

Effects of Knee Extensor Eccentric Training on Dynamic Balance and Hamstring/Quadriceps Ratio in Young Healthy Athletes

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DOI: <https://doi.org/10.38021asbid.1712524>

ORIGINAL ARTICLE

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Abstract

In this study, it was aimed to measure the effects of the isoinertial training program applied to young athletes on their dynamic balance and leg strength. 51 athletes participated in the study (n=24, Study Group (SG); n=27, Control Group (CG), while 24 athletes in SG were applied an isoinertial training program for their lower extremities in addition to warm-up programs, no additional training intervention was made to CG athletes. Within the scope of pre-post tests of both SG and CG athletes, body mass indexes, dynamic balance measurements, and Hamstring (H) and Quadriceps (Q) muscle strengths of athletes were measured using a hand-held dynamometer to determine the H/Q ratio. In the evaluation of the pre- and post-tests of the groups in line with the obtained data, no statistically significant difference was found in pre- and post-test parameters in CG athletes ($p>0.05$), while statistically significant results were found in right leg H/Q ($p=0.01$), left leg H/Q ($p=0.04$), right leg Y balance ($p=0.01$), and left leg Y balance ($p=0.04$) parameters in SG athletes. ($p<0.05$). When the pre- and post-test differences between the groups of the athletes in the study and control groups were examined, statistically significant improvement was found in favor of the athletes in the SG, in the parameters of y-balance right leg change difference ($p=0.00$), y-balance left leg change difference ($p=0.02$), right leg quadriceps change difference ($p=0.00$), right leg hamstring change difference ($p=0.00$), left leg quadriceps change difference ($p=0.04$), and left leg hamstring change difference ($p=0.01$), while no statistically significant change was found between the change differences between the groups in the left leg and right leg H/Q ratios ($p>0.05$). In conclusion, eccentric training is particularly effective on the hamstring muscle group, but it is also effective on the quadriceps muscle group.

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Keywords: Eccentric, Strength, Dynamic Balance, Hamstring, Quadriceps

Genç Sağlıklı Sporcularda Diz Ekstansör Eksantrik Antrenmanlarının Dinamik Denge ve Hamstring/Quadriceps Oranına Etkileri

Öz

Bu çalışmada, genç atletlere uygulanan izonertiyeel antrenman programının dinamik denge ve bacak gücü üzerindeki etkilerinin ölçülmesi amaçlanmıştır. Çalışmaya 51 sporcu katıldı (n=24, Çalışma Grubu (ÇG); n=27, Kontrol Grubu (KG), ÇG'deki 24 sporcuya ısınma programlarının yanı sıra alt ekstremiteleri için izonertiyeel antrenman programı uygulanırken, KG'deki sporlara ek bir antrenman müdahalesi yapılmadı. ÇG ve KG sporcularının pre-post testleri kapsamında, H/Q oranını belirlemek amacıyla sporcuların vücut kitle indeksleri, dinamik denge ölçümleri ve Hamstring (H) ile Quadriceps (Q) kas güçleri elde taşınabilir bir dinamometre kullanılarak ölçüldü. Elde edilen veriler doğrultusunda grupların ön test ve son test değerlendirmelerinde, ÇG sporcularında ön test ve son test parametrelerinde istatistiksel olarak anlamlı bir fark bulunmazken ($p>0.05$), SG sporcularında sağ bacak H/Q ($p=0.01$), sol bacak H/Q ($p=0.04$), sağ bacak Y dengesi ($p=0.01$) ve sol bacak Y dengesi ($p=0.04$) parametrelerinde istatistiksel olarak anlamlı sonuçlar bulunmuştur. ($p<0.05$). Çalışma ve kontrol gruplarındaki sporcuların ön ve son test farkları incelendiğinde, SG'deki sporcular lehine y-balance sağ bacak değişim farkı ($p=0.00$), y-balance sol bacak değişim farkı ($p=0.02$), sağ bacak quadriceps değişim farkı ($p=0.00$), sağ bacak hamstring değişim farkı ($p=0.00$), sol bacak quadriceps değişim farkı ($p=0.04$) ve sol bacak hamstring değişim farkı ($p=0.01$) parametrelerinde istatistiksel olarak anlamlı iyileşme bulunurken, gruplar arasındaki sol bacak ve sağ bacak H/Q oranlarındaki değişim farkları arasında istatistiksel olarak anlamlı bir değişim bulunmamıştır ($p>0.05$). Sonuç olarak, eksantrik antrenman özellikle hamstring kas grubunda etkili olmakla birlikte, quadriceps kas grubunda da etkilidir.

Anahtar kelimeler: Eksantrik, Kuvvet, Dinamik Denge, Hamstring, Quadriceps

Received:
02.05.2025

Accepted:
11.09.2025

Online Publishing:
28.09.2025

Introduction

Soccer is a sport defined by teamwork and interaction among players and teams, resulting in a complex and unpredictable dynamic (Sarı and Tutar, 2025; Bayrakdar and Kılınç, 2020). The positioning and actions of players on the field depend on the arrangement of teammates, opponents, and the evolving information inside the game's context (Dambroz et al., 2022). As a result, different scenarios and contexts within the game require players to exhibit varied behaviors and make distinct decisions to tackle obstacles that arise during gameplay (Roca et al., 2021). Balance refers to the mechanisms that prevent body mass from descending to the ground (Sucan et al., 2005) or the relationship via the body's centre of consent and center of dignity. Balance necessitates the synchronization of several muscles throughout the body and the synthesis of sensory information (Çelenk et al., 2018).

The capacity for human balance encompasses both static and dynamic abilities, and balance is a vital factor in the development of athletic skills (Nikiforov et al., 2021; Kolias et al., 2022). A significant link exists between slow muscle strength and quick muscle strength in athletes' knee joints; elevated peak torque values signify superior muscle function and greater balance maintaining abilities (Romahadi et al., 2020).

Studies examining the correlation between strength and dynamic balance have concentrated on the concentric and isometric aspects of force generation, determining that strength and dynamic balance are distinct variables (Paterno et al., 2009; Thorpe and Ebersole, 2008; Muehlbauer et al., 2013). Research indicates that the eccentric force of the lower leg may significantly influence dynamic balance. According to Norris heightened stimulated consisted of the lower extremity muscles during the descending phase of the Star Y dynamic balance test. This is likely due to eccentric contractions that absorb, decelerate, and counterbalance pressures exerted on the body's center of mass (Earl and Huertel, 2001).

The results of a number of studies suggest that eccentric resistance training could be an effective preventative intervention. By primarily strengthening the balance between the quadriceps and hamstring muscle groups, eccentric exercise of the hamstring muscles reduces the occurrence of hamstring strain injuries (Croisier et al., 2008). This is the primary mechanism by which eccentric exercise works. According to LaStayo et al. (2003), eccentric muscular contractions are known to generate more force at lower activation levels than concentric contractions. This results in a reduced metabolic expenditure and an increased likelihood of muscle injury. Conversely, concentric contractions are known to generate less force. The objective of this strategy is to improve eccentric

muscle strength in order to correct the imbalance between the hamstrings and quadriceps and to provide athletes with enhanced dynamic balance.

Material and Methods

Model of the Research

This study was conducted using a quasi-experimental research design. A pre-test–post-test control group experimental design was employed. Participants were randomly assigned to either the study group (SG) or the control group (CG) using a computer-generated randomization list to ensure unbiased allocation. The athletes participating in the study were divided into two groups: the study group (SG) and the control group (CG). The study was performed on U-16 adolescent football athletes inside the facilities of amateur teams recognized as eligible for participation. A 6-week isoinertial training program and subsequent post-tests were implemented. Anthropometric measurements, y-balance assessments, and leg strength evaluations were conducted during the tests. The application group utilized the isoinertial device, which maintains equal energy during concentric and eccentric phases due to the lack of frictional force. This device provides adjustable resistance during both concentric and eccentric muscle actions through flywheel technology, allowing for repeated movements with consistent load.

This approach facilitates substantial eccentric effort at minimal metabolic cost, implemented three times a week for six weeks, with each session lasting 10–12 minutes following a warm-up program. The eccentric load was reassessed weekly using the force measuring sensor (PowrLink Loadcell), and the resistance was adjusted to maintain 80–90% of the maximal eccentric load throughout the 6-week program, rather than being set only once at baseline. Following the 6-week training program, the post-tests were conducted by the same team, at the identical location, under the same conditions, utilizing the same measuring instruments. The study was designed to include pre-tests, a 6-week isoinertial training regimen for the SG, and post-tests. The athletes in the CG maintained their conventional training regimen. The study commenced with the collection of pre-test data prior to the 6-week training period and post-test data subsequent to the training program implementation. Thus, it seeks to evaluate the impact of hamstring strength training on the research cohort. The study group encompasses the assessment of dynamic balance, dribbling proficiency, and shot velocity of adolescent soccer players.

Table 1
Isoinertial Training Program Protocol for the Study Group

Week	Sessions/week	Exercises	Sets x Reps	Intensity (inertia / %ecc max)	Rest	RPE
1–2	3	5	4 x 6	~80% max eccentric load	3 min	Moderate–High (≈14 Borg)

3-4	3	5	4 x 6	~85% max eccentric load	3 min	High (≈15 Borg)
5-6	3	5	4 x 6	~90% max eccentric load	3 min	High (≈16 Borg)

The athletes involved in the study were categorized into two groups: the study group (SG) and the control group (CG). The participants in the study group underwent isoinertial training to enhance eccentric muscular strength with the isoinertial strength device, alongside their standard football training routines conducted four days a week. Initially, a sample application was conducted with the athletes prior to the study to ascertain the appropriate wheel size and to calibrate the load. Prior to the strength exercises, both the control group and the athletes in the study group underwent a warm-up regimen consisting of static and dynamic stretches following a 10-minute jog (Ayala et al., 2017). The application program was administered to the athletes in the study group on weekdays, specifically on Tuesday, Wednesday, and Thursday, immediately following the warm-up protocol. The athletes then proceeded with their standard football training regimen, which comprised five movements: squat, right forward lunge, left forward lunge, right side lunge, and left side lunge. The regimen of 6 repetitions and 4 sets. The rest interval between sets was established as 3 minutes (Picerno, 2017).

Population and Sample

51 athletes participated in the study (SG n=24, CG n=27). The sample size was determined a priori using G*Power software (version 3.1) based on an expected medium effect size ($f = 0.25$), $\alpha = 0.05$, and power $(1-\beta) = 0.80$, resulting in a required minimum of 48 participants. Adolescent athletes participating in U-16 football within amateur team facilities, demonstrating eligibility for the study across the six-week research program, and free from health issues or injuries constitute the inclusion criteria. The exclusion criteria were failure to complete the stipulated 6-week program, the incidence of any injury, and voluntary withdrawal by the athletes from the study.

Data Collection Tools

Height-Weight Measurement

Athletes' weight, height and BMI were measured. A flat wall was used to position a tape measure for the height measurement test. Participants were instructed to hold their heels and toes together at an angle of around 60 degrees and wait upright. The ruler was put on the vertex and measurements were obtained with bare feet and standing upright. Felix 150 kg digital scales measured body weight with 0.1 precision. Participants were measured in shorts, t-shirts, and bare feet, and the values were recorded in kg (Kocadağ, 2014). The BMIs of athletes were computed utilizing the formula: body weight (kg) divided by height squared (m).

Y-Balance Test

The "Y Balance Test" was utilized to evaluate dynamic postural control. Millimeters were quantified "Y" configuration on the ground. During the assessment, participants were directed to position their elbows, maintain level heels, and gently touch the most distant point with their reaching foot.

During the barefoot test, participants reached anterior (ANT), posterolateral (PL), and posteromedial. The anterior reach was measured from the central toe tip, the posterolateral and posteromedial from the heel. Participants took the test nine times, three times each way. Participants made mistakes if they removed their hands from their hips, lifted the stance foot heel, or put their weight on the supporting foot. First, the person was verbally corrected, then the measurement was repeated. While supine, both legs were measured in cm from the anterior superior iliac spine to the distal medial malleolus. Every reaching distance was measured in cm, and the scores were normalized to account for leg length advantage: $\text{Best Reaching Distance} / \text{Leg Length} \times 100\% = \% \text{ Directional Best Reaching Distance}$. This ensured consistent results among participants (Rudarlı et al., 2024).

Lower Extremity Muscle Strength Measurement

VALD Performance's DynaMo hand dynamometer measured quadriceps and hamstrings. After being told, participants contracted muscle groups submaximally by resisting the practitioner's hand without utilizing the gadget. Participants sat in 90° flexion with their hands on their chests and no support to test quadriceps muscle strength. Maximal muscular strength was assessed on the anterior ankle with a hand dynamometer. The hand dynamometer was placed on the proximal posterior surface of the ankles while participants lay face down with their hips in 90° knee flexion to test hamstring strength (Leporace et al., 2020).

Isoinertial Training Volume

The athletes in the study group were determined the weight wheels according to the force loads in the maximal eccentric phase with the force measuring sensor (PowrLink Loadcell) on the belt on their waist during the squat exercise in the isoinertial training device, and then they practiced with weight wheels corresponding to 80–90% of the maximal loads, reassessed weekly throughout the 6-week program (Fernandez et al., 1976).

Analysis of Data

Statistical analyses of the acquired data were conducted utilizing SPSS 22 and the associated package program. The normality of the data distribution was assessed using the Shapiro–Wilk test, and the results indicated that the data exhibited a normal distribution. A mixed-design ANOVA was

conducted to examine the interaction effects of group (SG vs CG) and time (pre-test vs post-test), followed by Bonferroni post hoc tests for multiple comparisons where applicable. The Paired Samples t-test, a parametric test, was employed for intra-group comparisons of the Study and Control Groups, whereas the Independent Samples t-test was utilized for inter-group comparisons. The significance level was set at $p < 0.05$. Descriptive data were represented using numerical values, percentages, means, and standard deviations.

Ethics of Research

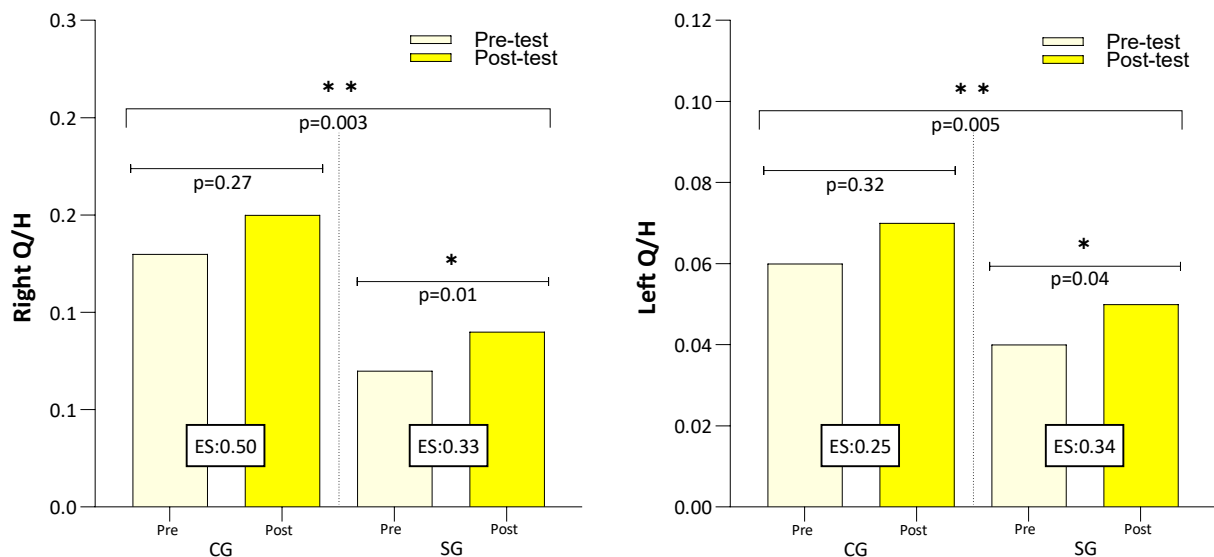
All participants were thoroughly briefed about the study's objective and significance, potential hazards, and their right to withdraw at any time, in accordance with the Declaration of Helsinki, and a permission form was completed and signed. Approval from the Rumeli University for the project.

Results

Table 2
Age, Height, Body Weight and BMI Averages of Study and Control Groups

Parameters	SG (n=24) $\bar{x} \pm sd$	CG (n=27) $\bar{x} \pm sd$
Age (year)	15.04 $\pm$ 0.69	15.14 $\pm$ 0.71
Height (cm)	171.1 $\pm$ 0.64	169.2 $\pm$ 0.06
Weight (kg)	58.93 $\pm$ 9.71	59.77 $\pm$ 5.81
BMI (kg/m ²)	19.87 $\pm$ 2.42	20.93 $\pm$ 2.34

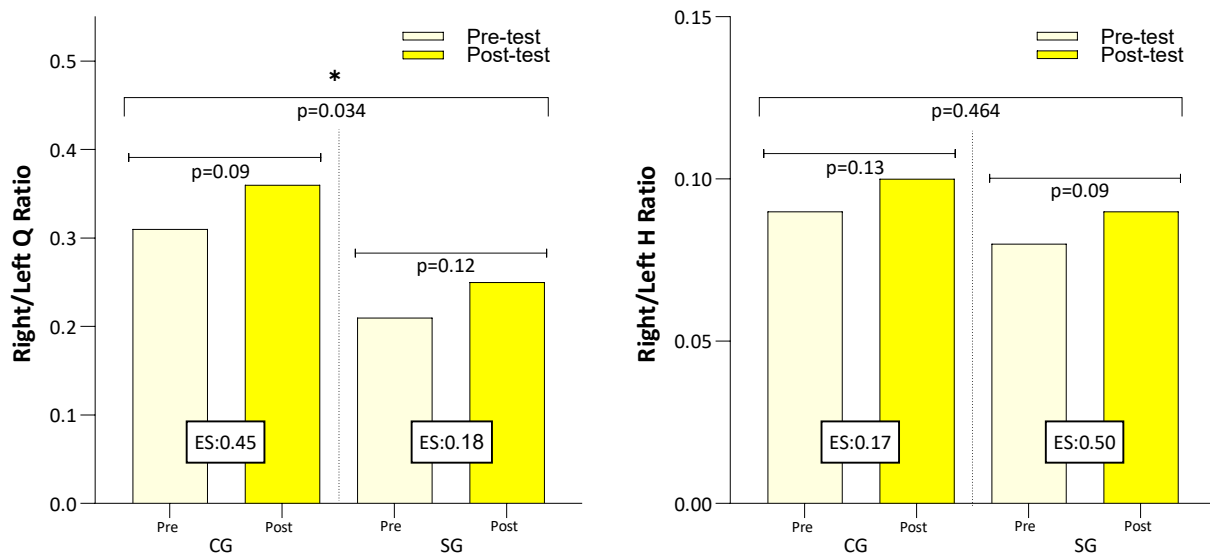
$\bar{x}$; mean, sd; standard deviation, BMI; Body mass index



Graphic 1. Changes in Right and Left Q/H Ratios Between Control and Study Groups

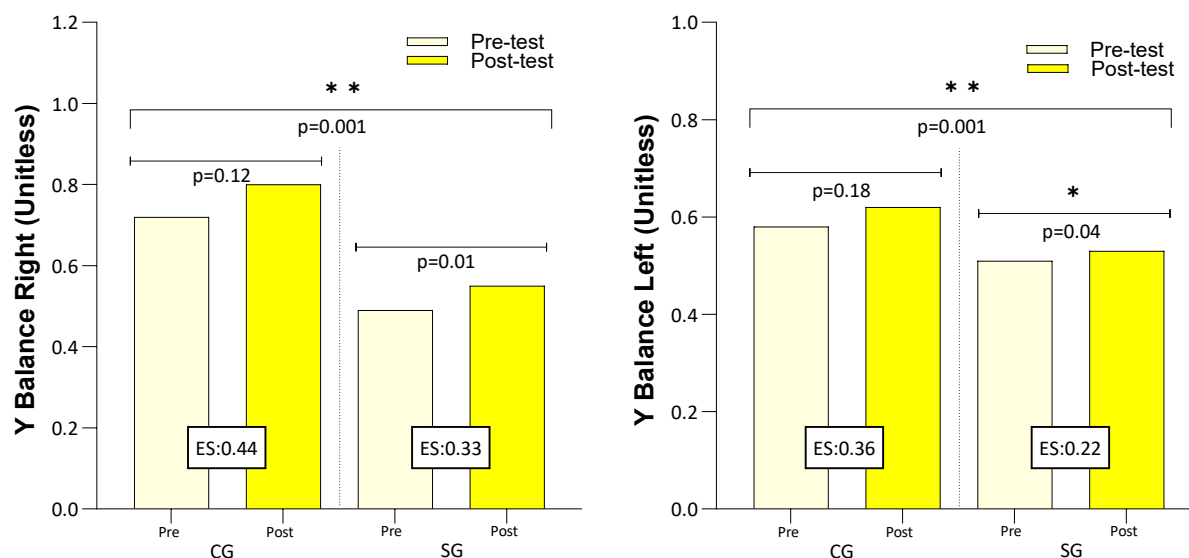
In the control group, the right Q/H ratio increased from 0.13 in the pre-test to 0.15 in the post-test, with a t value of 2.93 and a p value of 0.27. The 95% confidence interval ranged from 0.04 to

0.21, the effect size was 0.50, and the ANOVA results showed $F=6.24$ with $p=0.003$. In the study group, the ratio increased from 0.07 to 0.09, with $t=1.88$, $p=0.01$, a 95% confidence interval of 0.05–0.29, and an effect size of 0.33. For the left Q/H ratio, the control group showed an increase from 0.06 to 0.07, with $t=1.31$ and $p=0.32$. The 95% confidence interval ranged between 0.03 and 0.14, the effect size was 0.25, and the ANOVA indicated $F=1.04$ with $p=0.005$. In the study group, values rose from 0.01 to 0.02, with $t=0.28$, $p=0.04$, a confidence interval of 0.09–0.20, and an effect size of 0.34.



Graphic 2. Right/Left Quadriceps and Hamstring Ratios in Control and Study Groups

The right/left quadriceps ratio in the control group increased from 0.31 to 0.36, with $t=2.71$, $p=0.09$, a 95% confidence interval ranging from 0.54 to 0.08, and an effect size of 0.45. ANOVA results were $F=8.83$ and $p=0.034$. In the study group, values increased from 0.21 to 0.25, with $t=0.97$, $p=0.12$, a confidence interval of 0.66–0.07, and an effect size of 0.18. For the right/left hamstring ratio, the control group progressed from 0.09 to 0.10, with $t=1.54$ and $p=0.13$. The 95% confidence interval ranged from 0.20 to 0.03, the effect size was 0.17, and the ANOVA results showed $F=2.98$ with $p=0.464$. In the study group, the ratio increased from 0.08 to 0.09, with $t=3.95$, $p=0.09$, a confidence interval of 0.12–0.06, and an effect size of 0.50.



Graphic 3. Y-Balance Right and Left Test Scores in Control and Study Groups

The Y-Balance right test in the control group showed an increase from 0.72 to 0.80, with $t=2.34$ and $p=0.12$. The 95% confidence interval ranged from 0.09 to 0.12, the effect size was 0.44, and ANOVA results were $F=4.21$ with $p=0.001$. In the study group, values rose from 0.49 to 0.55, with $t=1.89$, $p=0.01$, a confidence interval of 0.01–0.05, and an effect size of 0.33. In the Y-Balance left test, the control group improved from 0.58 to 0.62, with $t=1.88$ and $p=0.18$. The 95% confidence interval was between 0.06 and 0.15, the effect size was 0.36, and ANOVA results showed $F=3.24$ with $p=0.001$. In the study group, the mean value increased from 0.21 to 0.23, with $t=1.36$, $p=0.04$, a confidence interval of 0.04–0.17, and an effect size of 0.22.

Discussion and Conclusion

Football ranks as one of the most popular team sports globally among the youth, with over 735 initiatives organized annually to enhance the youth sector. Literature indicates that participation at elite levels necessitates superior speed and power in players compared to their counterparts in non-elite categories. The findings of the research indicate that there is a difference of 0.12 seconds in a 15-meter sprint between elite and non-elite soccer players (2.44 ± 0.07 seconds versus 2.56 ± 1.2 seconds). Additionally, there is a difference of 5 centimeters in the standing vertical jump (55.80 ± 5.82 cm versus 50.21 ± 7.58 cm), which highlights the fundamental significance of speed and power in the sport of soccer. These distinctions are significant in numerous competitive scenarios, including brief sprints to secure ball control, altering movement direction, executing tackles, restraining opponents, and performing headers during set-pieces and free kicks (Brito et al., 2014). Strength training is an effective method to enhance speed and power, particularly at the juvenile top level. Numerous strength and conditioning coaches use squats and lunges to improve speed and power due

to their dynamic flexibility in force angles and power at particular angles. Norrbrand et al. (2010) found that certain equipment makes the same squat isotonic (barbell back) or isoinertial (flywheel).

The purpose of this research was to investigate the effects of an isoinertial training program that lasted for six weeks on the dynamic balance and leg strength of athletes. Exercises that allowed for unlimited linear resistance throughout both concentric and eccentric muscle motions were introduced into this program. This allowed for the modification of resistance overloads during each repetition. This was facilitated by an isoathoretical device that employs the inertia of rotating flywheels to generate eccentric overloads during the athletes' movements. There was no statistically significant change in the characteristics of the pre-test and post-test for the CG athletes, as determined by the isolated strength measures acquired by the use of a hand dynamometer. In contrast, athletes from the MV group demonstrated statistically significant enhancements in the values of the right leg H/Q ($p=0.01$) and the left leg H/Q ($p=0.04$). On account of the training program that was performed for the SG athletes, the observed difference that favored the CG athletes reached comparable values. However, in the post-tests, there was no statistical significance found between the groups. Comparing the pre- and post-tests of the training program administered to the study group revealed that the hamstring and quadriceps muscle groups exhibited superior development compared to the athletes in the Control Group, who engaged solely in standard football training. The accuracy and dependability of measurements obtained using a handheld dynamometer have been extensively examined in the literature. One study demonstrated that the handheld dynamometer is an effective instrument for assessing quadriceps strength in patients prior to and following total knee arthroplasty, as noted by According to Baron et al. These findings require validation in sport-specific cohorts (Gonzalo et al., 2017; Baron et al., 2024). The utilization of a handheld dynamometer in clinical environments provides support for the assessment of knee muscle strength at various muscle lengths in healthy adults. However, the hamstrings in the extended position (hip flexed and knee extended) are not included in this recommendation.

Upon analyzing the differential changes between the pre and post-tests of the groups, a statistically significant enhancement was observed in favor of the athletes within the study group for the y-balance right leg composite ($p=0.00$), y-balance left leg composite ($p=0.00$), right leg Q ($p=0.00$), and right leg H ($p=0.09$) parameters ($p<0.05$), whereas no statistically significant alterations were detected in the remaining parameters ($p>0.05$). The differences in change between the pre- and post-tests of the athletes in the study and control groups were analyzed. The parameters indicating change differences included the right leg quadriceps ($p=0.00$), right leg hamstring ($p=0.00$), left leg quadriceps ($p=0.04$), and left leg hamstring ($p=0.01$), all favoring the athletes in the study group ($p<0.05$). However, no statistically significant difference was observed in the change differences of

the left and right leg H/Q ratios between the groups ($p>0.05$). The implemented training program yields effective outcomes for both the hamstring and quadriceps muscles in athletes, enhancing strength parameters, particularly within the hamstring muscle group. It appears to improve the hamstring/quadriceps (H/Q) muscle balance; however, this finding lacks statistical significance, potentially attributable to the limited participant pool or the brief duration of the study. Nonetheless, the muscle strength achieved in both legs contributes to improved balance and knee stability in the athletes.

The eccentric training utilized in our work enhances muscular force production during the elongation period and significantly impacts the H/Q ratio and dynamic balance. The H/Q ratio denotes the proportion of hamstring muscle strength to quadriceps muscle strength and is a vital factor in assessing knee joint stability and injury susceptibility (Croisier et al., 2008). An appropriate hamstring-to-quadriceps (H/Q) ratio necessitates adequate hamstring strength in relation to the quadriceps, which is crucial for preventing anterior cruciate ligament (ACL) injuries (Hewett et al., 2006). The current study revealed enhancements, particularly in the hamstring muscle group, by eccentric training utilizing the isoinertial device. Proske and Morgan demonstrated in a relevant publication that eccentric training positively influenced the hamstring-to-quadriceps (H/Q) ratio by enhancing hamstring strength and endurance, thereby achieving a more balanced strength ratio relative to the quadriceps (Proske and Morgan, 2001). This enhances knee joint stability, facilitates movements like abrupt stops and directional changes common in football, which are crucial for athletic performance, and diminishes the likelihood of anterior cruciate ligament injury (Coombs and Garbutt, 2002). Despite the fact that isoinertial training is often compared to other methods in literature, a brief study comparing isotonic training and isoinertial training (10 weeks, 3 sessions weekly) found that isotonic training significantly increased strength during the 1RM squat (18.4% vs. 6.8%; Higbie et al., 1996). Both groups used the same load (10 repetitions x 3 sets). The authors demonstrated that isoinertial training significantly increased thigh circumferential surface area more than isotonic training, attributing this to enhanced mechanical stress in the muscle fibers; however, they contended that isometric training was superior (Higbie et al., 1996). Isoinertial exercise increased muscle development more than isotonic strength training (21%-5%), according to another study. According to Francie et al. (2017), isoinertial strength training is better than isotonic strength training for muscle development, however this may depend on gender and age. Human balancing capability primarily consists of static and dynamic balance abilities, which are crucial for the advancement of athletic talents (Nikiforov et al., 2021; Koliass et al., 2022). A substantial correlation exists between slow and fast muscular strength in athletes' knee joints; higher peak torque values indicate enhanced muscle function and improved balance maintenance capabilities (Romahadi et al., 2020). Dynamic balance and strength are independent, according to research on concentric and isometric force

production (Paterno et al., 2009; Thorpe and Ebersole, 2008). Dynamic balance may be more affected by lower extremity eccentric force, according to studies. While descending the star balance test, Norris and Trudelle-Jackson found increased Vastus Medialis activity (Norris and Jackson, 2011). Eccentric contractions likely absorb, decelerate, and prevent body center of mass pressures (Earl and Hertel, 2001). Numerous research indicate that eccentric resistance training may serve as a significant preventive measure. Eccentric training of the hamstring muscles is recognized for enhancing the equilibrium between the quadriceps and hamstring muscle groups, resulting in hamstring strain injuries necessitating lower metabolic expenditure and subjecting the muscles to greater damage compared to concentric movements (LaStayo et al., 2003). Eccentric exercise improved dynamic balance in this study. Significant pre-post test increases were detected in both the right and left legs ($p=0.01$ and 0.04 , respectively) and were also visible in the intergroup analysis of differential changes among groups. The differences in right leg y-balance changes ($p=0.00$) and left leg y-balance changes ($p=0.02$) are statistically significant, favoring the athletes in the study group ($p<0.05$). Eccentric contractions enhance joint stability and movement control by augmenting the flexibility and strength of the muscle-tendon unit (Higbie et al., 1996). This enhances the efficacy and safety of balance-related movements, particularly in athletes. Research indicates that dynamic balance, defined as the body's capacity to sustain equilibrium during motion, directly influences injury risk and positively impacts athletic performance (Hrysomalis, 2011). Another study confirmed our findings that eccentric training improves dynamic balance by increasing the hamstrings' eccentric force production capacity, which improves knee joint flexion and extension control (Higbie et al., 1996). This is believed to enhance performance by allowing athletes to execute quick movements and maintain stability in precarious positions more safely and effectively. An independent study found that eccentric training improved athletic performance and reduced injury risk by improving the H/Q ratio and dynamic balance (Mjølunes et al., 2004). In high-performance sports like football, the consistent application of eccentric training programs is crucial for enhancing athletes' physical capabilities and reducing injury risk (Askling et al., 2003).

Ethics Committee Permission Information

Ethics review board: Rumeli University- Scientific Research Ethics Committee

Date of ethical approval document: 06.09.2024

Issue number of the ethical approval document: E-53938333-050-42580

Authors' contributions

The subject and planning of the research was carried out by the first, second and third author, the processes related to the method and findings were carried out by the second, third and fourth author,

the collection of data was carried out by the first and sixth author, the processes related to statistics were carried out by the third, fourth and fifth author, the writing and control of the article were carried out by all authors, and the processes related to the discussion and conclusion were carried out by the second, fifth and sixth authors.

Conflicts of interest

The authors have no conflict declaration regarding the research.

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