Research Square

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Impact of a Six-Week Accentuated Eccentric Load Training Program on Dynamic Balance and Maximal Strength in Young Male Football Players

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Abstract

Background:

Eccentric muscle actions play a critical role in performance development due to their high force-producing capacity and potential to enhance neuromuscular adaptations. Accentuated eccentric load (AEL) training is a resistance training method that applies greater load during the eccentric phase of movement. Although its effects on strength and power are well documented, limited research has investigated its potential influence on dynamic balance performance.

Objectives:

The aim of this study was to examine the effects of a six-week accentuated eccentric load (AEL) training program on dynamic balance and maximal strength in young male football players.

Methods:

A total of 14 amateur male soccer players (mean age: 20.00 ± 1.52 years) participated in this study. A single-group pre-test/post-test quasi-experimental design was employed. Dynamic balance performance was assessed using the Y Balance Test (YBT-LQ), and maximal strength was evaluated using the barbell hip thrust one-repetition maximum (1RM) test. Participants completed the AEL training program twice per week for six weeks. The eccentric phase load was set at 80% of 1RM, while the concentric phase load was set at 40% of 1RM. Data were analyzed using paired samples t-tests with a significance level set at $p < 0.05$.

Results:

Significant improvements were observed in all directions of the Y Balance Test following the six-week AEL training intervention ($p < 0.001$). In addition, a significant increase in maximal strength was detected. Effect sizes were large across all variables.

Conclusion:

Accentuated eccentric load training may effectively enhance both maximal strength and dynamic balance performance in young football players. These findings suggest that AEL training can be considered a practical and efficient training strategy for performance development and injury prevention in athletic populations.

Trial Registration

Trial Registration ClinicalTrials.gov Identifier NCT07538557.

Introduction

Soccer is a highly complex sport based on the interaction of technical skills, tactical intelligence, physiological capacity, and mental processes [1, 2]. Technical proficiency stands out as one of the most important elements in determining players' performance levels [3, 4]. However, most of the basic technical actions in football, such as vertical jumping, changing direction, passing and receiving, shooting, dribbling, and ball control, are performed on one foot [5]. In this context, balance emerges as a critical neuromuscular component in the sustainability and efficiency of athletic performance [6, 7].

Dynamic and static balance performance have been widely investigated in recent years due to their importance in athletic performance and injury prevention. In particular, studies examining lower-extremity injury risk in active individuals frequently

evaluate dynamic balance together with variables such as joint range of motion (ROM) and neuromuscular control [8, 9]. One of the most commonly used assessment tools for evaluating dynamic balance is the Y-Balance Test for the Lower Quarter (YBT-LQ). The YBT-LQ was developed as an instrumented and standardized version of the Star Excursion Balance Test (SEBT), focusing on three reach directions: anterior, posteromedial, and posterolateral [10]. This simplified structure enables easier administration while maintaining the ability to assess dynamic postural control in athletes. The standardized testing protocol—including controlled foot placement, reach distance measurement, and limb length normalization—improves measurement consistency and enhances the practicality of the test in both clinical and field settings [11]. Previous studies have also demonstrated that the YBT-LQ exhibits high levels of inter-rater and intra-rater reliability, making it a widely accepted tool for evaluating dynamic balance performance in athletic populations [12].

The literature emphasizes the relationship between Y-Balance Test (YBT) performance and various neuromuscular factors [10]. Several studies have examined the association between lower-extremity muscle strength and dynamic balance performance assessed by the YBT-LQ. Findings from these studies indicate a significant positive relationship between hip muscle strength—especially hip abduction—and YBT-LQ scores. Similar associations have also been reported for hip extension and external rotation strength [10, 13]. These findings suggest that the YBT-LQ should not be considered solely as a test of dynamic balance, but rather as a functional assessment tool reflecting the neuromuscular capacity of the lower extremity and the ability to control body position during single-leg tasks [10, 13, 14].

Eccentric strength refers to the ability of a muscle to produce force while lengthening and plays a fundamental role in controlling and decelerating body movements. Compared with concentric contractions, eccentric actions can generate higher force levels, which provide important advantages for strength development and muscular adaptations [15, 16]. These adaptations are generally attributed to mechanisms such as increased motor unit recruitment, neural adaptations, and structural changes within the muscle–tendon unit [17, 18]. The importance of eccentric strength becomes particularly evident in sport-specific movements that involve rapid deceleration or landing tasks, where athletes must effectively control external forces [19]. Recent research has also reported that eccentric training may contribute not only to improvements in muscular strength but also to enhanced balance performance [20]. For example, eccentric training interventions have been shown to improve dynamic balance and neuromuscular performance in young athletes participating in sports such as weightlifting and handball [21, 22].

Lower-extremity eccentric strength is considered a key component for both balance control and the sustainability of sport performance. Previous studies have consistently reported that eccentric training contributes to improvements in muscle strength, hypertrophy, and neuromuscular performance. In this context, the Accentuated Eccentric Load (AEL) approach has gained increasing attention in strength and conditioning research. AEL training involves applying a greater external load during the eccentric phase of movement compared with the concentric phase, thereby providing a stronger mechanical stimulus to the muscle during the lengthening action [16]. This loading strategy is thought to enhance neuromuscular adaptations more effectively than traditional resistance training by specifically targeting the force-producing capacity of the eccentric phase.

AEL protocols are generally used in the literature with supramaximal (> 1-RM) loads, especially to increase maximal strength and explosive power and to obtain more effective hypertrophic responses. However, in this study, submaximal loads (80% of 1-RM in the eccentric phase) were preferred in order to maintain exercise technique and optimize neuromuscular control in young football players. This approach targets not only strength capacity but also stability in the control phase of movement.

Although the effects of Accentuated Eccentric Load (AEL) training on strength, power, and hypertrophic adaptations have been widely investigated in the literature, research examining its potential influence on dynamic balance performance remains limited [16]. Most previous studies have primarily focused on performance outcomes such as maximal strength, explosive power, and neuromuscular adaptations, while the possible contribution of AEL training to postural control and balance-related performance has received comparatively little attention. Considering the important role of dynamic balance in many sport-specific movements, further research is needed to clarify whether eccentric overload strategies such as AEL may also contribute to improvements in balance performance in athletes.

Therefore, the aim of this study was to examine the effects of a six-week Accentuated Eccentric Load (AEL) training program using the barbell hip thrust exercise on dynamic balance and maximal strength in young male football players. It was hypothesized that the implementation of a submaximal AEL protocol would improve both dynamic balance performance and maximal strength.

Materials and Methods

Participants

A total of 14 male amateur soccer players (n = 14) participated in this study. G*Power 3.1 software [23] was used to calculate the appropriate sample size. The power of the study was determined as 0.80, the effect size as 0.70, and the significance level as 0.05. The descriptive characteristics of the participants are presented in Table 1. Inclusion criteria included being between 18 and 22 years of age, having at least three years of regular training history, not having suffered a musculoskeletal injury in the last six months, and not using any drugs or supplements that could affect neuromuscular performance. Participants were asked to avoid strenuous physical activity for at least 24 hours before each test session. All athletes were informed about the procedures and their written consent was obtained before participating in the study. The research was approved by the Yalova University Ethics Committee (Protocol No: 285858) and conducted in accordance with the principles of the Helsinki Declaration.

Measurements:

Body height was measured with an accuracy of ± 1 mm using a SECA 213 portable height measuring device (SECA GmbH, Hamburg, Germany) and body mass was measured with an accuracy of ± 0.1 kg using a Tanita BC-418 digital scale (Tanita Corporation, Tokyo, Japan). The demographic information of the participants is presented in Table 1.

Table 1
Demographic Information of the Participants

Variable	n	$\bar{X}$	SD	Min	Max
Age	14.00	20.00	1.52	18.00	22.00
Height (cm)	14.00	176.14	7.77	157.00	185.00
Weight (kg)	14.00	67.71	5.64	61.00	80.00

Research Design

This study employed a quasi-experimental single-group pre-test/post-test design to examine the effects of a six-week submaximal AEL training intervention. The primary outcome of the study was dynamic balance performance assessed by the Y-Balance Test-Lower Quarter, whereas maximal barbell hip thrust strength (1RM) was considered a secondary outcome. Participating athletes underwent a 1-Repetition Maximum (1RM) barbell hip thrust (BHT) test 48 hours prior to the training intervention, and loading parameters were determined based on these results. The loads used in the Accentuated Eccentric Load (AEL) protocol were determined based on 80% of 1RM for the eccentric phase and 40% of 1RM for the concentric phase. The weight difference between the phases was achieved using a specially designed bar-mounted device called an eccentric hanger, which allows for the addition of extra weight (Fig. 1). The eccentric hanger was adjusted in height according to each participant's lowest landing point in the hip thrust technique [24]. Due to the angle of the base of the eccentric hanger mounted on the bar, it is designed to separate from the barbell with its lower incline when performing BHT movements, thus allowing the eccentric part of the movement to be loaded more than the concentric phase [25, 26]. In addition, the Y Balance Test – Lower Quarter (YBT-LQ) was administered as a pre-test and post-test 24 hours before the start of training and 24 hours after the end of the 6-week training period to measure the level of dynamic balance (Fig. 2). To improve internal consistency,

all assessments were conducted in the same facility, using the same equipment and testing sequence, under the supervision of the same research team. Pre- and post-intervention assessments were performed under comparable conditions to reduce measurement variability. A non-training control group was not included; therefore, the findings should be interpreted as preliminary evidence of training-related change rather than definitive causal effects.

Barbell Hip Thrust 1-RM Test

1-RM test was administered for barbell hip thrusts, which participants performed twice a week for six weeks. For the test, participants were instructed to sit on the floor with their feet flat on the ground, shoulder-width apart, and their upper backs resting against a padded exercise bench. A protective cushion was placed on the bar for comfort [27, 28]. A standard Olympic barbell (180 cm length; 20 kg weight) and weight plates were placed on their lower legs, slightly below their knees. After placing the barbells on their pelvis, participants assumed the starting position by bending their knees and bringing their heels towards the bench. Subjects then raised their hips until their knee joints formed a 90° angle with their vertical shins (this was visually assessed by the researcher; they held this position for one second before lowering the barbells in a controlled manner [29, 30]. Participants performed a custom BHT warm-up consisting of eight repetitions with a load between 40–50% of the perceived 1-RM load for the 1-RM test. After a one-minute rest interval, a second warm-up set of 6 repetitions was performed with the load adjusted to 50–60% of the perceived 1-RM.

Then each participant was given a maximum of 3 attempts to reach the maximum load in the 1-RM test. When a repetition was successfully completed, the load was increased by 0.5–10.0 kg and a new attempt was made after a five-minute rest. If the participant could not perform the repetition with the predicted load, the load was reduced by 0.5–10 kg and a new attempt was made after a five-minute rest. However, this procedure was not required for any participant.

Range of motion was checked during the 1-RM test: In the eccentric phase, the hips were lowered to the lowest possible position, while in the concentric phase, they were pushed back up until full hip extension was achieved. Additionally, the bar was kept stable on the pelvis, the feet were fixed to the ground, and care was taken to ensure the heels did not lift off the ground. The speed of movement was left to the participants' own preference. Verbal encouragement was provided to the participants throughout all tests, and all procedures were performed by the same research group [27, 28]. All 1RM assessments were conducted by the same research team following a standardized testing protocol to ensure measurement consistency.

Y Balance Test

To reduce potential learning effects, participants were familiarized with the Y-Balance Test protocol through a standardized practice procedure before formal data collection. Participants were shown an informative video including the test and application procedure. Studies have shown that there is a significant learning effect during the Star Excursion Balance Test (SEBT) and that the longest reach distances are achieved after approximately six trials, reaching a plateau level [29]. Therefore, before proceeding to formal measurements, all participants completed the practice process by performing six repetitions in three different reach directions for each leg. Following the practice sessions, the tests were conducted within 20 minutes. The test was performed barefoot on the Y-Balance kit; all participants were instructed to keep their hands at hip level during the test because the position of the hands alters the measurement values [30]. Participants positioned themselves on the plate on one foot, aligning their toes with the starting line. They were asked to reach anteriorly, posteromedially, and posterolaterally with the standing foot while maintaining their balance position. A fixed test sequence was adopted to ensure consistency of measurements and improve standardization. Accordingly, three trials were performed in the anterior direction first, standing on the right foot, and then the same procedure was repeated on the left foot. This sequence was applied similarly for posteromedial and posterolateral reach directions [12, 31, 32]. In addition, lower extremity length (from the anterior superior iliac spine to the medial malleolus) was measured in the supine position to normalize reach distances [12, 24]. Normalization was obtained as follows:

Normalized reach (Mean of the last three trials) / (Limb length) × 100

All measurements were conducted by the same trained assessor to ensure measurement consistency [12, 31, 32].

Data Analysis

The data obtained from this study were analyzed using the SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA) software package. The distribution of all variables was evaluated using the Shapiro–Wilk test and visual inspection methods (histogram and Q–Q plot). The paired samples t-test was used for variables that met the normality assumption. The effect sizes of the obtained results were determined using Cohen's d method and classified as small (0.20), medium (0.50), and large (0.80) effects. The significance level was accepted as $p < 0.05$ for all analyses.

Training Program

Barbell Hip Thrust (BHT) is one of the most biomechanically effective ways to work the gluteal muscles. This exercise can be used to maximize gluteal muscle activation, improve hip extension strength in the gluteus maximus muscles, increase lateral force production, and increase the contribution of the gluteus maximus to the hamstrings during hip extension movement [33].

In the training protocol, the BHT exercise was performed as 4 sets of 6 repetitions. For the BHT exercise, the participant performed a fast eccentric phase with 80% (1RM) with 40% of 1RM fixed on the bar and 40% on an eccentric sling. Immediately after the eccentric sling was removed from the bar, a concentric phase was performed quickly with 40% of 1RM attached to the bar. Assistants attached the sling to the bar within 3 seconds [34] to start the 2nd repetition, and 6 repetitions were performed in this way. Then, a 3-minute rest period was observed between sets, and sets 2, 3, and 4 were performed according to the same protocol. Participants completed the program for a total of 6 weeks, with two training sessions per week (48 hours apart) (Fig. 3).

Results

Table 2
Effects of Accentuated Eccentric Load (AEL) Training on Y Balance Test Performance in Young Football Players

Variable	Measurement	n	$\bar{x}$	SD	Change (Δ)	Change (%)	df	t	95% CI Lower Upper	p	ES
Anterior Right	Pre	14	68.57	8.73	7.29	10.63	13	-10.164	5.74 8.84	< .001	2.71
	Post		75.86	9.71							
Anterior Left	Pre	14	72.66	7.98	4.70	6.47	13	-5.551	2.87 6.53	< .001	1.48
	Post		77.36	8.79							
Posteriomedial Right	Pre	14	83.38	9.93	7.62	9.14	13	-8.290	5.63 9.61	< .001	2.21
	Post		91.00	8.85							
Posteriomedial Left	Pre	14	86.45	9.15	5.74	6.64	13	-7.340	4.05 7.43	< .001	1.96
	Post		92.19	9.31							
Posteriolateral Right	Pre	14	84.56	12.14	8.15	9.64	13	-8.297	6.03 10.27	< .001	2.21
	Post		92.71	11.83							
Posteriolateral Left	Pre	14	87.49	11.74	6.57	7.51	13	-6.718	4.46 8.68	< .001	1.79
	Post		94.06	11.32							
1 RM	Pre	14	83.93	9.64	11.64	13.87	13	-13.222	9.74 13.54	< .001	3.53
	Post		95.57	10.81							

Note: Values represent mean differences between pre- and post-test measurements. Confidence intervals (95% CI) were calculated for the mean change scores. Effect size (ES) was calculated using Cohen's d.

Table 2 presents the pre-test and post-test comparisons following the six-week additional eccentric load training program. Significant differences were observed in all directions of the Y Balance Test (anterior, posteromedial, and posterolateral) ($p < .001$), with large effect sizes (ES = 1.48–3.53). In addition, a significant increase was observed in athletes' 1RM values (pre-test: 83.93 ± 9.64; post-test: 95.57 ± 10.81; $p < .001$), with a very large effect size (ES = 3.53).

Discussion

The main findings of this study are that accentuated eccentric load (AEL) training significantly improves dynamic balance performance in football players. While this result is consistent with previous studies reporting the positive effects of AEL on force and power outputs, the key finding of this study is its demonstration of its effects on dynamic balance performance. Accentuated eccentric load (AEL) generally focuses on the effects of eccentric contractions on sports performance, muscle adaptations, and muscle damage. However, the number of studies directly addressing the concept of 'balance' is limited. In light of the current findings, inferences regarding balance can be made indirectly. Similarly, in research conducted with the AREL (Augmented Repetitive Eccentric Loading) method, which can be considered as a different form of the AEL method and involves increasing the number of repetitions in the eccentric phase, it was emphasized that the AREL method "provided significant improvement in anterior-posterior stability and general stability indices" and has the potential to improve balance performance more than traditional isotonic training. This is important evidence for the effectiveness of AEL-type training in balance performance [19].

The review by Wagle et al. (2017) from the articles examined states that AEL leads to acute and chronic performance improvements, but does not provide specific information on its direct effects on balance. However, the fact that AEL provides

higher force production and muscle adaptations may indirectly point to neuromuscular improvements that can improve balance control. Strong and fast muscles can respond more quickly and effectively to unexpected balance disorders [16].

Godwin et al. A study by (2021) on professional soccer players showed that AEL increased countermovement jump (CMJ) peak power. Jumping performance is closely related to lower extremity strength and explosiveness. Control of body position and movement during such explosive movements requires good balance ability. Therefore, it is thought that AEL improving jumping performance may also positively affect the dynamic balance abilities of athletes. In particular, athletes' ability to maintain balance during sudden changes of direction, accelerations and decelerations may benefit from the muscle strength and control improved by AEL [35].

When we examine the articles on the relationship between eccentric contraction and balance, the study by Caserotti et al. (2008) examined the changes in force and power production of concentric eccentric muscle contraction in the elderly. The study showed that 36 weeks of multi-component training (including aerobic, strength, balance, flexibility and coordination components) prevented the age-related decline in muscle strength and functional performance in elderly men [36].

Hody et al. A review by (2019) addresses the risks of muscle damage and DOMS from eccentric contractions, while also highlighting their potential benefits for rehabilitation and clinical purposes. The fact that eccentric exercises are characterized by the elongation of the muscle-tendon complex and lead to unique adaptations can play a significant role in improving balance. In particular, eccentric training has great potential in reducing the risk of falls and increasing functional independence in elderly populations. The ability of muscles to absorb shock and adapt to sudden load changes is vital for maintaining balance. Eccentric training can help individuals remain more stable in situations of imbalance by improving these abilities [37]. Dafkou et al. (2021) reported that eccentric strength training, performed twice a week for 8 weeks, supported the development of strength and balance, especially in the non-dominant leg, while also contributing to the maintenance of core stability in football players [38].

Another study was conducted to examine the effects of different eccentric exercise protocols applied for 4 weeks on dynamic balance performance in young and healthy recreational athletes. The effect of balance on both the dominant and non-dominant legs was evaluated using the Lower Quarter Y-Balance Test (YBT-LQ). Both Group A and Group B were reported to show significant balance improvement in both the dominant and non-dominant legs compared to the control group ($p < 0.01$) [39]. Eight weeks of isoinertial strength training has been reported to significantly increase shooting speed and significantly improve dynamic balance and dribbling performance in young football players [40]. Studies have shown a positive correlation between muscle strength and balance performance [41]. We believe that the enhancing effect of eccentric training on balance performance is due to the fact that eccentric contraction leads to different specific adaptations compared to concentric and isometric contraction [42–46].

Eccentric exercise is a powerful method that not only improves muscle morphology but also enhances neuromuscular control. During eccentric contractions, the involvement and firing rate of alpha motor neurons increase, corticospinal excitability rises, and motor cortex activation is significantly enhanced. Simultaneously, spinal reflex inhibition decreases, allowing for more efficient muscle activation. Studies using Transcranial Magnetic Stimulation (TMS) and Functional Magnetic Resonance Imaging (fMRI) have shown that eccentric contractions require a higher level of brain cortex stimulation than concentric contractions [42–46].

This study has some limitations. The number of participants was relatively limited; this may restrict the generalizability of the findings. Only male soccer players were studied. Since female athletes or different age categories (youth, veteran) were not included, the results cannot be directly applied to the entire soccer population. The training program was limited to a specific period (six weeks). Long-term effects, sustained adaptations, or changes in injury incidence could not be assessed. Dose-Response Relationship: Dose-response relationships should be investigated to determine the optimal effects of different AEL and eccentric training protocols (load, repetitions, sets, rest periods) on balance. Dynamic balance was assessed only with the Y-Balance Test. While this test is valid and reliable, it does not offer a broader perspective on balance performance because biomechanical measurements such as force plates or postural sway analyses were not included. Football-specific

performance metrics such as sprinting, changing direction, and jumping were not included in the study. Therefore, the contribution of AEL to game performance along with balance can be interpreted indirectly. The study was conducted in a single training environment. It is unclear whether similar results could be obtained under different club structures or training arrangements.

Conclusion

The main findings of this study reveal that accentuated eccentric load (AEL) training significantly improves dynamic balance performance in football players. This result is consistent with the known positive effects of AEL on strength and power outputs, and makes a significant contribution to the literature by highlighting its specific effects on dynamic balance. Other studies reviewed also show that while eccentric training does not directly target balance performance, it contributes to balance indirectly by improving key physiological and neuromuscular mechanisms related to balance, such as muscle strength, explosive power, muscle-tendon unit stiffness, and proprioceptive feedback.

Practical Applications

AEL training supports dynamic balance and functional stability in football players, in addition to increasing muscle strength. This improvement can provide a direct performance advantage in movements requiring agility, change of direction, and balance during play. Improvements in dynamic balance capacity play a significant role in preventing lower extremity injuries. Inclusion of AEL in preventive training programs has the potential to reduce the frequency of injuries in football players. AEL applications can be used to support strength and balance development in the preseason; During the season, low-volume additional loads can contribute to maintaining performance. AEL protocols, implemented with flywheel systems or additional load devices, can be easily applied in a field environment when properly dosed. This feature makes the method both accessible and practical for coaches.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Yalova University Ethics Committee (Protocol No: 285858). All athletes were informed about the procedures and their written consent was obtained before participating in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

ME: Supervision, Conceptualization, Methodology, Writing – original draft, SP: Conceptualization, Investigation, Methodology, Writing – review & editing, SK: Conceptualization, Investigation, Methodology, Writing – review & editing.

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Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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Figures



Figure 1

Hanger for eccentric training.

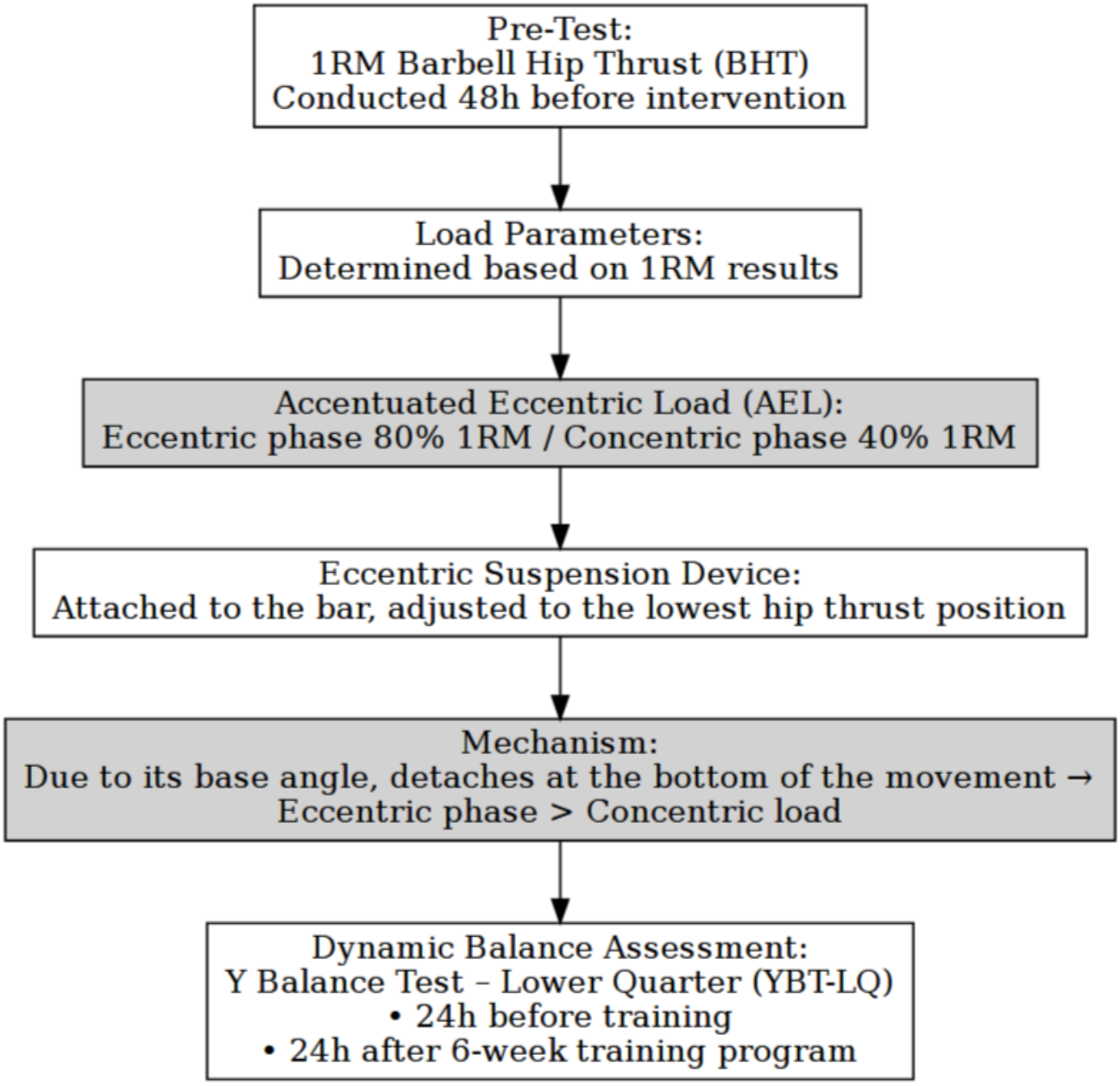


Figure 2

Research Design

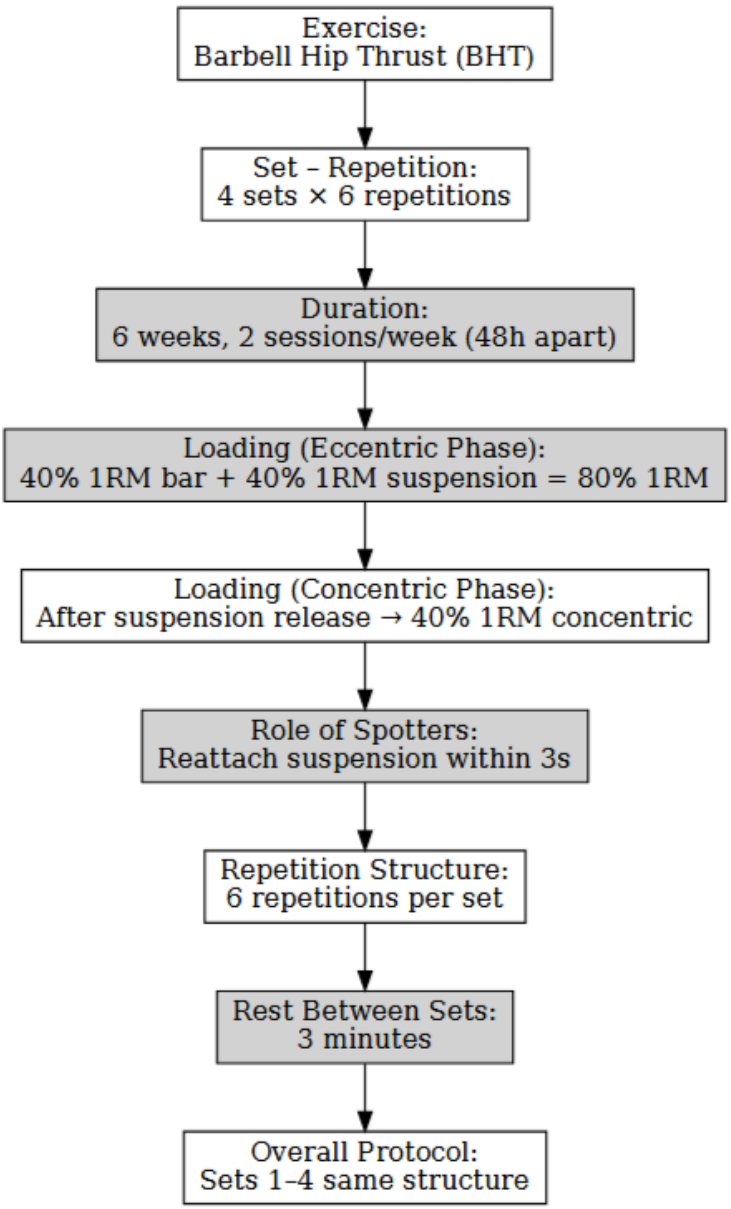


Figure 3

Training Design