different rates. The quadriceps peak torque to body weight increased 3.8% concentrically, and 5.1% eccentrically. The hamstrings peak torque to body weight increased 13.3% concentrically, and 9.3% eccentrically. These percentages show that the H:Q strength ratio improved from pre to post-test, because the hamstrings increased in strength more than the quadriceps. This was likely due to the emphasis in hamstring strengthening in the training program.

There were statistically significant differences in terms of isokinetic strength testing for the experimental group between the pre and post test. The increase in concentric quadriceps and hamstring strength ($p<.02$, $p<.00$), eccentric quadriceps strength ($p<.02$) and conventional H:Q strength ratio were identified. These results support earlier investigations, for example, Askling et al (2003) reported that by using a special device aiming at specific eccentric overloading of the hamstrings the leg strength of the soccer players were significantly increased after the training period. And also they claimed that addition of specific preseason strength training for the hamstrings – including eccentric overloading – would be beneficial for players, both from injury prevention and from performance enhancement.

However, Clark and his friends (2005) reported that Nordic hamstring strength training has not had a great effect on peak hamstring torque. Clark and his friends (2005) were also demonstrated that there was a dramatic reduction in the quadriceps peak torque between the pre test and post test. These results may be due to a number of factors, like limited number of subjects participating in that study (N = 9).

Mjolnes et al (2004) found that Nordic hamstring strength training has no significant enhancement effect on concentric quadriceps strength, on the contrary, the present study was found significant increase in quadriceps strength in training group. For both studies there can be missing points. For example, in the current study, players in training group continued to be trained their regular training program. That program may be factor for this increase in quadriceps peak torque or may not. This can not be controlled or the other activities can be isolated. In the study of Mjolnes et al (2004) the limited number of subjects may be a factor for non-significant results.

The results of the present study suggest that the training intervention created a greater difference in H:Q ratio in dominant leg from 48.9 ± 10.0 to 54.7 ± 7.1 (11.7%) in the experimental group ($p<.05$). Mjolnes et al (2004) also demonstrated similar findings with the current study that performed eccentric hamstring strength training created significant increase in the H:Q ratio (11%) in the experimental group.

5.2 Jumping Measurements

In pre test measurements there were no significant differences in the average jumping performance in vertical jump, and free jump for the both groups. The subjects in the experimental group, NHSTG demonstrated a significant ($p<.05$) mean improvement in vertical jumping (cm) performance from pre-to-post-treatment. However , the control group BTG increase in vertical jumping ability from pre-to-post-treatment was non-significant ($p<.05$). This results is consisted with the findings of Clark et al (2005).

In the current study, the subjects in the experimental group demonstrated an increase of 15% in vertical jump, 9% in squat jump, 7.5% in free jump from pre-to-post treatment.

5.3 Proprioception Measurements

Researchers have proposed that exercise, rehabilitation, and sport specific training may enhance the proprioceptive sense in the knee (Lephart et al., 1998). Based on these knowledge, in present study, for the experimental group, proprioception measurement was performed before and after strength training. However, between the pre and post test scores there were no any significant difference in the proprioceptive sense of basketball players ($p>.05$). Gear (2004) attempted to examine the effect of incremental levels of isokinetic concentric muscle exertion on passive reproduction of passive positioning (PRPP) at the knee joint in male and female collegiate soccer and basketball players. PRPP for pre to post-test values at all angular velocities and levels of exertion except for angular velocities of $90^{\circ}\cdot s^{-1}$ and

120°□s^{-1} at an exertion level of 50% below maximum hamstring torque showed no significant differences. As muscle fatigue increased and the speed of joint motion (stretch) increased, there was no change in pre-test to post-test passive reproduction ability. These results are also in agreement with current study.

Beside these results, some studies reported that 6-week of strength training has an increasing effect on proprioceptive sense for the trained group (Thompson, 2001). Their findings also suggest proprioception is a key factor in improving functional performance. This challenges current wisdom regarding the unique benefits of resistance training to improve functional ability.

Finally, the current study revealed that NHST has a positive effect on developing the hamstring strength. In other words, these findings suggest that hamstring exercise may be beneficial or helpful for preventing the hamstring injury occurrence and improving the physical performances such as jumping ability. Therefore, specific muscle strength training of the hamstring muscle should be a part of the training program for all athletes. Further research on this aspect of the study is needed to clarify the relationship between strength training and proprioceptive ability.

CHAPTER VI

CONCLUSIONS AND RECOMENDATIONS

6.1. Conclusions

Based upon the findings of the study, it was concluded that Nordic Hamstring Strength Training combine with Basketball Training for five weeks was significantly improved the hamstring dominant and non-dominant leg strength concentrically. Non-dominant quadriceps strength was also increased significantly. The increase in the peak torque of quadriceps strength might be explained by the continued basketball trainings.

In this investigation it was also revealed that H:Q strength ratio was increased significantly in experimental group due to NHST program, despite the observed increment in quadriceps strength.

One of the practical benefit of this study, in terms of the basketball performance, was the increment in the jumping performance in trained group. By means of the NHST program vertical, squat and free jump performances were increased significantly. However, NHST was not improved proprioceptive.

6.2. Recommendations

1. Future research should be carried out to determine the gender effect.
2. Nordic Hamstring exercise should be a part of sports which require jumping because of its ease of implementation, reducing possibility of occurrence of injury and enhancing performance.

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APPENDICES

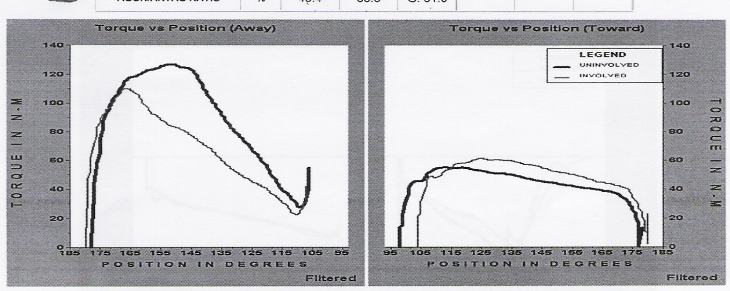
APPENDIX A

ISOKINETIC STRENGTH ASSESSMENT SHEET

Comprehensive Evaluation

Name:	CAGLAR KALKAN	Session:	19.11.2006 13:31:32	Windowing:	None
ID:	BARAN7	Involved:	None	Protocol:	Isokinetic Bilateral
Birth Date:	(dd.MM.yyyy)	Clinician:		Pattern:	Extension/Flexion
Ht:		Referral:		Mode:	Isokinetic
Wt:	47.0	Joint:	Knee	Contraction:	CON/CON
Gender:	Male	Diagnosis:		GET:	20 N-M at 90 Degrees

		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC		
# OF REPS: Right 5		UNINVOLVED	INVOLVED	DEFICIT	UNINVOLVED	INVOLVED	DEFICIT
# OF REPS: Left 5		LEFT	RIGHT		LEFT	RIGHT	
PEAK TORQUE	N-M	127.0	110.3	13.1	55.1	61.6	-11.6
PEAK TQ/BW	%	271.6	236.0		117.9	131.7	
TIME TO PK TQ	MSEC	430.0	230.0		260.0	370.0	
ANGLE OF PK TQ	DEG	152.0	167.0		113.0	125.0	
TORQ @ 30.0 DEG	N-M	0.0	0.0	0.0	0.0	0.0	0.0
TORQ @ 0.18 SEC	N-M	115.1	105.5	8.3	53.0	53.4	-0.7
COEFF. OF VAR.	%	11.3	5.3		4.7	5.6	
MAX REP TOT WORK	J	111.2	87.3	21.5	62.3	69.2	-11.1
MAX WORK REP #	#	4	4		1	5	
WRK/BODYWEIGHT	%	237.8	186.7		133.2	148.0	
TOTAL WORK	J	517.8	408.5	21.1	259.0	331.8	-28.1
WORK FIRST THIRD	J	169.5	143.0		101.0	115.7	
WORK LAST THIRD	J	174.6	117.6		75.2	104.3	
WORK FATIGUE	%	-3.0	17.8		25.5	9.8	
AVG. POWER	WATTS	80.5	63.7	20.9	39.5	49.5	-25.2
ACCELERATION TIME	MSEC	30.0	20.0		30.0	40.0	
DECELERATION TIME	MSEC	40.0	60.0		90.0	90.0	
ROM	DEG	79.5	78.8		79.5	78.8	
AVG PEAK TQ	N-M	114.2	103.3		52.0	57.8	
AGON/ANTAG RATIO	%	43.4	55.8	G: 61.0			



Biodex Medical Rev 3.31 06/26/2003

APPENDIX B

WRITTEN CONSENT FORM

Informed Consent Form

Dear parent:

We would like to ask for your permission regarding the below-mentioned exercise.

I approve the participation of my son ……………………………………into "the project on the effects of a five-week hamstrings strengthening exercise on the hamstring muscle strength and jumping ability of male basketball players between the ages of 10 to 12," by Prof. Dr. Feza Korkusuz (Faculty of Education, Physical Education and Sports Department, 2104951). I am not obliged in anyway to let my son take part in this work-out; we-myself and my son-can at any time decide to leave the research without assigning any reason or being subject to any sanction. I have the right to ask for transfer of information on my son to myself, elimination of research records or their absolute removal.

The objective of this study, is to do research on the effects of a five-week strength training program for basketball players of age group 10-12, by using their body weights, on the hamstring muscle strength and jumping ability. The applied strength training program shall also be examined for its impacts on flexibility and strength parameters.

We have no personal interest out of this research . Such a study shall play an important role in the improvement of the performance of basketball players at the given age group.

My son, together with other basketball players of his age group, shall be subject to strength, vertical leap, lateral leap and proprioception tests at the beginning and end of the research.

INCONVENIENCES AND STRESSES

No inconvenience or stress is expected. The participants can however feel strain during the strength tests.

RISKS

There are no associated risks.

The outcomes of participation to the study are confidential. All information regarding your son shall be kept secret. All the data enregistered by the researcher shall be concealed at the Middle East Technical University for 3 years and then be abolished.

Detailed questions (now and during the course of the project) shall all be answered by the researcher. The researcher can be accessed from the following telephone number: 2104951.

I have read and understood the above-defined research procedure. All my related questions are answered and I do accept to take part in this research. I was provided with a copy of this form.

Many thanks for your support.

………………………..	………………………..
Sign of Parent/Guardian	Date
………………………..	………………………..
Sign of Researcher	Date

Aydınlatılmış Onam Formu

Sayın veli:

Aşağıda anlattığımız çalışmada oğlunuzun yer alması için sizden izin istiyoruz.

Oğlum …………..…………………………'ın Prof.Dr. Feza Korkusuz (Eğitim Fakültesi, Beden Eğitimi ve Spor Bölümü, 2104951) tarafından yürütülen "10-12 yaş arası erkek basketbolcularda 5 haftalık arka bacak kuvvetlendirme egzersizinin arka bacak adale kuvveti ve sıçrama üzerine etkisi" isimli araştırma projesinde yer almasını kabul ediyorum. Oğlumun bu çalışmada yer almasına izin vermek zorunda değilim; Ben ve oğlum herhangi bir sebep belirtmeksizin ve herhangi bir yaptırım olmaksızın araştırmada yer almaktan vazgeçebiliriz. Oğlum ilgili bilgilerin şahsıma aktarılmasını, araştırma kayıtlarından silinmesini veya tamamen yok edilmesini isteyebilirim.

Bu çalışmanın amacı, 10-12 yaş grubu basketbolcularda 5 hafta boyunca kendi vücut ağırlıkları ile uygulanan kuvvet antrenmanlarının arka bacak adele kuvveti ve sıçrama üzerine etkisinin araştırılmasıdır. Ayrıca uygulanan kuvvet antrenmanlarının esneklik ve kuvvet parametreleri üzerine etkise de incelenecektir.

Bu araştırmadan hiçbir şahsi çıkarımız yoktur. Ancak yapılacak olan çalışma bu yaş grubundaki basketbolcuların performanslarının geliştirilmesinde önemli rol oynayacaktır.

Oğlum yaş grubundaki diğer basketbolcularla ile birlikte araştırmanın başlangıcında ve sonunda kuvvet, dikey sıçrama, yatay sıçrama ve propriosepsion testlerine girecektir.

<u>RAHATSIZLIKLAR VE STRESLER</u>

Herhangi bir rahatsızlık veya stres beklenmemektedir. Ancak kuvvet testlerinde zorlanma hissedilebilir.

<u>RİSKLER</u>

Herhangi bir risk beklenmemektedir.

Çalışmaya katılımın sonuçları güvenilir olacaktır. Oğlunuz ile ilgili tüm bilgiler gizli tutulacaktır. Kayıt edilen bütün veriler araştırmacı tarafından 3 yıl Orta Doğu Teknik Üniversitesinde saklı tutulacak ve daha sonra yok edilecektir.

Araştırma ile ilgili detaylı sorular (şimdi ve proje sırasında) araştırmacı tarafından cevaplanacaktır. Araştırmacıya 2104951 nolu telefondan ulaşılabilir.

Yukarıda bahsedilen araştırma prosedürünü anlamış bulunmaktayım. Konu ile ilgili tüm sorularım cevaplanmıştır ve bu çalışmaya katılmayı kabul ediyorum. Bu formun bir örneği şahsıma verilmiştir.

Desteklerinizden dolayı teşekkür ederiz.

………………………………… ……………………………

Araştırmacının İmzası Tarih

………………………………… ……………………………

Velinin İmzası Tarih