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The Effects of Resistance Training and Plyometric Training on Lower Limb Power in College Students at Baoshan University

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Abstract
Background and Aim: Enhancing lower limb power is essential for improving human movement efficiency and athletic performance. However, many college students in China lack knowledge about appropriate training methods to improve this physical attribute. This study examines the effects of resistance, plyometric, and complex training on the development of lower limb power in college students.
Materials and Methods: The study utilized three training interventions: resistance training, plyometric training, and complex training. Lower limb power was assessed using the Standing Broad Jump (SBJ), Squat Jump (SJ), and Countermovement Jump (CMJ). A total of 45 college students who volunteered and passed the inclusion criteria participated. The training programs were developed based on existing power training principles and validated using the index of Item-Objective Congruence (IOC). Measurements were conducted at three time points: pre-training, after the 4th week, and after the 8th week. Data were analyzed using mean, standard deviation, one-way repeated measures ANOVA, and LSD post hoc multiple comparisons with a significance level of 0.05.
Results: The results showed that complex training significantly outperformed resistance and plyometric training in enhancing lower limb power significant at a level of 0.05. All three groups demonstrated progressive improvements in lower limb power indicators throughout the 8 weeks. No significant differences were observed among the groups at week 4, but significant differences emerged by week 8, particularly favoring the complex training group.
Conclusion: Complex training is more effective than resistance or plyometric training alone in improving lower limb power among college students. While all training modalities contributed to improvements over time, significant differences were observed only after eight weeks, highlighting the importance of sustained intervention for measurable outcomes.
Keywords: Resistance Training; Plyometric Training; Complex Training; Lower Limb Power

Introduction

Power refers to the maximum work done in a short time, which is a kind of physical quality of the body, and its essence is the combination of muscle coordination, speed, strength, and other qualities (Huang, 2023). Lower limb power is the basis for the human body to engage in all physical activities and physical labor. A series of activities in daily life requires a high level of power, and a high level of lower limb power will make the human body achieve better performance in a series of specific sports and activities (Tian & Liu, 2016). The ability to perform high power output is considered by research to be one of the fundamental characteristics of successful performance in a variety of sporting activities, any sport requiring the ability to generate power in a relatively short amount of time, including jumping, throwing, and changing direction. Extensive training interventions are recommended to enhance their ability to deliver high power output and improve their overall athletic performance.

“China College Student Health Survey Report” shows that 70% of college students ensure their physical and mental health and a series of sports. Among the independent exercise of college students, 31% of college students tend to improve the lower limb power through resistance training has reached the purpose of improving athletic ability (Yan, 2023). However, resistance training has high requirements on movement techniques, and improper exercise methods or body posture can easily cause joint muscle damage (Ma, 2023). In addition, resistance training for ordinary college students with poor basic strength

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and no exercise foundation has certain safety risks, and wrong training movements and heavy load training are easy to cause sports injuries, which is not conducive to the healthy physical and mental development of college students (Wang, 2018).

With the development of modern physical training theory and practice, lower limb power training shows a scientific, data-based, and diversified trend, such as plyometric training and complex training, which can effectively develop athletic power. (Wang, S. & Xu, Q. 2022). Plyometric training mainly activates muscles and tendons through high-intensity exercises, which can effectively improve the athletes' rapid strength quality and significantly improve the power of the lower limbs. This novel training method has low requirements for venues and equipment, is very easy to carry out, and has no safety problems associated with resistance training (Sammoud et al., 2024). Complex training is a training method in which heavy-weight resistance training with similar biomechanical characteristics is alternated with light load, rapid stretching compound training in the same training course. At present, a few studies at home and abroad have confirmed that compound training can improve the strength and power level of athletes at the same time, which is a very efficient training method with a low risk of injury. At present, plyometric training and complex training are only applied to high-level sports teams and are rarely used in the teaching and training of ordinary universities. Most teachers and college students do not know how to carry out this training method (Thapa et al., 2021; Biel et al., 2023).

Therefore, how to use more scientific and simple training methods to improve the lower limb power of college students is a problem worthy of further study. This study hopes to design a training program to improve the lower limb power of college students, explore the impact of resistance training, plyometric training, and complex training on the lower limb power of college students, provide a reference for enriching the training methods of college students to improve the lower limb power, and enrich the relevant research content.

Objectives

1. To study the effects of resistance training, plyometric training, and complex training on lower limb power in college students.

2. To compare the effects of resistance training, plyometric training, and complex training on lower limb power in college students after 4 weeks and after 8 weeks.

Literature review

Power is defined as the maximum amount of work a muscle can perform in a short period, calculated as the product of speed and strength (Tian & Liu, 2016). Specifically, lower limb power refers to the ability of lower limb muscles to exert maximal force rapidly and is achieved through a combination of strength and speed under the coordinated function of various muscle groups. Lower limb power plays a vital role in supporting dynamic athletic movements such as running and jumping, and can be categorized into explosive power, emphasizing single bursts of force, and power endurance requiring sustained or repeated explosive actions across time. Explosive power is crucial in sports like shot put, high jump, weightlifting, and javelin throw, while power endurance is essential in activities such as basketball, football, volleyball, and badminton (Santos & Janeira, 2012).

Resistance training has been shown to improve both maximal strength and muscular power. However, its effectiveness is contingent on the individual's baseline strength, and the rate of power development tends to plateau with continued training unless modified appropriately. As Santos & Janeira (2012), Huang (2023) noted, training load in resistance programs must align with specific training goals to optimize outcomes.

Plyometric training is recognized as an effective method for developing lower limb power. Compared to other strength training forms, plyometric training emphasizes rapid muscle contraction and stretch-shortening cycles to enhance neuromuscular efficiency. Key variables affecting its effectiveness include the contraction velocity, the stretch length, and the interval between repetitions. Studies have demonstrated that plyometric training significantly improves lower limb power, agility, and speed, particularly in adolescents. Nevertheless, there remains a scarcity of research focused on college-aged populations, as most studies target youth or professional athletes (Hariyanto et al., 2022; Sammoud et al., 2024).

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Complex training, which combines resistance exercises with plyometric movements within the same session, is commonly employed in elite athletic training environments. Indicated that while complex training is believed to improve power output effectively, its physiological mechanisms and optimal rest intervals remain inconclusive. There is also limited research comparing its effectiveness against other methods in non-elite populations, such as college students (Cheng, 2022; Biel et al., 2023).

The power of the lower limbs, crucial for dynamic athletic motions, arises from the integration of strength and velocity. Although resistance training enhances strength, its effect on power may stagnate without modifications to the program. Plyometric exercise improves neuromuscular efficiency via quick, explosive movements, although it remains inadequately studied in collegiate populations. Complex training, which combines resistance and plyometric workouts, demonstrates potential in enhancing power; nevertheless, additional research is necessary to validate its processes and efficacy in non-elite populations, such as college students.

Conceptual Framework

This research is a research study. The effects of resistance training and plyometric training on lower limb power in college students. The researcher defines the research conceptual framework based on the concept/theory of the principle of training. The details are as follows.

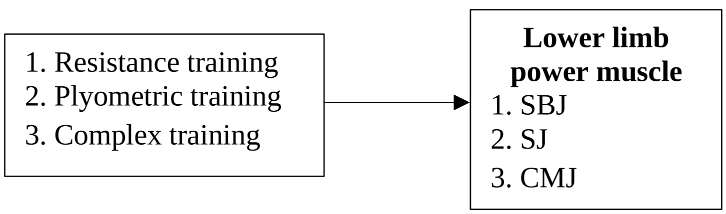

Figure 1 Conceptual Framework

Methodology

Population and sample

The study population consisted of 586 male students from Baoshan University. From this group, participants were initially selected using volunteers, 45 students, and selected as samples and passed the test criteria, divided into 3 experimental groups with 15 students in each group. Experimental group 1 practice resistance training, experimental group 2 practice plyometric training, experimental group 3 practice complex training, three times a week for 8 weeks of the experiment. This research was subjected to ethical review by the Ethics Board of the Udon Thani Rajabhat University (HECUD.263/2024).

1. Inclusion Criteria:
   - 1.1 Male college students majoring in physical
   - 1.2 More than 2 years of resistance training
   - 1.3 The 1RM can reach more than 1.5 times the volunteer's own body weight
2. Exclusion Criteria:
   - 2.1 Sports injury within 1 year of education
   - 2.2 Competition assignment experience
   - 2.3 Participate in other strength and power training

Research instruments

The research instruments included:

1. The program of experimental group 1 resistance training, the program of experimental group 2 plyometric training, and the program of experimental group 3 complex training, the lower limb power training program with objectives through Item Objective Congruence (IOC) average between 0.93, 0.90, and 0.94.

2. Lower limb power test items include Standing Broad Jump (SBJ), Squat Jump (SJ), and Countermovement Jump (CMJ), with a reliability of 0.85.

Data collection

Data were collected over 8 weeks, with measurements at three time points:

1. Pre-Test: Before training began.
2. Mid-Test: During the 4th week of training.

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3. Post-Test: After the 8th week of training.

Data Analysis

The analysis methods are as follows:

1. The mean and standard deviation for both the experimental and control groups.

2. Compared lower limb muscle power (Standing Broad Jump (SBJ), Squat Jump (SJ), and Countermovement Jump (CMJ) at three time points (before the experiment, after 4 weeks, and after 8 weeks) using:

2.1 One-Way ANOVA with Repeated Measures to analyze within-group and between-group differences, with Post hoc multiple comparisons LSD.

Results

To determine whether the variance in mean SBJ, SJ(High), SJ(Power), and CMJ in the three experimental groups was different at the time before the experiment, after 4 weeks, and after 8 weeks of the experiment. The researcher therefore performed a One-Way ANOVA with repeated measures analysis of variance, as shown in Table 1.

Table 1 Results of One-way ANOVA repeated measure Analysis of Variance on the mean SBJ, SJ(High), SJ(Power), and CMJ in the three experimental groups at the time before the experiment, after 4 weeks, and after 8 weeks of the experiment.

Experimental group 1 (n=15)	**Source of variation**	**SS**	**df**	**MS**	**F**	***p***
SBJ	Between	285.378	2	142.689	4.881	0.012*
	Within	1227.867	42	29.235		
	Total	1513.244	44	171.924		
SJ (High)	Between	294.028	2	147.014	22.906	0.000*
	Within	269.564	42	6.418		
	Total	563.592	44	153.432		
SJ (Power)	Between	1558559.511	2	779279.756	34.718	0.000*
	Within	942724.400	42	22445.819		
	Total	2501283.911	44	801725.575		
CMJ	Between	128.896	2	64.448	4.046	0.025*
	Within	669.036	42	15.929		
	Total	797.932	44	80.377		
Experimental group 2 (n=15)	**Source of variation**	**SS**	**df**	**MS**	**F**	***p***
SBJ	Between	480.044	2	240.022	12.439	0.000*
	Within	810.400	42	19.295		
	Total	1290.444	44	259.317		
SJ（High）	Between	62.899	2	31.450	4.183	0.022*
	Within	315.784	42	7.519		
	Total	378.683	44	38.969		
SJ (Power)	Between	119644.044	2	59822.022	3.712	0.033*
	Within	676853.200	42	16115.552		
	Total	796497.244	44	75937.574		
CMJ	Between	337.456	2	168.728	12.582	0.000*
	Within	563.236	42	13.410		
	Total	900.692	44	182.138		

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Experimental group 3 (n=15)	Source of variation	SS	df	MS	F	*p*
SBJ	Between	1252.844	2	626.422	43.675	0.000*
	Within	602.400	42	14.343		
	Total	1855.244	44	640.765		
SJ（High）	Between	488.134	2	244.067	24.762	0.000*
	Within	413.976	42	9.857		
	Total	902.110	44	253.924		
SJ (Power)	Between	3726178.311	2	1863089.156	44.302	0.000*
	Within	1766293.600	42	42054.610		
	Total	5492471.911	44	1905143.76		
CMJ	Between	477.314	2	238.657	25.226	0.000*
	Within	397.356	42	9.461		
	Total	874.670	44	248.118		

$^{*}p<0.05$

Table 1 shows that: In all 3-group experiments, there are significant differences between SBJ, SJ(High), SJ (Power), and CMJ, significant at the level of 0.05.

Experimental group 1 SBJ (F=4.881, p=0.012*), SJ(High) (F=22.906, p=0.000*), SJ (Power) (F=34.718, p=0.000*) and CMJ (F=4.046, p=0.025*). Experimental group 2 SBJ (F=12.439, p=0.000*), SJ(High) (F=4.183, p=0.022*), SJ (Power) (F=3.712, p=0.033*) and CMJ (F=12.582, p=0.000*). Experimental group 3 SBJ (F=43.675, p=0.000*), SJ(High) (F=24.762, p=0.000*), SJ (Power) (F=44.302, p=0.000*) and CMJ (F=25.226, p=0.000*).

To know which stages of the experimental groups are different. The researcher, therefore, tested the differences in pairs using the LSD method, as shown in Table 2.

Table 2 Results of Pairwise Comparisons of the mean SBJ, SJ(High), SJ(Power), and CMJ of the Experimental Group 1 Over Time

Variable	Time		Mean	Comparison	*p*
SBJ (A)	Pre-test	A_E1	262.80 ± 5.77	A_E1- A_E2	0.220
	After 4 weeks	A_E2	264.87 ± 5.59	A_E2 - A_E3	0.094
	After 8 weeks	A_E3	268.87 ± 4.81	A_E3 - A_E1	0.007*
SJ (B) (High）	Pre-test	B_E1	44.39 ± 2.29	B_E1 - B_E2	0.276
	After 4 weeks	B_E2	45.41 ± 3.32	B_E2 - B_E3	0.000*
	After 8 weeks	B_E3	50.25 ± 1.72	B_E3 - B_E1	0.000*
SJ(C） (Power)	Pre-test	C_E1	4048.87 ± 134.46	C_E1 - C_E2	0.516
	After 4 weeks	C_E2	4084.67 ± 112.96	C_E2 - C_E3	0.000*
	After 8 weeks	C_E3	4460.33 ± 191.05	C_E3 - C_E1	0.000*
CMJ (D)	Pre-test	D_E1	53.00 ± 4.29	D_E1 - D_E2	0.029*
	After 4 weeks	D_E2	55.65 ± 4.15	D_E2 - D_E3	0.001*
	After 8 weeks	D_E3	57.09 ± 3.50	D_E3 - D_E1	0.001*

$*p<0.05$

Table 2 shows that: SBJ, there was no significant difference pre-test and after 4 weeks (p=0.220), after 4 weeks and after 8 weeks (p=0.094); however, pre-test and after 8 weeks ($p=0.007^{*}$), there are significant differences at the level of 0.05.

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SJ (High) there was no significant difference pre-test and after 4 weeks (*p*=0.276), however, after 4 weeks and after 8 weeks (*p*=0.000*), pre-test and after 8 weeks (*p=0.000**), there were significant differences at level 0.05.

SJ (Power) there was no significant difference pre-test and after 4 weeks (*p*=0.516), however, after 4 weeks and after 8 weeks (*p*=0.000*), pre-test and after 8 weeks (*p=0.000**), there were significant differences at the level 0.05.

CMJ pre-test and after 4 weeks (*p*=0.029*), after 4 weeks and after 8 weeks (*p*=0.000*), pre-test and after 8 weeks (*p=0.000**), there were significant differences at the level of 0.05.

Table 3 Results of pairwise comparisons of the mean SBJ, SJ(High), SJ(Power), and CMJ of the Experimental Group 2 Over Time

Variable	Time		Mean	Comparison	*p*
SBJ (A)	Pre-test	A_E1	264.07 ± 3.43	A_E1- A_E2	0.523
	After 4 weeks	A_E2	265.13 ± 4.67	A_E2 - A_E3	0.005*
	After 8 weeks	A_E3	271.47 ± 4.93	A_E3 - A_E1	0.000*
SJ (B) (High)	Pre-test	B_E1	44.75 ± 3.38	B_E1 - B_E2	0.128
	After 4 weeks	B_E2	46.31 ± 2.72	B_E2 - B_E3	0.188
	After 8 weeks	B_E3	47.65 ± 1.94	B_E3 - B_E1	0.006*
SJ(C) (Power)	Pre-test	C_E1	4037.87 ± 112.98	C_E1 - C_E2	0.398
	After 4 weeks	C_E2	4077.47 ± 140.91	C_E2 - C_E3	0.077
	After 8 weeks	C_E3	4161.53 ± 125.40	C_E3 - C_E1	0.011*
CMJ (D)	Pre-test	D_E1	53.79 ± 4.68	D_E1 - D_E2	0.019*
	After 4 weeks	D_E2	55.11 ± 3.84	D_E2 - D_E3	0.000*
	After 8 weeks	D_E3	60.15 ± 1.88	D_E3 - D_E1	0.000*

*p<0.05

Table 3 shows that: SBJ, there was no significant difference pre-test and after 4 weeks (*p*=0.523); however, after 4 weeks and after 8 weeks (*p*=0.005*), pre-test and after 8 weeks (*p=0.000**), there are significant differences at the level of 0.05.

SJ (High) there was no significant difference pre-test and after 4 weeks (*p*=0.128), after 4 weeks and after 8 weeks (*p*=0.188), however, pre-test and after 8 weeks (*p=0.000**) there were significant differences at level 0.05.

SJ (Power) there was no significant difference pre-test and after 4 weeks (*p*=0.398), after 4 weeks and after 8 weeks (*p*=0.077), however, pre-test and after 8 weeks (*p=0.000**), there were significant differences at the level of 0.05.

CMJ pre-test and after 4 weeks (*p*=0.019*), after 4 weeks and after 8 weeks (*p*=0.000*), pre-test and after 8 weeks (*p=0.000**), there were significant differences at the level of 0.05.

Table 4 Results of pairwise comparisons of the mean SBJ, SJ(High), SJ(Power), and CMJ of the experimental group 3 over time.

Variable	Time		Mean	Comparison	*p*
SBJ (A)	Pre-test	A_E1	265.13 ± 4.05	A_E1- A_E2	0.260
	After 4 weeks	A_E2	266.47 ± 3.29	A_E2 - A_E3	0.000*
	After 8 weeks	A_E3	276.93 ± 3.97	A_E3 - A_E1	0.000*
SJ (B) (High)	Pre-test	B_E1	45.37 ± 3.42	B_E1 - B_E2	0.242
	After 4 weeks	B_E2	46.73 ± 3.57	B_E2 - B_E3	0.000*
	After 8 weeks	B_E3	52.93 ± 2.25	B_E3 - B_E1	0.000*
SJ (C) (Power)	Pre-test	C_E1	4067.07 ± 137.21	C_E1 - C_E2	0.601
	After 4 weeks	C_E2	4106.53 ± 132.94	C_E2 - C_E3	0.000*
	After 8 weeks	C_E3	4696.27 ± 299.44	C_E3 - C_E1	0.000*

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CMJ (D)	Pre-test	D_E1	55.17 ± 3.77	D_E1 - D_E2	0.000*
	After 4 weeks	D_E2	57.51 ± 3.26	D_E2 - D_E3	0.000*
	After 8 weeks	D_E3	62.95 ± 1.88	D_E3 - D_E1	0.000*

*$p<0.05$

Table 4 shows that pairwise comparisons within experimental group 3 revealed the following patterns. For SBJ, significant improvement was observed between weeks 4 and 8 (p=0.000*) and between pre-test and week 8 (p=0.000*), while the change from pre-test to week 4 was not significant (p=0.260). In SJ (Height) and SJ (Power), similar trends were observed, with significant improvements appearing only after the 8th week. For CMJ**,** all pairwise comparisons showed significant differences (p<0.000*), indicating continuous and progressive enhancement in lower limb power throughout the training period.

Table 5 Results of One-way ANOVA repeated measure Analysis of Variance on the mean SBJ, SJ(High), SJ(Power), and CMJ between the three experimental groups at the time before the experiment, after 4 weeks, and after 8 weeks of the experiment.

Pre-test	**Exp-1**		**Exp-2**		**Exp-3**		**F**	***p***
	x̄	**SD**	**x̄**	**SD**	**x̄**	**SD**		
SBJ	262.80	5.77	264.07	3.43	265.13	4.05	0.998	0.377
SJ (High)	44.39	2.29	44.75	3.38	45.37	3.42	0.384	0.683
SJ (Power)	4048.87	134.46	4037.87	112.98	4067.07	137.21	0.197	0.822
CMJ	53.00	4.29	53.79	4.68	55.17	3.77	0.992	0.379
Post-test After 4 weeks	**Exp-1**		**Exp-2**		**Exp-3**		**F**	***p***
	x̄	**SD**	**x̄**	**SD**	**x̄**	**SD**		
SBJ	264.87	5.59	265.13	4.67	266.47	3.29	0.517	0.600
SJ (High)	45.41	3.32	46.31	2.72	46.73	3.57	0.649	0.528
SJ (Power)	4084.67	112.96	4077.47	140.91	4106.53	132.94	0.205	0.815
CMJ	55.65	4.15	55.11	3.84	57.51	3.26	1.673	0.200
Post-test After 8 weeks	**Exp-1**		**Exp-2**		**Exp-3**		**F**	***p***
	x̄	**SD**	**x̄**	**SD**	**x̄**	**SD**		
SBJ	268.87	4.81	271.47	4.93	276.93	3.97	12.076	0.000*
SJ (High)	50.25	1.72	47.65	1.94	52.93	2.25	26.605	0.000*
SJ (Power)	4460.33	191.05	4161.53	125.40	4696.27	299.44	22.776	0.000*
CMJ	57.09	3.50	60.15	1.88	62.95	1.88	20.014	0.000*

*$p<0.05$

Table 5 shows that: presents the comparison of lower limb power indicators SBJ, SJ (Height), SJ (Power), and CMJ among three experimental groups across three time points: pre-test, after 4 weeks, and after 8 weeks. At the 8-week post-test, statistically significant differences were found between the groups in all variables (*p<0.00), with experimental group 3 consistently demonstrating the highest mean scores. No significant differences were observed at the pre-test and 4-week post-test stages, suggesting that notable performance gains occurred predominantly in the latter phase of the intervention.

Table 6 Results of pairwise comparisons of the mean SBJ, SJ(High), SJ(Power), and CMJ of the three experimental groups at the time after 8 weeks of the experiment.

Variable	**Time**	**Mean**	**Comparison**	***p***
SBJ (A)	Experiment group 1 A_E1	268.87 ± 4.81	A_E1 - A_E2	0.128
	Experiment group 2 A_E2	271.47 ± 4.93	A_E2 - A_E3	0.002*
	Experiment group 3 A_E3	276.93 ± 3.97	A_E3 - A_E1	0.000*

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SJ (B) (High)	Experiment group 1 B_E1	50.25 ± 1.72	B_E1 - B_E2	0.001*
	Experiment group 2 B_E2	47.65 ± 1.94	B_E2 - B_E3	0.000*
	Experiment group 3 B_E3	52.93 ± 2.25	B_E3 - B_E1	0.001*
SJ (C) (Power)	Experiment group 1 C_E1	4460.33 ± 191.05	C_E1- C_E2	0.001*
	Experiment group 2 C_E2	4161.53 ± 125.40	C_E2- C_E3	0.000*
	Experiment group 3 C_E3	4696.27 ± 299.44	C_E3- C_E1	0.005*
CMJ (D)	Experiment group 1 D_E1	57.09 ± 3.50	D_E1- D_E2	0.002*
	Experiment group 2 D_E2	60.15 ± 1.88	D_E2- D_E3	0.004*
	Experiment group 3 D_E3	62.95 ± 1.88	D_E3- D_E1	0.000*

$^{*}p<0.05$

Table 6 shows that it presents pairwise comparisons of SBJ, SJ (Height), SJ (Power), and CMJ across the three experimental groups after the 8-week intervention. Significant differences ($^{*}p<0.05$) were observed in all variables between most group comparisons. Experimental Group 3 consistently demonstrated the highest mean scores across all measures, indicating superior improvements in lower limb power compared to Groups 1 and 2. These results suggest that the training used in group 3 was more effective in enhancing explosive strength and power performance.

Discussion

1. Discussion on lower limb power in all experimental groups

1.1 Resistance training has been widely recognized as an effective method for enhancing lower limb power, including both horizontal and vertical explosive performance. Specifically, an 8-week training cycle is typically required to observe significant improvements in horizontal power, such as the Standing Broad Jump (SBJ) distance (Tai et al., 2022). Research indicates that vertical power performance—measured through Squat Jump (SJ) and Countermovement Jump (CMJ) also improves significantly during the 4th to 8th weeks of resistance training (Vanderka et al., 2016; Ramírez-Campillo et al., 2018). Notably, the second half of the training cycle (weeks 4-8) tends to show greater improvements compared to the first half (weeks 1-4), suggesting a cumulative training effect over time.

From the perspective of performance development amplitude, early- to mid-phase training (weeks 1-4) yields sharper gains, possibly due to neural adaptation and motor learning (Vanderka et al., 2016). However, continued training into the mid- to late-phase (weeks 5-8) still contributes to further progress in dynamic vertical power, albeit at a slightly diminished rate, consistent with the principle of diminishing returns in resistance adaptation (Santos & Janeira, 2012; Ramírez-Campillo et al., 2018). These findings reinforce the necessity of structuring resistance training programs to optimize improvements in both horizontal and vertical power, particularly in adolescent athletes involved in sports requiring explosive movements such as basketball and football.

1.2 Plyometric training has been proven to be highly effective in improving explosive physical qualities such as horizontal power (Standing broad jump-SBJ), vertical base power (Squat jump-SJ), and vertical dynamic power (Countermovement jump-CMJ). An 8-week training duration appears to be the optimal cycle for eliciting significant gains in horizontal and vertical jump performance (Ramírez-Campillo et al., 2018; Tai et al., 2022). Studies suggest that while improvements begin to emerge after four weeks, the gains achieved during the middle-to-late phase of training (weeks 4-8) are typically greater than those in the early phase (weeks 0-4), due to accumulated neuromuscular adaptations (Vanderka et al., 2016).

Moreover, plyometric training has been consistently shown to enhance agility and speed performance among collegiate populations, likely due to improvements in muscle-tendon stiffness and neural drive (Asadi et al., 2016; Hariyanto et al., 2022). These enhancements make plyometric training a widely adopted method in athletic training and physical education programs aiming to improve lower-limb power and functional performance.

1.3 Complex training, which integrates strength training and plyometric movements within the same session, has also demonstrated significant effectiveness in improving power-related performance measures. Research shows that an 8-week complex training cycle leads to significant improvements in horizontal power (SBJ) and vertical jump components (SJ and CMJ), particularly in the latter half of the training period

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During weeks 4 to 8 of the training intervention, noticeable gains in both base vertical power (SJ) and dynamic vertical power (CMJ) are observed, reflecting a cumulative adaptation effect. The middle-to-late training stages appear to yield more substantial improvements than earlier stages, aligning with the delayed potentiation effects typical in complex training protocols (Pereira et al., 2018). These findings emphasize the necessity of sustained, progressive training to optimize performance outcomes, particularly for athletic populations seeking enhancements in explosive strength (Thapa et al., 2021; Biel et al., 2023).

2. Discussion on lower limb power in different experimental groups

2.1 Through 8 weeks of training, the enhancement of horizontal direction power, assessed using the Standing Broad Jump (SBJ), ranked in effectiveness as follows: complex training, plyometric training, and resistance training. This order of improvement aligns with existing research indicating that complex training, which combines high-load strength and plyometric elements within the same session, produces superior neuromuscular adaptations (Biel et al., 2023). In contrast, resistance training lacks the specificity of rapid, dynamic movement, which is characteristic of SBJ and other explosive actions. Moreover, plyometric and complex training programs frequently involve jumping actions that directly mimic SBJ movement patterns, enabling a higher degree of movement transfer (Thapa et al., 2021).

2.2 The effect of vertical dynamic power (CMJ) improvement after 8 weeks of training is as follows: complex training, plyometric training, and resistance training. Wang (2018), Cheng (2022), and Huang (2023) believe that the efficiency of complex training is not possessed by resistance training and plyometric training. On the one hand, the entire motion process in SBJ and CMJ is a typical Stretching-Shortening Cycle (SSC), a mechanism that resistance training does not target. While plyometric training employs SSC effectively, complex training integrates both force and velocity components, resulting in more pronounced adaptations in muscle power output and neuromuscular coordination (Cormier et al., 2020)

2.3 After 8 weeks of training, vertical basic power measured by Squat Jump (SJ High and SJ Power) showed improvement in the order of complex training, resistance training, and plyometric training. (Cormier et al., 2020) Suggested that resistance training primarily enhances SJ performance by increasing maximal strength of the lower limb musculature. According to the power equation ($P=F\times V$), resistance training focuses on increasing the force component (F), which directly affects SJ output. In contrast, plyometric training emphasizes SSC to increase contraction speed (V) and neural efficiency. However, SJ is a purely concentric movement that does not engage SSC mechanisms, hence showing less improvement from plyometric training alone. Complex training, by combining the benefits of both, results in superior gains across multiple power indicators (Pereira et al., 2017).

Conclusion

The findings of this study can be concluded according to the research objectives as follows:

1. Compared with resistance training and plyometric training, complex training can significantly improve lower limb power. Three training methods after 8 weeks of training can make progress in SBJ, SJ, and CMJ. Comparing resistance training and plyometric training, complex training has the best effect on improving horizontal power (SBJ), vertical base power (SJ), and dynamic power (CMJ). These results highlight the effectiveness of complex training in improving the lower limb power of college students.

2. When comparing the results before training, after 4 weeks of training, and after 8 weeks of training, the three experimental groups showed continuous improvement in all lower limb power variables, and there was no difference in the mean lower limb power at the level of 0.05 at the 4th week of the experiment, and there was a difference in the mean lower limb power at the level of 0.05 at the 8th week of the experiment.

Recommendation

Suggestions in this research

1. Resistance training remains essential as a foundational method for building muscular strength, even if not the most effective for explosive power alone.

2. Training methods should align with the biomechanical demands of specific sports to optimize sport-specific power development.

Suggestions for further research

Design and validate sport-specific training programs for targeted lower limb power development.

Explore the long-term effects and underlying physiological adaptations of training, especially in non-athletic populations such as college students.

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