Jurnal Sains Sukan dan Pendidikan Jasmani Vol 13, Isu Khas, 2024 (91-103)
ISSN: 2232-1918 / eISSN: 2600-9323
https://ejournal.upsi.edu.my/journal/JSSPJ

THE EFFECTS OF PLYOMETRIC AND HILL TRAINING ON LEG MUSCLE STRENGTH AMONG ATHLETES ACROSS DIFFERENT PHASES OF THE MENSTRUAL CYCLE

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Published online: 12 December 2024

To cite this article (APA): Ragawan, P., Mohd Rasyid, N., & Tengah, R. Y. (2024). The effects of plyometric and hill training on leg muscle strength among athletes across different phases of the menstrual cycle. *Jurnal Sains Sukan & Pendidikan Jasmani*, *13*(Isu Khas), 91–103. https://doi.org/10.37134/jsspj.vol13.sp.10.2024

To link to this article: https://doi.org/10.37134/jsspj.vol13.sp.10.2024

Abstract

This study aims to analyze the effects of plyometric and hill training on leg muscle strength among female athletes across the menstrual cycle phases. A total of 30 female athletes, aged 14 to 17, from the Cameron Highlands district participated in the study. The participants were divided into three groups: a control group (n=10), a hill training group (n=10), and a plyometric training group (n=10). The training interventions for the plyometric and hill training groups were conducted biweekly over a period of 12 weeks, specifically during the late follicular and early luteal phases of the menstrual cycle. Leg muscle strength was assessed using the squat jump test, conducted during both pre and post-intervention phases across different menstrual cycle phases. A three-way ANOVA revealed significant differences in leg muscle strength between the groups ($p<0.05$), at different test times ($p<0.05$), and across menstrual phases ($p<0.05$). The results indicated that leg muscle strength in the plyometric training group was significantly greater than control group (mean difference = 2.033, $p<0.05$) and the hill training group (mean difference = 1.367, $p<0.05$). Additionally, Tukey Post Hoc analysis demonstrated that leg muscle strength was significantly higher before menses compared to during menses (mean difference = 1.083, $p<0.05$) and also significantly higher after menses compared to during menses (mean difference = 1.667, $p<0.05$). These findings suggest that exercise serves as a mechanical stimulus for skeletal muscles, which must then be converted into biochemical signals to facilitate muscle adaptation. The hormonal fluctuations associated with the menstrual cycle, including variations in estrogen, progesterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH), are likely to influence strength outcomes. In conclusion, this study indicates that plyometric training effectively enhances leg muscle strength among female athletes aged 14 to 17, particularly when training is aligned with specific phases of the menstrual cycle for optimal results.

Keywords: plyometric training, hill training, leg muscle strength, menstrual cycle

INTRODUCTION

The capabilities of female athletes in sports activities warrant attention, and their participation should not be restricted based on political, cultural, economic, gender, or racial factors (Omiya et al., 2014; De

Soysa & Zipp, 2019; Nunes, 2019; Jeanes et al., 2021; Evans & Pfister, 2021). Gender should not be a determining factor in achieving excellence in sports events (Lena & Laura, 2018). Female athletes who undergo training, like male athletes, often experience performance declines (Whyte, Loosemore & Williams, 2015; Tibana et al., 2021). High-intensity and high-load training, when implemented without considering the psychological and sociological aspects of athletes, can lead to decreased performance (Bangsbo, Elbe, Andersen & Poulsen, 2010; Petway et al., 2020). Overall, structured training programs for female athletes are still minimal, and specific training programs need to be developed to positively impact their performance (Sommi, Gill, Trojan & Mulcahey, 2018).

Plyometric and hill training enhance both upper and lower body strength in female athletes (Faigenbaum et al., 2007; Fischetti, Cataldi & Greco, 2019; Bogdanis et al., 2019). Both types of training have been shown to improve leg muscle strength in female athletes (Akinbiola & Yekeen, 2022; Kavaliauskas, Babraj & Jakeman, 2018). The frequency of eccentric and concentric muscle movements during training promotes the production of myosin, actin, and tropomyosin, which contribute to the formation of strong myofibrils, thereby strengthening muscles, ligaments, and tendons (Sandler, 2005; Preedy, 2012; Hansen, 2018). However, an athlete's physical performance is closely related to the secretion of estrogen and progesterone during the menstrual cycle. Choosing the appropriate phase of the menstrual cycle for training is crucial, as hormone secretion levels vary across different phases. Higher levels of estrogen and progesterone during the late follicular phase and early luteal phase positively affect muscle metabolism (Stefani et al., 2016; McNulty, 2020; Gimunova et al., 2022).

Plyometric and hill training programs are more effectively designed through periodized training that considers the menstrual cycle phases to identify optimal timing and hormone secretion rates (Koltun et al., 2020). A well-structured training program with gradually manipulated intensity stimulates the hypothalamus to prompt the pituitary gland to secrete luteal and follicular hormones during the menstrual cycle phases (Burd et al., 2019; Litwack, 2019). Luteal and follicular hormones stimulate the secretion of high levels of estrogen and progesterone. Estrogen enhances protein synthesis, leading to increased muscle nuclei, while progesterone stimulates high neurotransmitter interaction in the protein synthesis process, resulting in stronger muscle structures (Nakamura & Aizawa, 2023; Sato et al., 2022).

Training programs should incorporate the principles of FITT (Frequency, Intensity, Time, Type) and consider the athlete's gender and menstrual cycle phases to create a well-structured program that effectively enhances leg muscle strength (Erhman et al., 2009; Prentice, 2016; Burnet et al., 2019; Scantlebury et al., 2020; McNulty et al, 2020; Towlson et al., 2021; Duggan et al., 2021). Therefore, plyometric and hill training programs must be designed with FITT principles and consider the appropriate menstrual cycle phases for female athletes aged 14-17 to determine their impact on physical performance.

METHODOLOGY

Subject

Thirty female athletes aged 14-17, with Grade A physical performance in the SEGAK test and regular menstrual cycles, as determined by a menstrual cycle chart, were selected to participate in the study. The athletes were randomly assigned to three groups: a control group, a plyometric training group, and a hill training group, using a simple random sampling method. Researchers employed a random number table to assign respondents to each group.

Study Design

A true experimental design was implemented to evaluate the effects of the intervention during pre-and post-tests. Phase 1 of the study involved a screening test conducted on 50 respondents. Based on the screening results, 30 respondents were selected after achieving a Grade A score in the SEGAK test, normal stress levels, normal blood pressure, and a regular menstrual cycle. The respondents were evenly divided into three groups: the control group, the plyometric training group, and the hill training group, using a simple random sampling method. Phase 2 involved the pre-test squat jump, which was conducted during the pre-menstrual phase (8 days before the expected start of menstruation), the menstrual phase (on day 3 of menstruation), and the post-menstrual phase (day 8 after menstruation ended). Phase 3 was the implementation of the intervention program, where the control group followed a training program set by the Cameron Highlands District Education Unit, while the treatment groups underwent plyometric and hill training interventions. The training was conducted twice a week for 12 weeks during the late follicular phase and early luteal phase, based on the respondents' menstrual cycle charts. Phase 4 was the post-test, which involved the standing broad jump test, conducted before menses (8 days before menstruation), menses phase (day 3 of menstruation), and after menses (day 8 after menstruation). The findings were analyzed using a three-way ANOVA to evaluate the pre- and post-test results across the menstrual cycle phases.

Research Instrument

Squat Test
The squat test was conducted to measure muscle strength according to the procedure outlined by Meininger (2012). The reliability of this test was r = 0.607 (Meininger, 2012).

Research Tools

1. Chair with height based on the measurement from knee to ankle.

Measurement from knee to ankle (cm)	Height of the chair (cm)
39-40	40
41-42	42
43-44	44

Figure 2: a. Measurement from knee to ankle (cm)**; b.** Height of the chair (cm) and **c.** Squat test performance (Adapted from *NSCA's Guide to Test and Assessments.* Meininger, 2012)

Squat Test Procedure.

1. Stand facing forward with heels positioned in front of the chair and knees shoulder width apart.
2. The athlete's hands should be crossed closely to the body.
3. The athlete performs a squat with a 45^0 forward body tilt, with thighs parallel to the chair surfaces, almost touching the chair and then stands back up.
4. Repeat the squat as in steps 2 and 3 until the athlete can no longer continue.
5. The number of successful squats is recorded.
6. A complete squat repetition is when the athlete lowers their thighs parallel to the chair surface, nearly touching it, and stands back up.

7. Each athlete is allowed only one attempt.
8. The researcher counts and records the number of successful squat repetitions completed by the athlete.

Menstrual Cycle Chart

The menstrual cycle chart (Sloane, 2012) was used during a 3-month observation period to monitor the athletes' menstrual cycle regularity. The athletes' menstrual phases and body temperatures were recorded throughout the intervention to identify the late follicular and early luteal phases. This allowed the researchers to implement the planned 12-week training intervention accordingly.

TRAINING PROGRAM

The training program was conducted over 12 weeks with a frequency of twice a week. The plyometric training group followed Mackenzie's (1997) "Model of Plyometric Drills and Their Intensity," while the hill training group followed Mackenzie's (2007) "Model of Hill Training." Both models were adapted and adjusted for female athletes aged 14 to 17 and were validated by expert reviewers.

i) Plyometric Training Program

Weeks	Plyometric Training			
Week 1 (2 times)	(Low intensity) (61%-70%)	*Squat Jump* 1 set = 20 jump Total set = 5 30 seconds rest between each set	8 minutes rest between training sessions	*Bounds and Hops over a distance of 10 meters* 1 set = 3 repetitions Total set = 4 30 seconds rest between each set
Week 2 (2 times)	(Low intensity) (61%-70%)	*Squat Jump* 1 set = 20 jump Total set = 5 30 seconds rest between each set	8 minutes rest between training sessions	*Bounds and Hops over a distance of 10 meters* 1 set = 3 repetitions Total set = 4 30 seconds rest between each set
Week 3 (2 times)	(Low intensity) (61%-70%)	*Squat Jump* 1 set = 20 jump Total set= 5 30 seconds rest between each set	8 minutes rest between training sessions	*Bounds and Hops over a distance of 10 meters* 1 set = 3 repetitions Total set = 4 30 seconds rest between each set
Week 4 (2 times)	(Low intensity) (61%-70%)	*Squat Jump* 1 set = 20 jump Total set= 5 30 seconds rest between each set	8 minutes rest between training sessions	*Bounds and Hops over a distance of 10 meters* 1 set = 3 repetitions Total set = 4 30 seconds rest between each sett
Week 5 (2 times)	(Moderate intensity) (71%-80%)	*Squat Jump* 1 set = 25 jump Total set = 5 40 seconds rest between each set	10 minutes rest between training sessions	*Bounds and Hops over a distance of 15m.* 1 set = 5 repetitions Total set = 4 40 seconds rest between each set

continued

Week 6 (2 times)	(Moderate intensity) (71%-80%)	*Squat Jump* 1 set = 25 jump Total set = 5 40 seconds rest between each set	10 minutes rest between training sessions	*Bounds and Hops over a distance of 15m.* 1 set = 5 repetitions Total set = 4 40 seconds rest between each set
Week 7 (2 times)	(Moderate intensity) (71%-80%)	*Squat Jump* 1 set = 25 jump Total set= 5 40 seconds rest between each set	10 minutes rest between training sessions	*Jump two foot over 4 hurdles* 1 set = 4 repetitions Total set = 5 40 seconds rest between each set
Week 8 (2 times)	(Moderate intensity) (71%-80%)	*Squat Jump* 1 set = 25 jump Total set = 5 40 seconds rest between each set	10 minutes rest between training sessions	*Jump two foot over 4 hurdles* 1 set = 4 repetitions Total set = 5 40 seconds rest between each set
Week 9 (2 times)	(High intensity) (81%-90%)	*Squat Jump* 1 set = 30 jump Total set = 5 50 seconds rest between each set	12 minutes rest between training sessions	*Bounds and Hops over a distance of 20 m.* 1 set = 6 repetitions Total set = 4 50 seconds rest between each set
Week 10 (2 times)	(High intensity) (81%-90%)	*Squat Jump* 1 set = 30 jump Total set= 5 50 seconds rest between each set	12 minutes rest between training sessions	*Bounds and Hops over a distance of 20 m.* 1 set = 6 repetitions Total set = 4 50 seconds rest between each set
Week 11 (2 times)	(High intensity) (81%-90%)	*Squat Jump* 1 set = 30 jump Total set= 5 50 seconds rest between each set	12 minutes rest between training sessions	*Jump two foot over 6 hurdles* 1 set = 5 repetitions Total set = 5 50 seconds rest between each set
Week 12 (2 times)	(High intensity) (81%-90%)	*Squat Jump* 1 set = 30 jump Total set = 5 50 seconds rest between each set	12 minutes rest between training sessions	*Jump two foot over 6 hurdles* 1 set = 5 repetitions Total set = 5 50 seconds rest between each set

Figure 1 Plyometric Training Program
(Source: Mackenzie, 1997: *Models of Plyometric Drills and Their Intensity)*

ii) Hill Training Program

	Hill Training Program	
Week 1 (2 times)	Running Distance: 60 m - 80 m Degree of slope: 3% Rest period: Jogging down Number of sets: 2 Number of repetitions : 4	(Low intensity) (61%-70%)
Week 2 (2 times)	Running Distance: 60 m - 80 m Degree of slope: 3% Rest period: Jogging down Number of sets: 2 Number of repetitions : 4	(Low intensity) (61%-70%)
Week 3 (2 times)	Running Distance: 80 m - 100 m Degree of slope: 4% Rest period: Jogging down Number of sets: 3 Number of repetitions : 4	(Low intensity) (61%-70%)
Week 4 (2 times)	Running Distance: 80 m - 100 m Degree of slope: 4% Rest period: Jogging down Number of sets: 3 Number of repetitions : 4	(Low intensity) (61%-70%)
Week 5 (2 times)	Running Distance: 100 m - 120 m Degree of slope: 5% Rest period: Jogging down Number of sets: 4 Number of repetitions : 4	(Moderate intensity) (71%-80%)
Week 6 (2 times)	Running Distance: 100 m - 120 m Degree of slope: 5% Rest period: Jogging down Number of sets: 4 Number of repetitions : 4	(Moderate intensity) (71%-80%)
Week 7 (2 times)	Running Distance: 120 m - 140 m Degree of slope: 6% Rest period: Jogging down Number of sets: 5 Number of repetitions : 4	(Moderate intensity) (71%-80%)
Week 8 (2 times)	Running Distance: 120 m - 140 m Degree of slope: 6% Rest period: Jogging down Number of sets: 5 Number of repetitions : 4	(Moderate intensity) (71%-80%)

continued

Week 9 (2 times)	Running Distance: 140 m - 160 m Degree of slope: 7% Rest period: Jogging down Number of sets: 6 Number of repetitions : 4	(High intensity) (81%-90%)
Week 10 (2 times)	Running Distance: 140 m - 160 m Degree of slope: 7% Rest period: Jogging down Number of sets: 6 Number of repetitions : 4	(High intensity) (81%-90%)
Week 11 (2 times)	Running Distance: 160 m - 180 m Degree of slope: 8% Rest period: Jogging down Number of sets: 7 Number of repetitions : 4	(High intensity) (77%-95%)
Week 12 (2 times)	Running Distance: 160 m - 180 m Degree of slope: 8% Rest period: Jogging down Number of sets: 7 Number of repetitions : 4	(High intensity) (77%-95%)

Figure 2: Hill Training Program
(Source: Mackenzie, 2007: Models of Hill Training)

Data Analysis

Descriptive statistics, including mean and standard deviation, were used to assess the athletes' leg muscle strength. A three-way ANOVA test was employed to analyze differences in the dependent variable, leg muscle strength, between groups during the pre and post-tests across the pre-menstrual, menstrual, and post-menstrual phases. Tukey's Post Hoc test was conducted if significant differences were found between the groups, menstrual phases, and test times. All data were analysed using SPSS version 26.0, with the significance level set at $p<0.05$.

RESULTS

Table 1 showed the descriptive analysis results for the pre-test in the control group. The mean leg muscle strength scores were as follows: before menses (M=9, SD=1.64), during menses (M=7, SD=1.55), and after menses (M=10, SD=1.97). For the post-test, the mean scores were: before menses (M=12, SD=2.23), during menstrual phase (M=11, SD=1.69), and after menses (M=15, SD=0.95). The results indicated that leg muscle strength improved in the post-test across the menstrual cycle phases. The lowest mean score for leg muscle strength was observed during menses, while the highest mean score was recorded after menses.

The descriptive analysis of the pre-test for the plyometric training group showed the following mean scores for leg muscle strength: before menses (M=8, SD=1.77), during menses (M=7, SD=1.81), and after menses (M=7, SD=1.81). For the post-test, the mean scores were: before menses (M=16, SD=1.19), during menses (M=13, SD=1.83), and after menses (M=13, SD=1.82). The descriptive results indicate an increase in leg muscle strength performance in all three phases. The lowest mean score was observed during and after the menstrual phase, while the highest mean score was found in the before menses for the plyometric group.

The effects of plyometric and hill training on leg muscle strength among athletes across different phases of the menstrual cycle

The descriptive analysis of the pre-test for the hill training group showed mean scores for leg muscle strength as follows: before menses (M=9, SD=2.20), during menses (M=7, SD=2.13), and after menses (M=9, SD=2.27). For the post-test, the mean scores before menses (M=13, SD=2.42), during menses (M=11, SD=1.73), and after menses (M=16, SD=2.00). The results indicated improved leg muscle strength performance across all three phases. The lowest mean score was observed during menses, while the highest mean score was recorded in the after menses for the hill training group.

Table 1: Descriptive analysis of leg muscle strength among the control, plyometric and hill training group for pre- and post-tests across the menstrual cycle phases.

Research group	Num of respondents (n)	Menstrual Cycle Phase	Test times	Mean (number of repetitions)	Standard Deviation (SD)
Control	10	Before	Pre	9	1.64
			Post	12	2.23
		During	Pre	7	1.55
			Post	11	1.69
		After	Pre	10	1.97
			Post	15	0.95
Plyometric	10	Before	Pre	8	1.77
			Post	16	1.19
		During	Pre	7	1.81
			Post	13	1.83
		After	Pre	7	1.81
			Post	13	1.82
Hill	10	Before	Pre	9	2.20
			Post	13	2.42
		During	Pre	7	2.13
			Post	11	1.73
		After	Pre	9	2.27
			Post	16	2.00

Table 2 showed the results of the three-way ANOVA test for leg muscle strength between the control group, plyometric training group, and hill training group for both pre- and post-tests across the menstrual cycle phases. There was a significant difference in leg muscle strength, F (2,162) =18.841, p<0.05, for the main effect between the control group, plyometric training group, and hill training group. Additionally, a significant difference in leg muscle strength was observed, F (1,162) =72.287, p<0.05, for the main effect between test times (pre-test and post-test). The main effect of the menstrual phase also showed a significant difference in leg muscle strength, F (2,162) =12.543, p<0.05.

Table 2: Three-way ANOVA for leg muscle strength among the control, plyometric, and hill training group for pre- and post-tests across the menstrual cycle phases.

	Mean Square	df		F	Level of significance (p)
Research group	64.467	2	162	18.841	0.000*
Test times	247.339	1		72.287	0.000*
Menstrual cycle phases	42.917	2		12.543	0.000*

Research group*Test times*Menstrual cycle phase	0.789	4	0.231	0.921

*Significant level p < 0.05

Table 3 showed the results of the Tukey Post Hoc test for leg muscle strength between the control group, plyometric training group, and hill training group. The Tukey Post Hoc analysis revealed that the leg muscle strength performance of the plyometric training group was significantly higher than that of the control group (mean difference = 2.033, p<0.05). The plyometric training group's leg muscle strength was also significantly higher than the hill training group (mean difference = 1.367, p<0.05). Therefore, the leg muscle strength performance was highest in the plyometric training group compared to the control and hill training groups.

Table 3: Tukey Post Hoc test for leg muscle strength between the control, plyometric training and Hill training group.

(I) Research Group	(J) Research Group	Mean Difference (I-J)	F
Plyometric	Control	2.033	0.000
	Hill	1.367	0.000

*Significant level p < 0.05

The three-way ANOVA also indicated a significant difference in leg muscle strength for the main effect of test time, comparing pre-and post-tests. Descriptive analysis (Table 1) revealed that the mean post-test scores increased for the control group, plyometric training group, and hill training group. For the hill training group, the highest mean post-test score was observed after menses (M=16, SD=2.00). For the plyometric training group, the highest mean post-test score was found before menses (M=16, SD=1.19). Descriptive comparisons showed that the mean post-test score was highest before menses for the plyometric training group and highest after menses for the hill training group.

Table 4 presents the results of the Tukey Post Hoc test for leg muscle strength across the - menstrual cycle phases. The Tukey Post Hoc analysis reveals that leg muscle strength was significantly higher before menses compared during menses (mean difference = 1.083, p<0.05). Leg muscle strength was also significantly higher after menses compared to the menstrual phase (mean difference = 1.667, p<0.05). Thus, leg muscle strength was found to be higher after menses compared to both phases before and during menses.

Table 4: Tukey Post Hoc test for leg muscle strength across the menstrual cycle phases.

(I) Menstrual Cycle Phase	(J)Menstrual Cycle Phase	Mean Difference (I-J)	F
Before menses	During menses	1.083	0.005
During menses			
After menses	During menses	1.667	0.000

*Significant level p < 0.05

DISCUSSIONS

Adolescent girls can improve their muscle strength through consistent physical exercise and a healthy lifestyle (World Health Organization, 2024). Muscle strength in adolescent girls develops alongside physical growth and hormonal changes during puberty and menses. During this time, the body produces hormones, including estrogen, progesterone and small amounts of testosterone, which influence muscle development. The impact of the different phases of the menstrual cycle on performance is among the most debated topics. Concerning that, this study focused on the effect of the menstrual cycle phases and physical performance during plyometric and hill training among female athletes. Plyometrics enhance neuromuscular coordination by training the nervous system, making movements more automatic during activity. This process, known as reinforcing motor patterns, leads to the automation of movements, which improves neural efficiency and boosts neuromuscular performance. While running uphill forces muscles to work harder, with the effort increasing as the incline becomes steeper. Over time, hill training enhances the strength of the involved muscles, contributing to improved muscle tone and overall body mechanics.

The findings of this study indicate a significant difference in leg muscle strength between the study groups, test times, and menstrual cycle phases. Leg muscle strength performance was significantly greater in the plyometric training group than in the control and hill training groups. According to Pink et al., (2021), the effectiveness of leg muscle strength performance is contingent upon systematic training planning, which facilitates the development of muscle capabilities essential for enhancing athletic performance. Previous research also indicates that the implementation of plyometric training for female athletes should specifically emphasize aspects such as the number of sets, repetitions, exercise arrangement, exercise variety, training duration, rest periods, and training frequency to develop high leg muscle strength (Coelho et al., 2019; Strasilova & Vajda, 2022; Sabillah, Nasrulloh & Yuniana, 2022).

Concurrently, the findings of this study also indicate that leg muscle strength varies between different phases of the menstrual cycle. The plyometric training group demonstrated higher leg muscle strength in both before and during menses, while the hill training group exhibited greater leg muscle strength after menses. The physiological mechanisms controlling menstruation, with different levels of estrogen and progesterone throughout the cycle have positively influenced sports performance. Some researchers have shown that the estrogen and progesterone secreted during the menstrual phase can affect both biological and psychological aspects in females. Elevated estrogen levels may lead to weight gain, low mood, and severe premenstrual syndrome (Blasi et al, 2022). Specifically, progesterone can contribute to fluid retention and increased body weight, potentially impairing performance (Konishi & Katabuchi, 2020).

The findings of this study align with previous research indicating after menses is particularly suitable for structured and strategic training, taking concern of hormone levels during the early luteal and late follicular phases (Julianet al., 2017; Sartori et al., 2021; Bruinvels et al., 2022). Adjusting for time-varying hormone concentrations in each phase can be advantageous for tailoring exercise routines accordingly. The research findings are consistent with recommendations (McNulty et al., 2020; Carmichael et al., 2021) that training programs for female athletes should account for menstrual cycle phases to enhance training effectiveness. This is due to the varying levels of estrogen and progesterone in each phase of the menstrual cycle, which influence the development of leg muscle strength (Preedy, 2012).

As athletes adapt to progressively increased intensity training, this process stimulates the hypothalamus, resulting in the pituitary gland secretion of luteal and follicular hormones throughout the menstrual cycle phases (Litwack, 2019). Luteal and follicular hormones are fundamental in stimulating elevated levels of estrogen and progesterone during the menstrual cycle phases. High estrogen levels facilitate increased protein synthesis, while progesterone enhances neurotransmitter interactions associated with glycogenolysis (Nakamura & Aizawa, 2023; Sato et al., 2022; Bernstein & Behringer, 2023). Glycogenolysis is vital for optimizing muscle performance. Efficient neurotransmitter interactions promote improved coordination and accelerated signal transmission between nerves and muscles, thereby enhancing overall muscle function during physical activities. Furthermore, increased frequency of eccentric and concentric leg muscle movements enhances protein synthesis i.e glycogenolysis (Suchomel et al., 2018; Ortenblad et al., 2022), which leads to the formation of more muscle nuclei and the production of myosin, actin, and tropomyosin, thereby creating stronger myofibrils. The development of strong myofibril structures enhances the strength of muscles, ligaments, and tendons (Preedy, 2012; Francaux & Deldicque, 2019; Burd et al., 2019).

Therefore, plyometric training specifically tailored to female athletes, with careful attention to training intensity and load, is more effective for enhancing leg muscle strength in adolescent female athletes. Furthermore, implementing plyometric training after menses has been shown to be more beneficial for muscle strength development.

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