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Comparing effects of different eccentric exercise protocols on balance in recreational athletes

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Abstract

Introduction. Efficient dynamic balance can improve motor performance and reduce the risk of injuries in athletes. Maintaining optimal balance is crucial for the performance and injury prevention in recreational athletes. The pursuit of optimizing athletic performance and injury prevention hasled to increased interest in eccentric exercise protocols. Aim of Study. To investigate an effect of different distinct eccentric exercise protocols on balance among recreational athletes in relation to dominant and non-dominant legs. Material and Methods. In this experimental study, a total of 42 healthy recreational athletes, both male and female, aged between 18 to 24 years, and within normal body mass index (BMI; 18.5–24.9 kg/m^2) were divided into three groups, Group A followed Protocol 1 (n = 14), which consisted of Nordic hamstring exercise (NHE) and Copenhagen adduction exercise (CAE), Group B performed Protocol 2 (n = 14), putting emphasis on NHE, reverse Nordic hamstring exercise (RNHE), and lunges, and Group C (n = 14) which served as a control group. Dynamic balance was measured pre- and post-intervention after four weeks by using lower quarter Y-Balance test (YBT-LQ). Results. After the four-week period dynamic balance (dominant and non-dominant legs) notably improved in both treatment groups, as compared to the control group. The improvement was significantly greater in Group A and Group B in contrast to Group C. Conclusions. This study concludes that engaging in different eccentric exercise protocols targeting lower limbs leads to improved dynamic balance performance following the intervention.

KEYWORDS: dynamic balance, Copenhagen adduction exercise, lunges, Nordic hamstring exercise, reverse Nordic hamstring exercise, lower quarter Y-Balance test.

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Introduction

The term “balance” refers to a body’s ability to maintain posture and prevent falling. Consequently, proper balance is essential for most daily activities and numerous sports endeavors, serving not only athletic performance but also injury prevention purposes [26]. Dynamic balance, on the other hand, can be defined as capacity to sustain a center of gravity within a body’s base of support while executing a planned movement [5]. Dynamic balance represents an inherent aspect of many team sports and requires examination in relation to injury risk [7]. Factors influencing balance include sensory input from the somatosensory, visual, and vestibular systems, as well as motor responses affecting coordination, joint range of motion, and strength.

There is a well-known proverb in sports: “injury is simply a part of sport.” In essence, this proverb underscores the inevitability of injuries in sports. Among the hamstring muscles, the biceps femoris is the most frequently injured, with a muscle-tendon junction and adjacent muscle fibers representing the most common sites of disruption [2]. Hamstring strain injury (HSI) stands as the most prevalent non-contact injury in contact sports. It typically occurs during high-speed running, particularly at the conclusion of balance phase, when the fibers contract eccentrically to decelerate knee extension and hip flexion movements.

The main goal of using eccentric movements in young athlete's training is to prevent injuries. Other benefits include improved strength, power, change of direction, injury recovery, and muscular hypertrophy [13]. A conducted meta-analysis revealed a significant 51% reduction in hamstring injuries (risk ratio 0.49, 95% confidence interval 0.29–0.83) among soccer players who engaged in injury prevention programs incorporating Nordic hamstring exercise (NHE), compared to teams that did not implement any injury prevention measures [3].

Adductor-related groin pain stands as the most prevalent groin injury among soccer players, and evidence suggests that low hip adductor strength serves as a risk factor for groin injuries in soccer. Notably, none of the exercises included in the FIFA 11+ program appear to specifically target hip adduction strength. However, a recent study, examining electromyographic activation patterns of eight strength exercises, revealed that Copenhagen adduction exercise (CAE) effectively targets hip adductors. This suggests its potential suitability for groin injury prevention and rehabilitation. In a study involving U-19 sub-elite soccer players who followed an intensive CAE protocol for eight weeks, a remarkable 36% increase in eccentric hip adduction strength was achieved [2].

The eccentric exercise known as reverse Nordic hamstring exercise (RNHE) is an open kinetic chain, stretch-shortening cycle, knee-dominant exercise that has demonstrated effectiveness in enhancing the optimal length of the quadriceps muscles by approximately 6.5 degrees and in reducing the incidence of injury. This exercise involves a simple technique and is performed using an athlete's own body weight, eliminating a need for additional equipment or materials. Moreover, it can be easily implemented either individually or in a group setting [4].

Lunge is a posture that promotes the mobility and stability of hips, knees, ankles, and feet. Unlike squats, lunges entail greater lateral movement and balance demands, as weight is distributed to legs on a floor. This weight distribution facilitates the storage of propulsion in elastic energy that is subsequently converted into a thrust that propels a body back into position. Additionally, lunges necessitate continuous and dynamic control of lower extremities to maintain sufficient stability, particularly when performed on narrow surfaces [18]. Additionally, numerous studies have demonstrated that eccentric exercises contribute to enhancing strength, performance, and balance among athletes. However, there remains a significant gap in knowledge regarding the optimal protocol for improving balance in recreational athletes.

Aim of Study

The aim of the study is investigation an effect of different distinct eccentric exercise protocols on balance among recreational athletes in relation to dominant and non-dominant legs.

Material and Methods

This study was an experimental design study, to compare the effects of different eccentric exercise protocols on balance in recreational athletes. A total of 42 healthy recreational athletes, both males and females, within normal body mass index (BMI; 18.5–24.9 kg/m^2) voluntarily participated in this study. The sample size was determined by using G* Power software, version 3.1.9.4, with an effect size of 0.5, $\dot{\alpha} = 0.05$. The athletes were randomly divided in two treatment groups and a control group through coin method, [17] 14 in each group. The athletes included were between 18 and 24 years of age, exercised more than twice a week [11], and within six months before the start of the study or at the time of testing had no history of any musculoskeletal injury, lower extremity injury, cardiovascular or neurological disorders, bone fractures, head injury or balance disorders or any surgery in the previous year. People unwilling to participate were excluded from the study. Before starting the testing, all participants signed a written informed consent form. This study was conducted between January and October, 2023, recruited from the Directorate of Sports, University, and approved by the institutional Ethics Committee of Guru Nanak Dev University, Amritsar, with ethical approval no. 1416 HQ dated 27/03/2023. This study was conducted in accordance with the guidelines outlined in the Declaration of Helsinki (6th September 2022).

Procedure

Prior to the testing, demographic data of the participants was noted on a subjective form, including age, height, and weight. Lower limb length of the participants was measured with a measuring tape to check for symmetry. The recreational athletes were divided into three groups: Group A followed Protocol 1 (n = 14) [2], Group B performed Protocol 2 (n = 14), [28] and Group C – the control group (n = 14) – that did not perform anything. Pre-testing for dynamic balance was done by lower quarter Y-Balance test- (YBT-LQ) [23]. To determine leg dominance in the healthy recreational athletes, the question "If you would shoot a ball on a target, which leg would you use?" is accurate for bilateral mobilizing tasks [30]. Subsequently, a warm-up protocol was done before the intervention in each session in the interventional groups. After this, the four-week intervention was applied to both treatment groups, with Group C not performing any specific exercises and continuing their regular daily routines. Then the dynamic balance was assessed again.

Dynamic balance testing

Lower Quarter Y-Balance Test (YBT-LQ) is a reliable, unilateral, functional, joint stability task. The test was explained to the participants who were provided with initial Y-Balance test (YBT) instructions and practice trials to avoid errors during the actual data collection. The participants were asked to stand in a single-leg stance, with the most distal aspect of toes just behind a starting line on an intersection point of "Y" symbol drawn on floor. While maintaining the single-leg stance, the subjects were asked to reach an unsupported limb in anterior (AT), posteromedial (PM), and posterolateral (PL) direction and return to the center after each direction without keeping the unsupported foot on the floor while reaching all the directions, as shown in Figure 1. The farthest reach for each direction was used for analysis. The YBT-LQ examines maximum lower extremity reach of a free leg in AT, PM, and PL directions while a subject maintains the unilateral stance with the opposite leg centered on a platform. This process is repeated after subjects switch to the contralateral leg. Three trials were performed in every direction and the maximum of the three was selected for data entry. A rest interval of one minute was given between the directions. Failed test criteria included: (a) failure to maintain the unilateral stance; (b) contact of a reach foot with the ground for support; (c) failure to return to the starting position, such as removing hands from hips; or (d) pushing or kicking an indicator to increase distance. The normalized composite score (CS) was calculated by summing the maximum reach in each of the three directions, then dividing it by triple leg length for the given side. Leg length was measured from the inferior tip of anterior superior iliac spine to the distal end of medial malleolus.

Figure 1. Athlete performing lower quarter Y-Balance test; a. Starting position, b. Anterior direction, c. Posteromedial direction, d. Posterolateral direction

Warm-up protocol

The protocol included stretching of calf, quadriceps, adductor, hamstring, hip rotator, and plantar flexor muscles of both legs with 30 seconds of holding in two sets, and with a 10-second rest period in between the sets.

Protocol 1

NHE: NHE is a partner exercise in which the participants kneel down and their ankles are held tightly by their partner so as to remain in contact with the ground. The subjects then lower their upper body in a controlled manner with arms crossed across a chest. The subjects continue lowering to the ground, and at the end point, where they can no longer control the forward falling by eccentric contraction of the hamstring, they can use their hands to break the forward fall and push themselves back up after their chest touches the ground to minimize loading in the concentric phase, as shown in Figure 2.

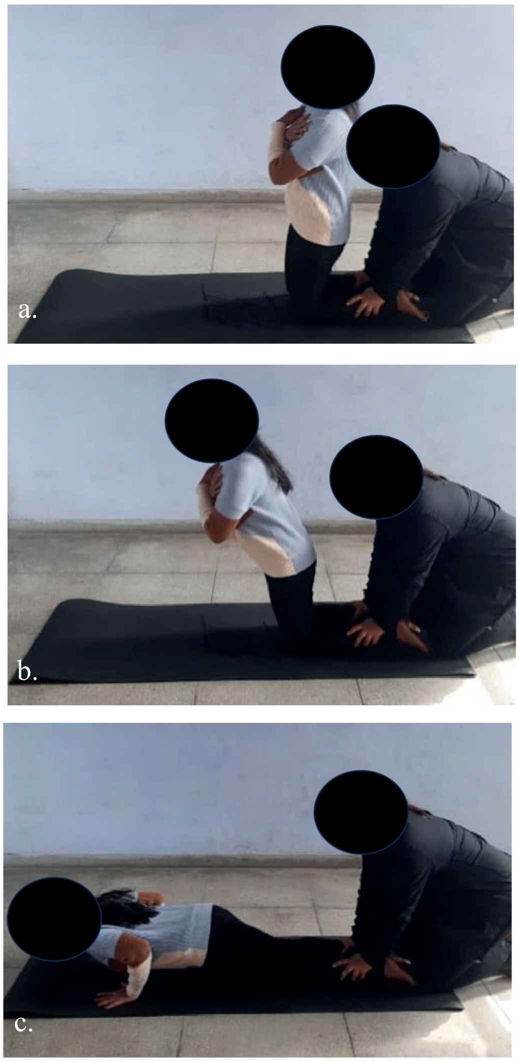

Figure 2. Athlete performing Nordic hamstring exercise; a. Starting position, b. Mid-position, c. End position

CAE: It is a partner exercise in which the athletes lie on their side with one forearm as support on the floor and the other placed along a body. The upper leg is held at hip height of the partner, who holds the leg with one arm, supporting the ankle, and the other one supporting the knee. The athletes then raise their body from the floor, and the lower leg is adducted so that the feet touch each other, and the body is in a straight line. The body is then lowered halfway to the ground. At the same time, the foot of the lower leg is lowered so that it just touches the floor without being used for support. The exercise is performed on both sides, as shown in Figure 3.

The protocol is given at beginner level with three sets × five repetitions, three sessions in a week.

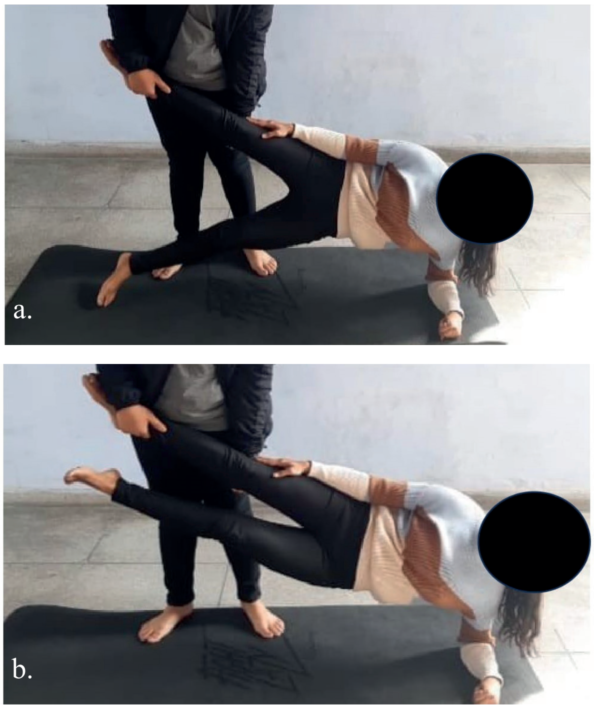

Figure 3. Athlete performing Copenhagen adduction exercise; a. Starting position, b. End position

Protocol 2

RNHE: The participants start by kneeling on the floor, with their hip and trunk in a high and completely aligned position. From that point, the participants lower the trunk to the floor by means of controlled knee flection, maintaining the starting hip and trunk position. This movement must be performed as slowly as possible in order to maximize the eccentric load on muscles and to reach the maximum flection point, as shown in Figure 4 [4].

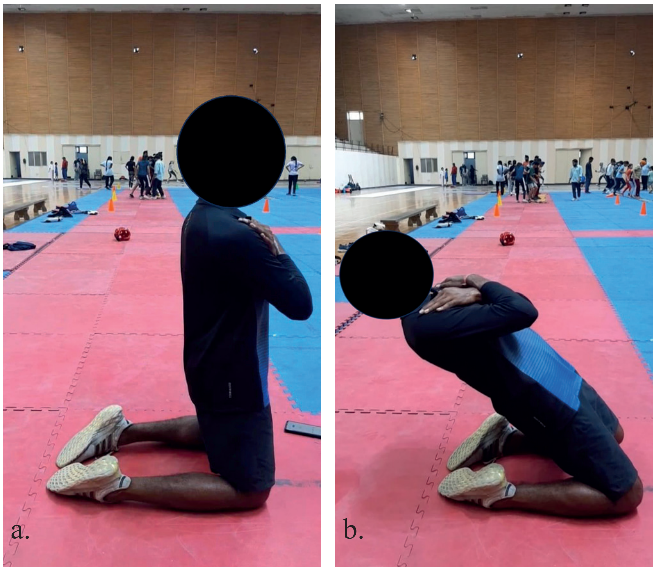

Figure 4. Athlete performing reverse Nordic hamstring exercise; a. Starting position, b. End position

Lunges: The standard lunge is performed by positioning a foot of a dominant leg forward in a distance equal to measurement from a greater trochanter to the floor. Once positioned, the subjects perform the lunge by flexing their forward knee to 90 degrees. Their trunk is maintained in a vertical position. The subjects' hands are maintained on their hips. The pace of descent and ascent is three seconds each, with a one- to two-second hold at the 90° knee flection position, as shown in Figure 5 [20].

Figure 5. Athlete performing lunges; a. Starting position, b. End position

The protocol was given at beginner level with two sets × eight repetitions, three sessions in a week.

Statistical analysis

Statistical analysis was performed using IBM SPSS software, version 27 (IBM, Corp, Armonk, NY, USA). Numerical values were expressed as a mean with 95% confidence interval. Normality of data was evaluated using the Shapiro–Wilk test. Homogeneity was checked by the Levene's test that showed no significant disparities between the groups regarding balance prior to the intervention. Analysis of variance (ANOVA) was used to identify the significant differences in means between the groups and within the groups while controlling for the effects of one or more variates. Eventually, the Bonferroni post hoc test was used for multiple comparisons.

Results

A total of 42 recreational athletes participated in the study, comprising Group A, Group B, and Group C. Table 1 depicts the demographic data of Groups A, B, and C. The comparison between pre- and post-intervention dynamic balance mean values for each group was conducted using a paired t-test. The findings indicated a noteworthy increase in post-intervention dynamic balance mean values across all three groups, as outlined in Table 2.

Table 1. Demographic data of the included participants

	Group A (Protocol 1) Mean ± SD	Group B (Protocol 2) Mean ± SD	Group C Mean ± SD
Age (years)	20.14 ± 1.61	22.92 ± 1.81	22.5 ± 2.02
Body height (m)	1.653 ± 1.05	1.657 ± 0.976	1.653 ± 0.90
Body weight (kg)	59.18 ± 7.88	62.11 ± 8.22	67.90 ± 8.31
Body mass index (kg/m^2)	21.6 ± 1.57	22.55 ± 1.80	21.77 ± 2.08

To determine differences in dynamic balance between the groups, ANOVA was applied. Following the interventions, dynamic balance performance significantly improved in both treatment groups (Group A and Group B) in contrast to the control group. Notably, Group A exhibited the most substantial enhancement in dynamic balance, with significantly higher changes ($p < 0.001$) as compared to Groups B and C.

Within each group, a dominant leg exhibited greater improvement than a non-dominant leg. After the four-week period, both treatment groups, Group A (NHE,

Table 2. Paired t-test table shows changes in dynamic balance within the intervention groups

Variable	Groups		Pre-intervention	Post-intervention	p	t	95% CI Upper	95% CI Lower	Results
Dynamic balance	Group A	Dominant	462.88 ± 46.81	559.61 ± 43.58	0.002**	−11.28	−115.25	−78.21	Highly sig
		Non-dominant	453.09 ± 47.55	532.63 ± 60.86	0.000**	10.90	−95.30	−63.79	
	Group B	Dominant	453.27 ± 53.31	530.58 ± 60.86	0.000**	−10.26	−93.57	−61.04	Highly sig
		Non-dominant	450.91 ± 44.06	509.23 ± 54.06	0.000**	−7.41	−75.30	−41.34	
	Group C	Dominant	448.66 ± 39.95	470.81 ± 51.02	0.000**	−3.23	−36.92	−7.36	Highly sig
		Non-dominant	450.54 ± 33.46	447.14 ± 49.37	0.000**	0.50	−11.02	17.82	

Intragroup comparisons calculated by using the paired sample t-test demonstrated the distribution of mean values and standard deviation of pre-test and post-test on dynamic balance of different eccentric exercise protocols and the control group. The differences observed were significant ($p < 0.005$) in all groups in both dominant and non-dominant leg.

** $p < 0.005$

CAE) and Group B (NHE, RNHE, lunges), demonstrated significant improvement in dynamic balance of both dominant and non-dominant legs in comparison with Group C (control group). Additionally, the improvement was more significant in a dominant leg compared to a non-dominant leg within each group.

The aim of the current study was to investigate the effects of different eccentric exercise programs on dynamic balance of dominant and non-dominant legs among recreational athletes. The findings of this study showed that there was the significant improvement in dynamic balance performance in both treatment groups (Groups A and B) in contrast to Group C ($p < 0.01$), as depicted in Tables 3 and 4 which shows the post hoc test used for pairwise comparison for both dominant and non-dominant leg. Additionally, the study found no substantial differences in dynamic balance between Groups A and B, although dynamic balance scores improved in comparison with the pre-intervention measurements, as shown in Tables 3 and 4.

Table 5 shows an intergroup comparison conducted through one-way ANOVA, demonstrating noteworthy enhancement in dynamic balance post-intervention for a dominant leg in all three groups. Similarly, Table 6 exhibits the results of intergroup comparison via one-way ANOVA, indicating significant enhancement in dynamic balance for a non-dominant leg across Group A, Group B, and Group C. This suggests that the observed improvement extended to both dominant and non-dominant legs of the athletes, with the dominant side displaying greater significance in each group compared to the non-dominant side. Prior research has indicated that leg dominance does not significantly influence balance performance [27].

Table 3. Post hoc test used for pairwise comparison for a dominant leg

Bonferroni's method for pairwise comparison for dominant leg							95% CI	
Groups	Pre			Post				
	Mean difference	p-value	Result	Mean difference	p-value	Result	Upper	Lower
A to B	9.60	1.000	Not sig	29.03	0.450	Not sig	−77.21	19.13
B to C	4.61	1.000	Not sig	59.76	0.013*	Sig	−136.97	−40.64
A to C	−14.21	1.000	Not sig	−88.80	0.000**	Highly sig	−107.94	−11.5982

Bonferroni post hoc test for pairwise comparison for a dominant leg showed highly significant improvement in Group C as compared to Group A ($p = 0.000$), and Group B as compared to Group C, but there were no significant differences between Group A and Group B.

* $p < 0.05$, ** $p < 0.005$

Table 4. Post hoc test used for pairwise comparison for a non-dominant leg

Bonferroni method for pairwise comparison for non-dominant leg							95% CI	
Groups	Pre			Post				
	Mean difference	p-value	Result	Mean difference	p-value	Result	Upper	Lower
A to B	2.17	1.000	Not sig	23.39	0.648	Not sig	−68.71	21.92
B to C	0.36	1.000	Not sig	62.08	0.006*	Sig	−107.40	−16.77
A to C	−2.54	1.000	Not sig	−62.08	0.006*	Sig	−130.80	−40.17

Bonferroni post hoc test for pairwise comparison for a non-dominant leg showed significant improvement in Group A as compared to Group C ($p = 0.006$), and in Group B as compared to Group C, but there were no significant differences between Group A and Group B.
* $p < 0.05$, ** $p < 0.005$

Table 5. Intergroup comparison, conducted through one-way ANOVA, on dynamic balance of a dominant leg for pre- and post-intervention in Groups: A, B, and C

Dynamic balance for dominant leg					
ANOVA	Group	Mean ± SD	F-test	p-value	Result
Pre	A	462.88 ± 46.81	0.344	0.711	Not sig
	B	453.27 ± 53.31			
	C	448.66 ± 39.95			
Post	A	559.61 ± 43.58	10.491	0.000**	Highly sig
	B	530.58 ± 60.86			
	C	470.81 ± 51.02			

** $p < 0.005$

Table 6. Intergroup comparison, conducted through one-way ANOVA, on dynamic balance of a non-dominant leg for pre- and post-intervention in Groups: A, B, and C

Dynamic balance for non-dominant leg					
ANOVA	Group	Mean ± SD	F-test	p-value	Result
Pre	A	453.09 ± 47.55	0.015	0.985	Not sig
	B	450.91 ± 44.06			
	C	450.54 ± 33.46			
Post	A	532.63 ± 60.86	11.276	0.000**	Highly sig
	B	509.23 ± 54.06			
	C	447.14 ± 49.37			

** $p < 0.005$

Discussion

In this investigation, Table 2 illustrates significant enhancement in dynamic balance for both Group A and Group B, following the intervention. Various studies [3, 14, 15] have explored the impact of NHE and CAE on injury reduction rates. Their findings indicate that the integration of CAE or NHE into injury prevention regimens diminishes injury incidence and yields favorable outcomes. A study by Brachman et al. has asserted that incorporating balance exercises into training protocols aims to enhance performance, prevent injuries, and optimize motor function [6]. Consequently, the positive influence of CAE and NHE on dynamic balance can mitigate the risks of injury and alleviate a financial burden on healthcare systems associated with injuries. For example, a meta-analysis [1] evaluating the preventive efficacy of the FIFA 11+ Injury Prevention Program incorporating NHE revealed a 34% reduction in overall injuries and a 29% reduction in lower limb injuries. Furthermore, it recognized the effectiveness of a simple adductor strengthening program with CAE in preventing and mitigating the risk of groin issues among semi-professional football players in Norway [12].

It is widely acknowledged that CAE significantly augments eccentric hip adduction (EHAD) strength, eccentric hip abduction (EHAB) strength, and an EHAD : EHAB ratio, given that a lower EHAD : EHAB ratio is implicated in adductor-related injuries [15, 24]. A study by Polglass et al. introduced a modified progressive Copenhagen adduction program spanning eight weeks, transitioning from hip adductors isometric contraction to conventional CAE. Their findings suggested that the modified progressive Copenhagen adduction program alleviates delayed onset muscle soreness while enhancing EHAD strength by 25%, EHAB strength by 13%, and adjusting the EHAD : EHAB ratio to an appropriate level for preventing groin and adductor-related injuries [24].

Literature [8, 25] indicates that NHE elicits improvements in neuromuscular adaptations affecting injury risk factors and consequently aids injury prevention. Additionally, a recent study [22] conducted electromyography and kinematic measurements during NHE, concluding that higher muscle activity in erector spinae, internal oblique, and multifidus muscles stabilizes a trunk and pelvis and optimizes hamstring contraction. Thus, sufficient activation of these muscles is imperative during NHE, assisting in the design of injury prevention programs for hamstring injuries and muscle imbalances. Furthermore, NHE enhances hamstring strength, functional hamstring-to-quadriceps torque ratio, and dynamic jump [25], aligning with the present study's findings that dynamic balance improved through CAE and NHE. Identified risk factors for injuries include deficits in eccentric strength [25] and dynamic balance [2].

Injuries to quadriceps muscles are common in sports involving repeated sprints, often leading to longer recovery times compared to other muscle injuries. These injuries also tend to recur frequently. Factors contributing to susceptibility include limited quadriceps flexibility, reduced capacity for eccentric force production, and a history of previous quadriceps or hamstring injuries. Muscle injuries affect muscle structure, resulting in decreased fascicle length and changes in pennation angle compared to uninjured muscles. A study [4] investigated changes in muscle architecture of vastus lateralis (VL) and vastus medialis (VM) following a seven-week eccentric training program based on RNHE, followed by a four-week detraining phase. Previous studies by Klimstra et al. [19], Coratella et al. [9], and Timmins et al. [29] also observed increases in fascicle length following eccentric training programs. Additionally, an increase in muscle thickness of VL and VM was noted, which is consistent with findings from other studies focused on enhancing muscle strength and performance.

The results suggest that the eccentric training program centered on RNHE induces muscle hypertrophy, enhancing force-generating capacity. However, these changes diminish after a four-week detraining phase, with significant reductions in fascicle length, pennation angle, and muscle thickness. These findings align with previous research by Timmins et al. [29].

A study [21] suggested that if the primary objectives revolve around balance or stability adaptations, then in-line lunges are recommended for challenging medio-lateral balance under load. Additionally, Jönhagen et al. [16] note that both jumping forward lunge and walking forward lunge entail prolonged periods of eccentric contractions for both rectus femoris and lateral gastrocnemius muscle groups, with 44% and 54% of lunge cycle for rectus femoris, and 63% and 61% for lateral gastrocnemius, respectively. During the forward lunge, particularly the jumping forward lunge, the quadriceps engage in eccentric contraction, while the hamstrings exhibit isometric contraction during the initial stance phase, and the gastrocnemius undergoes eccentric activity throughout most of the stance phase. This exercise involves eccentric, concentric, and isometric contractions across all three muscle groups. Contrary to popular belief within the track and field community, the forward lunge does not evoke prolonged eccentric hamstring activity [16].

In the current study dynamic balance was evaluated using YBT-LQ that aims to challenge subjects to disrupt their equilibrium to near maximum and then restore balance. This test necessitates neuromuscular control through appropriate joint positioning and strength from surrounding musculature throughout its execution. The study's results indicate the significant improvement in dynamic balance performance across both treatment groups (Groups A and B) in contrast to Group C ($p < 0.01$), as depicted in Tables 5 and 6. Additionally, the study found no substantial differences in dynamic balance between Groups A and B, although dynamic balance scores improved compared to the pre-intervention measurements, as shown in Tables 5 and 6. The study demonstrates that while Group A exhibited the highly significant outcomes compared to Group C, the difference between Group A and Group B was statistically insignificant. This discrepancy may be attributed to the unique nature of NHE in Group A, which requires a wider range of motion than RNHE and is perceived as more intense by participants [4]. This heightened intensity associated with NHE could potentially explain the comparatively lesser improvements induced by RNHE in Group B. Furthermore, it is noteworthy that all exercises were performed in the sagittal plane, with CAE being the only exercise necessitating movement in the frontal plane. This distinction in the planes of motion could contribute to the observed differences in the dynamic balance enhancement, favoring Group A over Groups B and C. Some studies suggest that NHE training conducted over 4–6 weeks can yield superior results that could potentially explain the insignificant results observed in dynamic balance [10].

Firstly, YBT-LQ, while used to assess dynamic balance, may have limited sensitivity in predicting dynamic balance accurately. It is suggested that additional testing devices could be incorporated alongside YBT-LQ for a more comprehensive evaluation of dynamic balance. Secondly, the small sample size across all groups is a significant limitation. Increasing the sample size in each group could improve the reliability and generalizability of the study's findings. Additionally, the demographic characteristics of the sample are limited since they only included young athletes without a history of lower limb injuries. This may bias the results as these athletes might have already possessed a good baseline level of dynamic balance. Including more diverse participants in terms of age and injury history could provide a more representative sample. This study was conducted over the four-week period; however, future research could be extended to longer durations to comprehensively assess the long-term effects.

Furthermore, the study focused on recreational athletes participating in various sports, rather than a specific population. This variation in sporting activities could have influenced the results due to differing dynamic balance requirements depending on the type of sport. A more homogeneous sample of athletes with similar sporting backgrounds could help to control for these variables and provide clearer insights into the impact of dynamic balance training.

Conclusions

This study concludes that engaging in eccentric exercises targeting lower limbs leads to improved dynamic balance performance of both dominant and non-dominant leg following the intervention. This suggests that either Protocol 1 or Protocol 2 could be easily integrated into training programs for recreational athletes. Improvement in dynamic balance could potentially lower injury rates, reduce time away from play, and decrease treatment expenses. Additionally, such improvements could assist coaches in incorporating these protocols into their training regimens.

Conflict of Interest

The authors declare no conflict of interest.

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