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Resistance Priming in Improving Strength: The Effects of Unilateral Isometric Strength Activation on cross-activation of Bilateral Quadriceps and Hamstring Strength at 24 and 48 Hours

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Abstract

Purpose: This study aims to investigate whether unilateral low-volume, high-intensity isometric strength activation (ISA) can enhance jump performance and bilateral isokinetic flexion and extension strength within 24 and 48 hours post-intervention.

Method: A total of 68 participants (40 males and 28 females) were included, all free from muscle, ligament, or skeletal disorders that could affect physical performance, and none had undergone lower limb surgery due to injury in the past year. Participants were randomly assigned to either the experimental group or the control group using a balanced randomization scheme. Athletic performance was assessed using unloaded countermovement jump (CMJ), unloaded squat jump (SJ), and isokinetic knee flexion and extension strength tests. The experimental group received an isometric activation protocol, while the control group maintained their regular exercise routines.

Results: The isometric activation protocol led to varying degrees of improvement across genders in the experimental group. Among male participants, there were significant increases in CMJ performance 24 hours post-activation, with flight time ((FT): +5%) and jump height ((JH): +9%) both showing statistical significance ($p < 0.05$). SJ performance also improved significantly, with FT ($p < 0.01$, ES = 1.101) and JH ($p < 0.01$, ES = 1.335) demonstrating large effect sizes. Furthermore, SJ performance remained significantly elevated 48 hours post-intervention compared to baseline ($p < 0.05$, JH: ES = 0.829). For female participants, SJ performance showed significant improvement 24 hours after activation ($p < 0.05$, FT: ES = 1.847; JH: ES = 1.789), although no other significant changes were observed.Regarding knee flexion and extension strength, at an angular velocity of 60° /s, the male group exhibited significantly greater strength at 48 hours post-intervention compared to 24 hours ($p < 0.05$, ES = 1.791). In the female group, bilateral knee strength significantly improved at both 24 and 48 hours post-intervention ($p < 0.05$, ES = 0.152).

Conclusions: ISA interventions can enhance knee joint strength in both male and female participants within 24 and 48 hours post-intervention, and also induce a cross-activation effect. Therefore, when coaches aim to improve athletes' performance in subsequent training sessions or competition days, ISA can be considered as an effective method to activate lower limb strength.

Key words: post-activation , jump height , knee joint torque , squat jump , co untermovement jump

Introduction

Previous studies have shown that a single bout of exercise can significantly enhance muscle performance in the short term, with this enhancement effect lasting for a "window period" of approximately 24 to 48 hours [15],[37],[38],[45]. Among these, low-volume, high-intensity training has demonstrated particularly positive effects on neuromuscular performance within a short timeframe [11], [33], [37], [46]. This phenomenon is known as post-activation performance enhancement (PAPE). Although PAPE is commonly associated with dynamic strength training [25], Lum et al. [25] reported that isometric strength activation (ISA) can also effectively improve muscle strength and explosive power.

In studies on ISA, it has been found that performing isometric contractions at specific knee joint angles (such as 90° and 140°) can improve vertical jump height, including performances in countermovement jump (CMJ) and squat jump (SJ) [2], [3], [46], [25]. CMJ, as a commonly used indicator for assessing muscle strength and explosive power, has been widely applied in the evaluation and analysis of athletic performance [12], [19], [39]. The critical role of muscle strength and power in executing movement has been well established and is recognized as a major determinant of various athletic performances [12], [18]. ISA typically involves activation of the quadriceps, hamstrings, and calf muscles. Stimulation methods include isometric squats [46], static stretching [12], and maximal voluntary contraction (MVC) [19], [25], etc. Evidence suggests that ISA has broad applicability in regulating lower limb strength, contributing not only to enhanced athletic performance but also to rehabilitation from sports-related injuries [40], [49], [53]. Additionally, reports indicate that the energy expenditure of the quadriceps during ISA is sustained compared to dynamic contraction training, thereby increasing the athlete's metabolic rate. In actual exercise, the energy demand is indirect, which reduces the athlete's sense of fatigue and extends exercise performance [16], [34].

Although long-term ISA training has been clearly shown to promote muscle strength development [2], [19], [26], [49] research on the effects of short-term, low-volume, high-intensity ISA interventions—particularly their sustained effects within 24 to 48 hours post-intervention—remains limited [4], [46], [35]. According to Harrison et al. [15], a single bout of high-intensity activation exercise can induce a series of short-term physiological and neuromuscular adjustments within the neuromuscular system. These include enhanced muscle fiber excitability, improved motor unit recruitment, and increased neural conduction velocity. The duration of these effects may vary depending on factors such as an individual's training status and the specific characteristics of the exercise modality, typically persisting for 24 to 48 hours. Therefore, this time window is considered critical for understanding the potentiation effects associated with PAPE. This time window is critical for understanding the mechanisms of the PAPE effect. Moreover, in current ISA-related studies, the majority have adopted bilateral knee joint training protocols, while research focusing on unilateral knee joint ISA is relatively scarce [5], [52]. The limited available evidence suggests that unilateral training may not only be more effective in enhancing jump performance, but also in improving bilateral isokinetic strength [24]. A study by Gregory et al. further indicated that the total force output generated by training each leg separately may exceed that produced when both legs are trained simultaneously [5], [50]. This may be due to reduced neural drive during bilateral contractions, which limits the maximal activation potential of the muscles.

PAPE has shown significant effects across various sports disciplines for athletes of different sexes. For example, the study by Pereira et al [36]. found that male sprinters experienced performance improvements after implementing a PAPE protocol. Similarly, Koźlenia[20] and Matusiński et al [30]. reported that PAPE had a positive impact on sprint and jump performance in female athletes. However, Tsolakis et al.[47] indicated that male athletes showed a decline in explosive performance following an isometric conditioning activity, while no significant changes were observed in females. Due to these conflicting findings, it is difficult to directly determine whether there are sex-specific differences in the effects of ISA.

Therefore, the purpose of this study is to investigate whether low-volume, high-intensity ISA can significantly improve lower limb jump performance and bilateral isokinetic strength at 24 and 48 hours post-intervention.We hypothesize that:(1) Lower limb strength will be significantly enhanced at 24 and 48 hours after ISA intervention; (2) Gender may play a moderating role in the strength enhancement response.

Method

Participants

The sample size was calculated using G-power with the following parameters: Es = 0.25, αerr prob = 0.05, power (1-βerr prob) = 0.8. The results indicated that at least 30 samples were needed. Given that this study adopts a controlled design, at least 60 participants need to be recruited. To account for potential sample loss, an additional 13% was added, resulting in a final recruitment target of 68 participants. In the experimental group ,there were 20 males (height: 179.8 ± 3.8 cm, weight: 69.7 ± 12.4 kg, age: 24.2 ± 2.9 years) and 14 females (height: 168.5 ± 2.3 cm, weight: 58.6 ± 4.4 kg, age: 21.9 ± 2.1 years).In the control group, there were 20 males (height: 178.6 ± 2.7 cm, weight: 69.1 ± 11.8 kg, age: 24.4 ± 4.1 years) and 14 females (height: 168.3 ± 2.2 cm, weight: 69.2 ± 11.5 kg, age: 22.4 ± 2.0 years) .Participants are required to have at least one year of resistance training experience. The resistance experience includes at least three sessions per week of moderate-intensity exercises such as squats, half-squats, sled pushes, and clean power lifts. Participants verbally report their relevant training experience, which is recorded by the staff. Recruited athletes are from the College of Physical Education, specializing in 100m, 200m, high jump, or long jump. These athletes are required to have maintained at least three sessions per week of low to moderate intensity strength training—such as barbell squats, half squats, and 50m sprints—during the year prior to testing. Additionally, their last training session must have occurred no later than 72 hours before testing to minimize any potential interference from regular training. Participants must also be in good physical health. Exclusion criteria include a history of lower limb surgery; diagnosis of muscle, ligament, bone, or joint diseases such as anterior cruciate ligament (ACL) or other joint ruptures; current neurological disorders such as spinal cord injuries; inability to freely extend and flex lower limb joints; sports injuries or chronic illnesses within the past year; and chronic cardiovascular, cerebrovascular, or endocrine diseases. The Ethics Review Committee of Shandong Normal University approved the experiment, and written consent was obtained from each participant. All procedures were in accordance with the Helsinki Declaration.

Experimental Approach to the Problem

This study adopts a repeated measures design to investigate the delayed potentiation effect of unilateral ISA on jump performance and changes in lower limb joint torque at 24 and 48 hours post-intervention. FT (flight time) and JH (jump height) were selected as the primary indicators for assessing jump performance, as their average values are more sensitive and accurate in reflecting neuromuscular function compared to other testing metrics [8]. Additionally, a baseline assessment was conducted for all participants (n=68) 36-120 hours before the isometric contraction intervention. This included the unloaded SJ and the unloaded CMJ, as well as the leg torques under the conditions of angular velocities of 60°/s and 120°/s, respectively. These tests were conducted in the sports biomechanics laboratory.

To ensure the independence of the control group and minimize training interference, participants in this group were instructed to maintain their regular exercise routines throughout the study and were strictly prohibited from engaging in any high-intensity training. Compliance was monitored through training logs provided by each participant, with their activity content and training load reviewed regularly by the researchers to assess adherence to control group criteria and effectively control the risk of intervention contamination.

Jump tests

The jump tests include CMJ and SJ, performed on a force platform (9287B, Kistler, Swiss) with a frequency of 1,000 Hz. Each type of jump was performed three times in a random order, and the average value was recorded. The CMJ and SJ are executed in random order sequentially.

During the SJ process, participants are required to stand on the force platform with their knee joint flexed to approximately 90° as the initial position. Participants are instructed to hold the squat position for 2-3 seconds before initiating the complete jump. Participants placed their hands at the sides of the pelvis to avoid applying extra force to the body with their arms during the jumping process. They perform the jump upon hearing the staff member give the command. After the jump, determine whether the participant engages in reverse motion by observing the force-velocity waveform data presented on the force platform [33].

During the CMJ process, the participants stood on the force plate with their feet shoulder-width apart. Their hands were placed in the same position as in the SJ. Before jumping, they maintained a standing position for 2-3 seconds. Upon hearing the command "start" from the staff, participants should perform a downward movement as deep and fast as possible. Upon reaching their personal lowest point, they should jump upward as quickly and as high as possible. The upper body was kept as upright as possible throughout the jumping process.

Joint Moment test

The joint moment during knee flexion–extension of the left and right leg was tested on a dynamometer (CON-TREX, Swiss). Participants were required to finish three flexion-extensions in concentric contraction model at an angular velocity of both 60˚/s and 120°/s, randomly[9]. During the test, the non-testing leg was fixed to prevent assistance.Participants cross their arms over their chest, looked straight ahead, and maintained an approximately 90° angle between the spine and the quadriceps.The time interval between the two angular velocities is 2 minutes. Three repetitions at both angular speeds, respectively, were averaged as data to be utilized for analysis.

Isometric contraction stimulus

Isometric contraction stimulus can effectively induce ISA by generating tension without changes in muscle length, thereby enhancing neuromuscular recruitment efficiency and force output capacity. The subject first underwent dynamic warm-up and standardized measurements, followed by an isometric contraction stimulus. The subject sat on the ergometer with arms crossed over the chest and looked straight ahead, with the angle between the spine and the quadriceps approximately 90°. The right knee was fixed at a flexion angle of 150° (with full extension at 180°), while the left leg remained relaxed. After hearing the staff's "start" command, the participant extends their right knee forward with maximum force for 20 seconds.The interval between groups was 5 minutes, with 2-3 repetitions.

The control group only participants in the testing phase and does not undergo isometric contraction stimulation.

Procedures

In the experimental procedure, the experimental group underwent unilateral ISA, while the control group performed only regular testing under the same warm-up and testing conditions, without any unilateral activation intervention. Both groups participated in jump tests and knee joint torque measurements at baseline, Post-24h, and Post-48h.After arriving at the laboratory, participants underwent measurements for height and weight, while age and training experience were self-reported and recorded. All measurements were conducted by the same staff. They then performed a warm-up lasting for over 5 minutes, which included 3 minutes of jump rope and at least 2 minutes of dynamic stretching to reduce the risk of exercise-related injuries [41,42]. Next, they completed jump tests, and the average value of each jump type was used for analysis. There was a 1-minute interval between each jump and a 3-minute rest between the two types of jumps. After the jump test, participants rested 5 minutes before undergoing knee joint torque testing based on their physical condition.First, bilateral torque was tested at an angular velocity of 120°/s. After completing these measurements, the experimental group performed 2-3 sets of ISA for the right knee. Pre-exercise jump tests and bilateral isokinetic torque measurements were repeated 24 and 48 hours post-training (Fig.1).

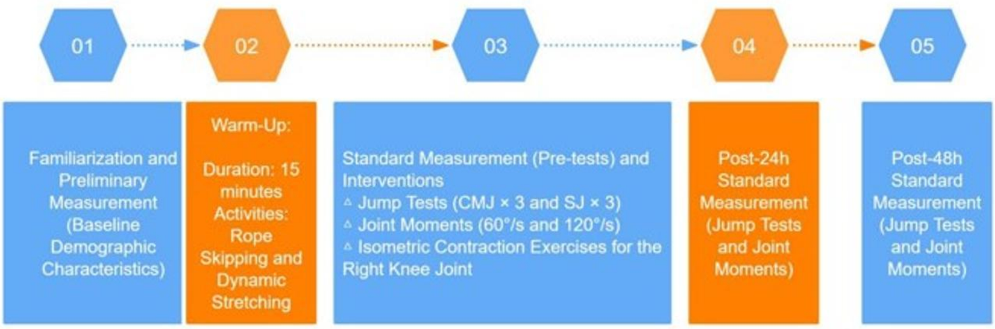


Figure 1. Experimental Design and Procedures for Isometric Strength Training. CMJ = CMJ; SJ = Squat Jump

Statistical Analysis

All statistical analysis were performed using SPSS (IBM SPSS Statistics, version 23).Data were tested for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene's test. A one-way repeated measures ANOVA was conducted within each group to assess changes in bilateral knee joint concentric torque (MAT/kg), CMJ, and SJ (FT, JH) across three time points: pre-intervention (Pre), 24 hours post-intervention (Post-24h), and 48 hours post-intervention (Post-48h). To examine between-group differences, a mixed-design repeated measures ANOVA was employed, with time (Pre, Post-24h, and Post-48h) as the within-subject factor, and group (experimental vs. control) and sex (male vs. female) as between-subject factors, in order to evaluate the influence of sex and its interaction effects on the experimental outcomes.When significant main or interaction effects were found, Tukey's post hoc test was applied to determine pairwise differences between groups.Effect size (ES) were calculated using Cohen's d, with thresholds of 0.2 (small), 0.5 (medium), 0.8 (large) to interpret the magnitude of changes.Statistical significance was set at $p < 0.05$, and all data are presented as mean ± SD.

Results

Jump measurements

In the CMJ, male participants experienced a significant increase in FT 24 hours after unilateral ISA ($p = 0.04$, ES = 1.26), with an increase of 0.028 seconds, approximately 5%. JH also increased significantly ($p = 0.04$, ES = 1.24), with an improvement of 0.038 meters, approximately 9%. However, no significant improvements were observed 48 hours post-intervention (FT: $p = 0.38$, ES = 0.36; JH: $p = 0.37$, ES = 0.36). No significant differences were observed in the female group.

In the SJ, male participants showed significant increases in both FT and JH 24 hours after the intervention (FT: $p < 0.01$, ES = 1.10; JH: $p < 0.01$, ES = 1.34). At 48 hours post-intervention, JH remained significantly improved ($p < 0.03$, ES = 0.83), with an increase of 0.043 meters, approximately 13%. In the female group, significant improvements were also observed 24 hours after the intervention in both FT ($p = 0.03$, ES = 1.85) and JH ($p = 0.03$, ES = 1.79). No other parameters showed significant improvements (Table 1).

No significant differences in the control group ($p > 0.05$).

Table 1.Data analysis in the force-time profile in squat jump and CMJ in resistance priming(means±SD)

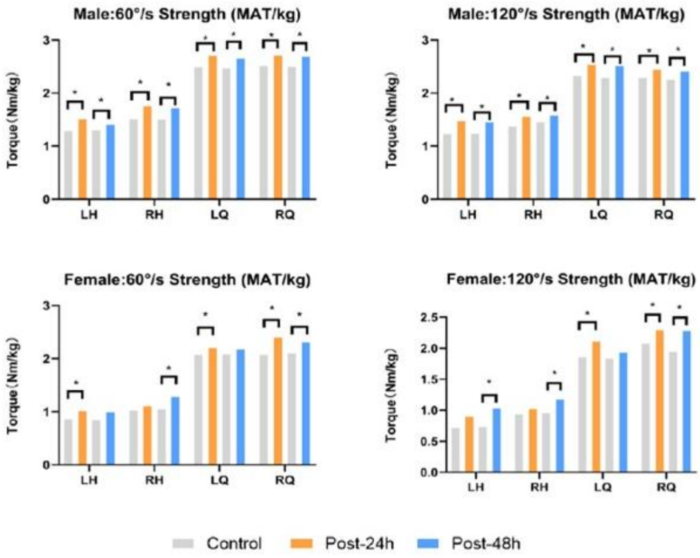
Gender	Jumps	Variables	Pre	$Post_{24h}$	$Post_{48}$	Absolute			Significance Comparison		
						$Post_{24h}$-Pre	$Post_{48h}$-Pre	$Post_{48h}$-$Post_{24h}$	$Post_{24h}$vs.Pre (P) and (ES)	$Post_{48h}$vs.Pre (P)and (ES)	$Post_{48h}$vs.$Post_{24h}$ (P) and (ES)
Male	CMJ	T(s)	0.56±0.04	0.59±0.03	0.57±0.04	0.028±0.02	0.012±0.03	-0.016±0.02	P:0.04*,ES:1.26	P:0.38,ES:0.36	P:0.24,ES:0.90
		H(m)	0.39±0.05	0.43±0.05	0.41±0.06	0.038±0.03	0.017±0.05	-0.219±0.02	P:0.04*,ES:1.24	P:0.37,ES:0.36	P:0.25,ES:0.91
	SJ	T	0.53±0.04	0.56±0.04	0.55±0.05	0.037±0.03	0.024±0.04	-0.014±0.02	P:0.01**,ES:1.10	P:0.10,ES:0.62	P:0.36,ES:0.59
		H	0.33±0.05	0.39±0.06	0.37±0.06	0.061±0.05	0.043±0.05	-0.018±0.03	P:0.01**,ES:1.34	P:0.03*,ES:0.83	P:0.36,ES:0.58
Female	CMJ	T	0.48±0.04	0.49±0.03	0.49±0.04	0.009±0.02	0.008±0.03	-0.002±0.01	P:0.53,ES:0.45	P:0.64,ES:0.34	P:0.91,ES:0.13
		H	0.29±0.04	0.3±0.04	0.3±0.05	0.01±0.02	0.008±0.02	-0.001±0.01	P:0.55,ES:0.44	P:0.64,ES:0.33	P:0.94,ES:0.08
	SJ	T	0.48±0.04	0.51±0.04	0.49±0.05	0.039±0.02	0.01±0.01	-0.028±0.01	P:0.03*,ES:1.85	P:0.56,ES:0.57	P:0.10,ES:0.53
		H	0.28±0.05	0.33±0.06	0.3±0.06	0.047±0.03	0.012±0.02	-0.035±0.01	P:0.03*,ES:1.79	P:0.56,ES:0.33	P:0.12,ES:0.67

*：There is a statistically significant difference between the two.$p<0.05$；**：There is a statistically significant difference between the two.$p<0.01$；CMJ:CMJ；SJ:squat jump；T：flight time；H：jump height；Absolute=after-before；ES:Effect sizes

Joint movement

Under the condition of 60°/s angular velocity, male participants exhibited a significant increase in isokinetic torque during the extension phase of the left knee 24 hours after the intervention (MAT/kg: $p = 0.02$, ES = 1.85), with an increase of 0.37 Nm/kg, approximately a 14% improvement. However, at 48 hours post-intervention, MAT/kg during extension of the left knee in males decreased by 0.7 Nm/kg.Among female participants, a significant increase in MAT/kg during flexion of the left knee was observed at 24 hours post-intervention ($p = 0.01$, ES = 0.94). Furthermore, MAT/kg during left knee flexion remained significantly improved compared to 48 hours post-intervention ($p = 0.03$, ES = 0.14) (see Figure 2).

Under the condition of 120°/s angular velocity, male participants had significantly higher MAT/kg during left knee flexion 24 hours after the intervention compared to the control group ($p = 0.04$, ES = 0.74), with an increase of 0.37 Nm/kg, approximately a 31% improvement. At 48 hours post-intervention, the increase in MAT/kg was 0.34 Nm/kg, approximately a 28% improvement. In the female group, at 48 hours post-intervention, MAT/kg of the right knee was significantly higher than that of the control group ($p = 0.05$, ES = 1.44). Additionally, MAT/kg of the right knee extensors increased by 0.27 Nm/kg compared to the control group ($p = 0.02$, ES = 0.81).



LH:left hamstring;RL： right hamstring； LQ： left quadriceps； RQ:right quadriceps； MAT/kg： maximum average torque； *： There is a statistically significant difference between the two.p < 0.05；

Figure 2 Comparison of isometric flexion and extension strength data before and after activation (mean±SD).

Discussion

The main findings of this study indicate that unilateral isometric knee strength training significantly improves lower limb strength and jumping performance by increasing muscle activation, and this cross-activation effect is evident within 24 to 48 hours post-training. In the jump test, both the male and female groups showed significant improvements primarily within 24 hours, with increases ranging from 5% to 13%. In the CMJ test, only the male group showed a significant improvement in jump height, increasing by 0.04m or 10.3%, while the female group did not show significant changes. In the SJ test, both the male group ($p < 0.01$) and the female group ($p = 0.03$) exhibited significant improvements in jump height. Interestingly, in the isometric torque test, significant improvements in strength were observed in both the male and female groups after 48 hours. In contrast, ISA may have a more immediate activation effect on muscle strength around a fixed knee angle within 24 hours. Although these findings support the hypothesis that ISA enhances jumping ability and bilateral knee isometric torque 24 and 48 hours after training, the specific response mechanisms for different degrees and times for male and female groups were not further investigated.

The mechanisms by which knee extension training affects isometric torque and jump height in both legs can be explored from multiple perspectives. Firstly, knee extension training primarily involves the activity of the quadriceps. Short-term fatigue of the quadriceps may impact the mechanical performance of the lower limbs, including isometric torque and jump height. Previous studies have reported [6] that under specific training conditions, unilateral interventions can lead to more significant muscle activation. The increased specificity of unilateral isometric strength can be explained by the enhanced activation of the quadriceps [6]. Additionally, isometric knee extension may directly affect muscle elasticity and force output, thereby influencing jumping performance.

From a physiological perspective, unilateral knee extension training may induce indirect effects on the contralateral leg. Although the training is performed on one side, the biomechanics of the entire lower limb chain might be affected [5], [31], [52]. Additionally, the post-training recovery phase involves muscle damage repair and adaptation processes, which could influence the recovery of strength output and jump height. One explanation for the increase in strength of the non-dominant leg is that the mechanism of muscle strength growth is related to the athlete's hormonal state and their readiness for physical performance. An increase in the ratio of free testosterone to cortisol can enhance the athlete's strength and performance. If the negative changes in hormonal state can be counteracted during resistance training, the athlete's performance will improve [15]. Changes in hormone levels not only affect performance responses after resistance priming but also influence the contraction properties of the muscles themselves, such as increased sensitivity to calcium ions (Ca2+). This physiological change explains how the effects in a unilateral ISA context can transfer to the contralateral lower limb [21], [43], [48].

This study indicates that ISA contributes to lower limb muscle activation in both male and female groups at different levels at 24 and 48 hours post-training. ISA exhibits a post-activation enhancement effect [46], [51].The short-term activation and long-term adaptation of muscle strength growth are interconnected.Muscle strength growth is the result of the interaction between short-term activation and long-term training. During the short-term activation phase, high-intensity training stimulates the neuromuscular system, rapidly activating a large number of muscle fibers, especially fast-twitch fibers, enhancing strength output in the short term. This phase is primarily related to neural adaptation, which manifests as an improved ability of the nervous system to recruit and coordinate muscle fibers. Long-term training, on the other hand, induces structural and functional changes in the muscle, such as fiber hypertrophy, increased fiber count, and muscle volume growth, which typically take longer to appear. Short-term activation provides the foundation for long-term training, while long-term training ensures sustained muscle strength development. The two processes work together to drive the growth of strength. Our data indicate that significant changes in bilateral isokinetic torque were observed at 24 and 48 hours after the knee extension training. This result may be related to muscle fatigue and adaptive responses following the training. In this study, we used active dorsiflexion of the ankle joint during isometric knee strength training. Kim et al. [43] reported that the impact of different ankle joint angles on the quadriceps during ISA shows significant differences. This explanation seems to partially account for the phenomenon of increased bilateral isometric torque. According to Kim et al. [22], motor radiation from the center point can cause a sudden spread of muscle coactivation due to the intense movement of the ankle joint when the hip and knee joints are fixed in place.

ISA, which stimulates the quadriceps, leads to a temporary fatigue effect that may influence bilateral isokinetic torque. According to some literature, a single session of high-intensity knee extension training can induce muscle fatigue, thereby affecting athletic performance and strength output [27]. At the same time, the recovery period following the training may be accompanied by partial restoration of muscle strength and function, which could also explain the changes observed at 48 hours [10], [28]. In the female group, 24 hours after the intervention, the muscles might still be in a fatigued state, so the reduction in bilateral isokinetic torque could be due to incomplete muscle recovery [7], [25], [23,24]. However, the changes in torque observed at 48 hours may be related to muscle adaptation and physiological adjustments induced by the training [10], [27,28]. This phenomenon has also been validated by previous research, which indicates that after experiencing fatigue in the short term, muscles typically undergo a recovery process.

Regarding the changes in jump height, we observed significant variations within 24 and 48 hours after training. Knee extension exercises may affect jump ability by altering the elasticity and strength output of the lower limb muscles. Research suggests that the effect of a single session of isometric knee strength training on jump ability may be due to a combination of muscle fatigue and physiological adaptive responses. This can help explain the increase in isokinetic torque observed in the female group at 48 hours [5], [6], [52]. The short-term decrease in strength and elasticity due to muscle fatigue may explain the reduction in jump height observed within 24 hours. At the same time, jump height 48 hours later may be influenced by enhanced compensation following activation, as well as muscle recovery and neuromuscular adaptation [13]. During the recovery period after training, the muscles and nervous system may gradually return to a state closer to that before training, thereby affecting the variation in jump height. Another explanation for the relatively poorer performance of women in jumping compared to men is that women generally have weaker neuromuscular control during the jumping process.From the perspective of hormones, estrogen and progesterone regulate physiological processes in women, but their effects on muscle growth and repair are not as pronounced as testosterone, which is much higher in men than in women [54]. Secondly, the menstrual cycle in women is also an important factor affecting athletic performance. The fluctuations in the menstrual cycle can cause individuals to experience a decrease in physical strength or other discomforting symptoms[29]. This results in insufficient dorsiflexion of the ankle joint and an increased occurrence of knee valgus [1]. According to research by Heweet et al., before puberty, boys and girls have similar neuromuscular control and strength. However, after puberty, women may experience a decline in strength and dynamic control of the knee joint compared to men [17]. This may, to some extent, explain the deficiencies in women's lower limb performance.

This study has several limitations. First, the choice of unilateral knee joints is a limitation. The intervention in this study focused on the dominant right leg, and results may differ for the non-dominant leg. The second limitation is the choice of knee joint angle. The angle selected in this study is approximately 150° (i.e., a knee flexion angle of 150°). Interventions at different angles might yield different results. Lastly, the knee joint torque experimental model used a concentric contraction model in this study. Results might vary with other contraction models, such as the commonly used isometric contraction model or eccentric contraction model for assessing knee joint torque and muscle damage[44]. Additionally, the 24-hour and 48-hour time frames chosen to assess the delayed enhancement effect of ISA may not fully capture all changes in neuromuscular performance, as observed in studies with time frames of 6-36 hours [15], [32], [14]. Exploring different post-intervention time points could provide a more detailed understanding of the changes in lower limb neuromuscular strength.

Practical Applications

The findings of this study are significant for the fields of sports training and rehabilitation. Understanding the impact of knee extension training on isometric torque and jump height can aid in developing more effective training and rehabilitation programs. Single-joint isometric contraction can isolate and target specific muscle groups. It can compensate for deficiencies or imbalances during the strength development process and also enhance coordination to a certain extent.Future research could explore a variety of intervention measures, including different intensities, frequencies, and durations of training, to further investigate their effects on the athletic performance and muscle adaptation of Sprinters and high jump. Simultaneously, in the development of exercise aids, the results of this study and related research can be used to improve exercise equipment by considering the individual athletic characteristics of the athletes.

Additionally, combining biomechanical analysis with electromyography studies can provide a deeper understanding of the specific effects of knee extension training on muscle function. Such research can offer more scientifically-based training recommendations for both athletes and recreational exercisers, optimizing performance and preventing exercise-related injuries.

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