The Effects of Eccentric-Dominant Training on Balance and Postural Stability

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Abstract

Aim: The aim of this study is to investigate the effects of a novel training approach called Augmented Repetitive Eccentric Loading (AREL) in which the eccentric contraction phase is performed with a greater number of repetitions compared to the concentric phase on balance performance. **Method:** Twenty participants aged between 18 and 23 were divided into three groups: isotonic training group (ISO), increased repetition eccentric training group (ECC+), and control group (CONT). Over an eight-week period, the ECC+ group performed additional eccentric repetitions beyond traditional strength training protocols, while the ISO group followed conventional isotonic training methods. Balance performance was assessed using the Biodex Balance System SD, which measures medial-lateral, anterior-posterior, and overall stability indices. **Results:** The ECC+ group showed significant improvements in anterior-posterior ($p=0.01$) and overall stability ($p=0.01$) compared to the other groups. No statistically significant changes were observed in the ISO and CONT groups. These findings suggest that the AREL method may be more effective than traditional strength training in enhancing balance performance. **Conclusion:** This study highlights the potential of the AREL method as an innovative approach for improving dynamic balance in athletes. Incorporating eccentric overload strategies into training programs may help optimize performance and reduce the risk of injury.

Eksantrik-Dominant Antrenmanın Denge ve Postüral Stabilite Üzerindeki Etkileri

Özet

Amaç: Bu çalışmanın amacı, eksantrik kasılma fazının, konsantrik kasılma fazına kıyasla daha fazla sayıda tekrar ile uygulandığı ve Artırılmış Tekrarlı Eksantrik Yüklenme (AREL) olarak adlandırılan yeni bir antrenman yaklaşımının denge performansı üzerindeki etkisini incelemektir. **Gereç ve Yöntem:** Çalışmaya yaşları 18–23 arasında değişen yirmi katılımcı dâhil edilmiş ve bu bireyler izotonik antrenman grubu (ISO), artırılmış tekrarlı eksantrik antrenman grubu (ECC+) ve kontrol grubu (CONT) olmak üzere üç gruba ayrılmıştır. Sekiz hafta süresince ECC+ grubu, geleneksel kuvvet antrenman protokollerine ek olarak ilave eksantrik tekrarlar gerçekleştirmiş, ISO grubu ise standart izotonik antrenman yöntemlerini uygulamıştır. Denge performansı, medial-lateral, anterior-posterior ve genel stabilite endekslerini ölçen Biodex Denge Sistemi SD ile değerlendirilmiştir. **Bulgular:** ECC+ grubunun anterior-posterior ($p=0,01$) ve genel stabilite ($p=0,01$) parametrelerinde diğer gruplara kıyasla anlamlı düzeyde iyileşme gösterdiği saptanmıştır. ISO ve CONT gruplarında ise istatistiksel olarak anlamlı bir değişiklik gözlenmemiştir. Bu bulgular, AREL yönteminin denge performansını artırmada geleneksel kuvvet antrenmanlarına göre daha etkili olabileceğini göstermektedir. **Sonuç:** Elde edilen sonuçlar, AREL yaklaşımının sporcularda dinamik dengeyi geliştirmeye yönelik yenilikçi bir yöntem olma potansiyeline sahip olduğunu ortaya koymaktadır. Eksantrik aşırı yüklenme stratejilerinin antrenman programlarına dâhil edilmesi hem performansın optimize edilmesine hem de yaralanma risklerinin azaltılmasına katkı sağlayabilir.

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Introduction

Eccentric strength, the muscle's ability to produce force while lengthening, is essential for movement control, deceleration, balance, and contributes to greater strength and hypertrophy due to its higher force output compared to concentric contractions (Suchomel et al., 2019; Wagle et al., 2017). Key mechanisms include increased fiber recruitment, neural adaptations, and structural changes (Cadore et al., 2014; Merrigan et al., 2022). It plays a key role in deceleration activities like landing and direction changes. Research links lower body eccentric strength to balance, with studies showing that eccentric training enhances both strength and balance (Lopez-Barreiro et al., 2021). Additionally, studies have shown that eccentric training can lead to improvements in dynamic balance, which is closely linked to an athlete's ability to maintain stability during rapid movements. Hammami et al. (2022) found that eccentric training significantly enhanced speed, dynamic balance, and muscle strength in prepubescent weightlifters, highlighting the importance of eccentric strength in developing overall athletic performance. Similarly, Nebigh et al. (2022) reported that eccentric hamstring training improved dynamic balance in youth male handball players, further supporting the relationship between eccentric strength and balance performance.

In this context, it is worth mentioning the Accentuated Eccentric Loading (AEL) method that inspired this study. It is a specific training method that involves applying a load greater than the individual's concentric strength during the eccentric phase of an exercise. This approach is designed to exploit the higher force-producing capacity of eccentric contractions to promote greater strength gains and muscle adaptations (Armstrong et al., 2022; Wagle et al., 2017). Research has shown that AEL can lead to significant improvements in maximal strength, muscle cross-sectional area, and performance in various athletic tasks (Friedmann et al., 2004; Harden et al., 2020; Walker et al., 2016). The rationale behind AEL is that by overloading the eccentric phase, athletes can enhance their concentric performance due to the potentiation effects that occur when transitioning from eccentric to concentric contractions (Merrigan et al., 2021; Tseng et al., 2021). In summary, eccentric strength is vital for high-intensity activities, and AEL enhances it by leveraging the unique properties of eccentric contractions. Eccentric strength is vital for balance across different populations. Eccentric training not only enhances muscle strength but also improves movement control and reduces injury risk.

Unlike previous studies, this study considered that equivalent concentric and eccentric external loads correspond to different intensity levels for each contraction type. Additionally, the eccentric contraction phase was trained with a higher number of repetitions than the concentric phase (Yılmaz, 2023). This approach was termed "Augmented Repetitive Eccentric Loading (AREL)". While earlier studies have primarily focused on equalizing loads across contraction types or emphasized eccentric training through increased resistance, they have often overlooked the potential impact of manipulating repetition volume specifically in the eccentric phase. AREL eliminates this oversight by systematically increasing the eccentric workload through repetition count rather than load magnitude alone.

This study was aimed to investigate the effects of AREL on balance performance development in athletes, with the hypothesis that targeting the eccentric phase through augmented repetitions rather than solely increasing resistance may lead to improvements in dynamic balance.

Method

Participants

This study initially included 24 male amateur football players aged between 18 and 23 years (M=20.45). However, due to attrition during the eight-week training period, the final sample consisted of 20 participants. Specifically, two participants from the isotonic training group (ISO) discontinued training, one participant from the eccentric+ group (ECC+) dropped out, and one participant from the control group (CONT) did not participate in the final testing phase.

The experimental groups comprised 13 volunteers who were in the off-season break and willing to engage in strength training. The control group consisted of seven amateur football players who were also in the off-season break but did not participate in any structured training during the study period. However, the daily physical activity levels of the control group participants were not standardized or monitored throughout the study.

Participants were assigned to three groups using a stratified randomization method based on their baseline eccentric and concentric strength levels of the quadriceps and hamstrings. The experimental groups included the isotonic group (ISO) (n=6), which performed strength training using a traditional isotonic method, and the eccentric+ group (ECC+) (n=7), in which the number of repetitions was determined based on eccentric strength levels. The control group (CONT) (n=7) did not engage in any additional strength training interventions and maintained their regular activity levels.

All participants were informed about the study procedures, potential risks, and benefits, and they provided written informed consent before participation. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki, and ethical approval was obtained from the relevant institutional review board.

Training Protocol

Prior to the commencement of the training period, the one-repetition maximum (1RM) strength of the quadriceps and hamstring muscles was determined separately for both the right and left legs of each participant using the Epley Equation (LeSuer et al., 1997):

$$1RM = (1 + 0,0333 \times repetitions) \times weight\ lifted$$

Participants were instructed to refrain from engaging in high-effort activities at least 48 hours before testing to minimize fatigue-related effects. A standardized warm-up protocol was implemented to ensure muscle activation without inducing fatigue. During the testing procedure, participants were permitted a maximum of five repetitions per attempt, with the total workload limited to 4–5 sets to accurately determine their 1RM values.

Prior to each strength training session, all participants performed a standardized warm-up protocol designed to prepare the neuromuscular system for the upcoming workload and reduce the risk of injury. The warm-up session lasted approximately 10–15 minutes and consisted of two phases: general and specific warm-up.

In the general warm-up phase (5–7 minutes), participants engaged in low-intensity aerobic activity (e.g., treadmill jogging or cycling) to increase core body temperature and stimulate blood flow to working muscles.

Following this, the specific warm-up phase (5–8 minutes) was performed, including dynamic stretching and movement-specific drills targeting the primary muscle groups involved in the subsequent strength training exercises. Additionally, participants performed 1–2 sets of the main resistance exercises (leg extension & leg curll) at 40–60% of their one-repetition maximum (1RM) for 8–10 repetitions to ensure neuromuscular activation and technique rehearsal. The warm-up protocol remained consistent across all training sessions to ensure standardization.

Throughout the testing and training sessions, participants were required to perform knee extension and flexion movements at a controlled angular velocity of $60°\cdot s^{-1}$, following a visual metronome for tempo guidance. If a participant failed to maintain the prescribed lifting or lowering speed at any point during the repetition, the attempt was considered invalid. Only repetitions successfully completed at $60°\cdot s^{-1}$ were recorded as valid 1RM values.

The training intervention lasted for eight weeks, with participants performing three training sessions per week. In addition to general strength, power, and muscular endurance exercises, the training regimens for the two experimental groups differed specifically in their knee extension and flexion protocols:

Isotonic Group (ISO): Participants in this group performed unilateral knee extension and flexion exercises using 80% of their 1RM, completing eight repetitions per set for four sets at an angular velocity of $60°\cdot s^{-1}$, following a traditional isotonic resistance training approach.

Eccentric+ Group (ECC+): Participants in this group also performed unilateral knee extension and flexion movements at the same $60°\cdot s^{-1}$ angular velocity. However, based on the assumption that eccentric strength is approximately 20% greater than concentric strength (Schoenfeld, 2020), the concentric contraction phase was performed with 80% of the 1RM, while the eccentric phase was extended beyond the standard eight repetitions. Specifically, after completing eight repetitions at 80% 1RM, participants performed an additional 2–3 eccentric-only repetitions.

To ensure that the total training volume was equalized between the experimental groups, the number of sets performed per session was adjusted accordingly. In this context, four sets were performed by the ISO group, whereas three sets were completed by the ECC+ group. This modification was made based on the differing characteristics of each contraction type, particularly in terms of time under tension and mechanical loading. As an example, the additional 2–3 eccentric-only repetitions performed at the end of each working set by the ECC+ group were considered equivalent to a fourth set in terms of total volume. By regulating the number of sets in this manner, an equivalent training stimulus—defined as the product of sets, repetitions, and intensity—was aimed to be achieved across groups. Thus, potential differences in performance outcomes could be attributed more specifically to the type of muscular contraction rather than disparities in training volume.

Anthropometric Measurements

Body weight was measured using a scale (Tanita 401 A, Japan) with an accuracy of ±100 g and recorded in kilograms (kg). Height was measured with a stadiometer (Holtain Ltd., UK) measuring ±1 mm in anatomical posture and bare feet and recorded in centimeters (cm).

Balance Test

Balance assessments were conducted using the Biodex Balance System SD (Biodex Medical Systems, Shirley, NY, USA) based on medial-lateral, anterior-posterior, and overall stability indices. The device calculates the medial-lateral, anterior-posterior and overall stability index by measuring the inclination in degrees in each axis during the application. High scores in these indices indicate poor balance and scores close to zero indicate good balance. The platform has mobility levels from 1 to 12. Level 12 is the most stable state of the platform, while level 1 is the most active. After the participants stepped on the device with platform stability set to level 6 without shoes, foot angle and heel position were recorded according to the placement of the dominant foot. For 20 seconds, they tried to balance with one foot on the movable platform with their hands crossed at chest level and at the end, medial-lateral, anterior-posterior and overall stability scores were recorded (Löklüoğlu et al., 2024; Taskuyu et al., 2024).

Data Analyses

The SPSS 24 software package was used for the statistical analysis of the data. Mean values and standard deviations for all parameters were reported. The normality of the data distribution was tested using the Shapiro-Wilk test. In cases where the data did not show a normal distribution, skewness and kurtosis values were examined; values within the range of ±2 were interpreted as indicating normal distribution. For data considered normally distributed, a paired samples t-test was used for comparisons between paired variables, while one-way analysis of variance (ANOVA) was employed for comparisons involving more than two groups. To identify the source of significant differences, the Tukey test, a post hoc analysis method, was applied.

Results

The medial-lateral, anterior-posterior, and overall stability parameters were analyzed across all groups (ISO, ECC+, CONT), and the results revealed that the ECC+ group showed statistically significant improvements in anterior-posterior and overall stability values ($p < 0.05$). However, no significant difference was found in medial-lateral stability values ($p > 0.05$). In the ISO and CONT groups, no statistically significant difference was observed in any of the parameters ($p > 0.05$) (Table 1).

Table 1. Pre-test and post-test comparisons of all groups

Parameter	Groups	Pre-Test X̄ ± SD	Post-Test X̄ ± SD	p
Medial-Lateral SI	ECC+	1,32±0,30	1,02±0,41	0,18
	ISO	1,55±0,35	1,33±0,43	0,35
	CON	1,52±0,40	1,45±0,25	0,64
Anterior-Posterior SI	ECC+	2,41±1,10	1,22±0,47	**0,01**
	ISO	1,85±0,47	1,60±0,60	0,35
	CON	1,62±0,66	1,38±0,33	0,45
Overall SI	ECC+	2,99±1,13	1,65±0,47	**0,01**
	ISO	1,85±0,47	1,60±0,60	0,30
	CON	2,28±0,62	2,35±0,44	0,77

P<0,05

In the ECC+ group, the pre-test mean for medial-lateral stability was 1.32±0.30, while the post-test mean was calculated as 1.02±0.41 (p=0.18). The anterior-posterior stability value decreased from 2.41±1.10 in the pre-test to 1.22±0.47 in the post-test, and this difference was found to be statistically significant (p=0.01). Similarly, the overall stability value was 2.99±1.13 in the pre-test and 1.65±0.47 in the post-test (p=0.01) (Table 1).

In the ISO group, the pre-test mean for medial-lateral stability was 1.55±0.35, and the post-test mean was 1.33±0.43 (p=0.35). The anterior-posterior stability value was 1.85±0.47 in the pre-test and 1.60±0.60 in the post-test (p=0.35). The overall stability value was similarly measured as 1.85±0.47 in the pre-test and 1.60±0.60 in the post-test (p=0.30). These findings indicate that there was no significant change in balance parameters in the ISO group (Table 1).

In the control group, the pre-test mean for medial-lateral stability was 1.52±0.40, while the post-test mean was calculated as 1.45±0.25 (p=0.64). The anterior-posterior stability value was 1.62±0.66 in the pre-test and 1.38±0.33 in the post-test (p=0.45). The overall stability value was 2.28±0.62 in the pre-test and 2.35±0.44 in the post-test (p=0.77). No significant change was observed in any parameter within the control group (Table 1).

Table 2. Pre-test comparisons between the groups

Parameter	ECC+	ISO	CONT	p
	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$	
Medial-Lateral SI	1,32±0,30	1,55±0,35	1,52±0,40	0,47
Anterior-Posterior SI	2,41±1,10	1,85±0,47	1,62±0,66	0,20
Overall SI	2,99±1,13	1,85±0,47	2,28±0,62	0,30

P<0,05

No statistically significant difference was found in the pre-test comparisons between the groups (Table 2) (p>0.05), indicating that there were no initial disparities in the measured variables. This suggests that both groups had comparable baseline characteristics before the intervention, confirming that they were homogeneously distributed. The lack of significant differences ensures that any changes observed in the post-test results can be attributed to the intervention rather than pre-existing variations between the groups.

Table 3. Comparison of post-test development differences between groups

Parameter	ECC+	ISO	CONT	p
	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$	
Medial-Lateral SI	0,30±0,52	0,22±0,52	0,07±0,39	0,67
Anterior-Posterior SI	1,19±0,88	0,25±0,59	0,24±0,80	0,06
Overall SI	1,33±1,01	0,37±0,77	-0,71±0,63	**0,01**

P<0,05

When the post-test improvement differences were analyzed, the ECC+ group showed significant improvements compared to the ISO and CONT groups, especially in overall stability (p=0.01) and anterior-posterior stability (p=0.06). There was no significant difference between the three groups in the medial-lateral stability parameter (p=0.12) (Table 3).

Discussion and Conclusion

Muscle strength and balance are fundamental components of athletic performance, particularly in young athletes. Strength is defined as the ability of a muscle or muscle group to resist external forces, while balance performance refers to the capacity to maintain body stability in both static and dynamic positions. The literature highlights a strong relationship between muscle strength and balance performance (Ludwig et al., 2020).

In this study, the method known as Augmented Repetitive Eccentric Loading (AREL) was observed to produce significant effects on balance. AREL aims to increase the mechanical load on the muscle by emphasizing repetitions during the eccentric phase. In this approach, while concentric and eccentric external loads were kept equal, the eccentric phase was performed with a higher number of repetitions. Thus, instead of increasing the load magnitude, the total eccentric workload was systematically enhanced by increasing repetition volume (Yılmaz, 2023). Whereas traditional eccentric training primarily targets load increments to induce adaptation, the AREL method offers a more neuromuscular-focused and effective stimulus by manipulating repetition count specifically in the eccentric phase.

In the ECC+ group, which was subjected to this method, statistically significant improvements were recorded in both anterior-posterior and overall stability scores. The anterior-posterior stability score improved by 49.37%, decreasing from 2.41±1.10 to 1.22±0.47, while the overall stability score improved by 44.81%, decreasing from 2.99±1.13 to 1.65±0.47. In contrast, no significant or notable improvements were observed in any of the balance test results within the ISO group.

These findings both align with and diverge from existing literature regarding the relationship between strength and balance. Studies by Katayama et al. (2004), McCurdy and Langford (2006), and Thorpe and Ebersole (2008) have suggested that increases in lower extremity strength do not directly enhance balance. However, other studies, such as those by Wang et al. (2016), Aka and Altundağ (2020), and Ambegaonkar et al. (2014), have emphasized a significant relationship between muscle strength and balance. The findings from the AREL protocol suggest that the relationship between strength and balance should be considered not only in terms of load magnitude but also through the lens of repetition volume.

The effect of muscle strength on balance performance can be explained through various physiological mechanisms. Stronger muscles can enhance the rigidity of the body's supporting structures (muscles, tendons, ligaments), thereby improving postural control. Additionally, the central nervous system may receive more precise and faster signals from stronger muscles, allowing for more effective muscle activation during balance tasks. Moreover, proprioception—critical for detecting body position—has been shown to correlate with muscular strength. Strong muscles contribute to improved proprioceptive feedback, aiding in the maintenance of balance (Pereira & Gonçalves, 2012; Wang et al., 2016).

The positive effects of the AREL method on balance performance are believed to stem from the neuromuscular adaptations specific to eccentric training. Eccentric contractions produce greater mechanical tension compared to concentric contractions, which increases motor unit recruitment and promotes both hypertrophy and maximal strength gains more effectively (Kasmi et al., 2023). In the AREL approach, repetition volume is increased while load magnitude remains constant, resulting in prolonged and intense

muscular tension. Such targeted loading may improve not only structural adaptations of the musculoskeletal system but also proprioceptive sensitivity and postural control mechanisms.

Kasmi et al. (2021) demonstrated that eccentric overload training yields significant improvements in muscle strength and hypertrophy, which are particularly advantageous for athletic performances that require dynamic balance and stability. Furthermore, this type of loading model—emphasizing high-repetition eccentric work—can support improved motor control, enabling the central nervous system to play a more effective role in maintaining and restoring balance. In conclusion, the AREL method appears to be an effective training strategy not only for increasing muscle strength but also for enhancing complex motor skills such as balance.

In conclusion, the relationship between eccentric strength and balance performance in athletes is well-supported by expirimental evidence. In the ECC+ group, which was subjected to this method, statistically significant improvements were recorded in both anterior-posterior and overall stability scores. The anterior-posterior stability score improved by 49.37% while the overall stability score improved by 44.81%. In contrast, no significant or notable improvements were observed in any of the balance test results within the ISO group. These findings suggest that the AREL method, through its emphasis on eccentric-phase repetition volume, can be an effective stimulus not only for strength development but also for enhancing dynamic balance performance. The absence of similar improvements in the ISO group further reinforces the added value of eccentric-focused training protocols. Coaches and athletes would do well to incorporate eccentric loading techniques such as AREL into their programs to optimize strength and balance performance, especially during off-season training.

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