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Research Article

# Experimental Study on the Influence of Unilateral and Bilateral Plyometric Training on the Lower Limbs Explosive Power of Male Students in Junior High School

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## Abstract

*Purpose:* Plyometric training is effective for improving the lower limbs explosive power of athletes, but less is known regarding if male students in junior high school equally benefit from plyometric training. The purpose of this study was to compare changes in male students' lower limbs explosive power across plyometric training. *Method:* A sample of students (45 males) in junior high school was cluster randomly assigned to the conventional lower limbs explosive power training group (CLT), the bilateral plyometric training (BPT) and the unilateral plyometric training group (UPT). Pre-tests were conducted on the basic information and five explosive power indices of 45 participants across three groups, followed by post-tests on the experimental indices after the experiment. Subsequently, one-way ANOVA was performed among the three groups for the pre- and post-test data, and paired-samples T-tests were conducted within each group. *Results:* There were significant differences in the five lower limbs explosiveness test indexes between the three groups and those after the experiment ($P<0.01$). *Conclusion:* After an eight-week experiment, UPT BPT and CLT can effectively enhance the lower limb power levels of ordinary junior high school male students. UPT group was better than that of the BPT group and the CLT group in the 50-meter run and 20-meter hop jump index. BPT group was better than that of UPT group and CLT group vertical jump and triple leap frog.

## Keywords

Unilateral and Bilateral Plyometric Training, Lower Limbs Explosive Power, Male Students, Junior High School, Experimental Study

## 1. Introduction

### 1.1. Research Background

Plyometric training means muscles overcome resistance to produce maximum force training method in the shortest time, its basic form of movement is: the muscle first passive centrifugal contraction, and then rapid centripetal contraction, so as to produce maximum force. [1] Plyometric Training (PT) is widely recognized as an effective method for enhancing explosive power, particularly in the lower limbs. This form of

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training involves rapid stretching and contracting of muscles, which improves neuromuscular efficiency and muscle recruitment patterns. [2-5] During the junior high school years, students undergo significant physiological development, including the maturation of the nervous system and the enhancement of muscle strength and coordination. This period is considered a sensitive phase for the development of explosive power, making it an ideal time to implement targeted training programs.

While PT has been extensively studied in athletes and older populations, [6] there is a notable gap in research focusing on its application among middle school students, especially those with relatively weak foundational strength. Most existing studies have concentrated on bilateral PT, which involves both limbs simultaneously, [7-11], but unilateral PT, which focuses on one limb at a time, has received less attention. Unilateral training may offer unique benefits, such as addressing muscle imbalances and improving stability, which are crucial for young adolescents who are still developing their motor skills. [12-15]

### 1.2. Problem Statement

Despite the potential benefits of PT, there is limited empirical evidence on its effectiveness for middle school students, particularly in comparing unilateral and bilateral approaches. The existing literature predominantly focuses on athletes or older age groups, leaving a gap in understanding how these training methods influence the explosive power of younger, less physically developed individuals. Furthermore, the optimal intensity and volume of PT for this age group remain unclear, raising concerns about the safety and efficacy of such training programs.

This study aims to address these gaps by investigating the impact of unilateral and bilateral plyometric training on the lower limb explosive power of male junior high school students. By comparing the outcomes of these two training methods, the study seeks to provide evidence-based recommendations for designing PT programs that are both effective and safe for this specific population.

### 1.3. Research Objectives

*To Compare the Effects of Unilateral and Bilateral Plyometric Training:* The primary objective is to determine whether unilateral or bilateral PT is more effective in enhancing lower limb explosive power among male junior high school students.

*To Provide Practical Recommendations:* Based on the findings, the study will offer guidelines for implementing PT programs that are tailored to the developmental needs and physical capabilities of junior high school students.

*To Explore Safety and Feasibility:* The research will also consider the safety and practicality of incorporating PT into the physical education curriculum for this age group, ensuring that the training is both beneficial and sustainable.

By addressing these objectives, the study aims to contribute to the growing body of knowledge on youth athletic development and provide actionable insights for educators and coaches working with junior high school students.

## 2. Materials and Methods

### 2.1. Research Design

This study employed a cluster randomized controlled trial design to investigate the effects of Unilateral Plyometric Training (UPT), Bilateral Plyometric Training (BPT), and Conventional Lower Limb Explosive Power Training (CLT) on the lower limb explosive power of male junior high school students. The study was conducted over an 8-week intervention period, with pre- and post-tests to measure changes in explosive power indices. The design ensured that the three groups (UPT, BPT, and CLT) were comparable at baseline, and the intervention effects could be attributed to the specific training methods.

### 2.2. Sample

*Participants:* A total of 45 male junior high school students from Changchun Foreign Languages School were recruited for the study. Participants were cluster-randomly assigned to one of three groups:

*Conventional Lower Limb Explosive Power Training Group (CLT):* 15 students.

*Bilateral Plyometric Training Group (BPT):* 15 students.

*Unilateral Plyometric Training Group (UPT):* 15 students.

*Inclusion Criteria:* Healthy male students aged 12–15 years, with no prior experience in plyometric training or lower limb injuries in the past six months.

*Exclusion Criteria:* Students with chronic medical conditions or those unable to complete the training program.

### 2.3. Data Collection

#### 2.3.1. Pre-Test and Post-Test Measures

*Basic Information:* Height, weight, and physical activity levels were recorded for all participants.

***Table 1.*** *Normal Distribution Test Table for Pre- and Post-experiment Test Data of Male Participants (N=45).*

| Test Indicators | Testing Time | UPT (N=15) | | BPT (N=15) | | CLT (N=15) | |
|---|---|---|---|---|---|---|---|
| | | Statistic | Sig. | Statistic | Sig. | Statistic | Sig. |
| Height (cm) | Pre-test | .955 | .605 | .962 | .725 | .938 | .364 |
| Weight (kg) | Pre-test | .956 | .625 | .911 | .139 | .938 | .353 |
| 50-Meter sprint | Pre-test | .929 | .267 | .979 | .960 | .897 | . 085 |
| | Post-test | .947 | .480 | .943 | .423 | .916 | .166 |
| Standing Long Jump | Pre-test | .901 | .098 | .884 | .055 | .922 | .207 |
| | Post-test | .906 | .119 | .903 | .106 | .920 | .191 |
| Vertical jump | Pre-test | .929 | .262 | .944 | .441 | .969 | .836 |
| | Post-test | .944 | .431 | .950 | .531 | .934 | .317 |
| 20-Meter Hop Jump | Pre-test | .924 | .220 | .923 | .213 | .950 | .520 |
| | Post-test | .922 | .208 | .954 | .596 | .973 | .899 |
| Triple Leap Frog | Pre-test | .933 | .302 | .890 | .067 | .958 | .665 |
| | Post-test | .948 | .496 | .934 | .317 | .962 | .723 |

Note: A Sig value greater than 0.05 indicates that the data in this group conforms to a normal distribution, allowing for statistical tests to be conducted on it.

*Explosive Power Indices:* The selection of experimental indices was based on the measurement methods for lower limb explosive power outlined in "The Measurement and Evaluation of Human Athletic Ability," with Standing Long Jump and 30-Meter Accelerated Sprint being chosen. Additionally, based on "Sports Measurement and Evaluation," and considering the developmental and age characteristics of junior high school students, Vertical Jump Reach, Standing Triple Jump, and Two-Hand Forward Shot Put were selected. Furthermore, authoritative books such as the "National Strength and Conditioning Association's Guidelines for Testing and Assessment," academic papers, and national documents related to the high school entrance examination, such as the "Compulsory Education Physical Education and Health Assessment and Evaluation Scheme," were referenced. Discussions were also held with experts in school physical education teaching and training, as well as frontline coaches. As a result, indicators such as 50-Meter Sprint, 20-Meter Hop Jump, and Triple Leap Frog were selected. Based on the results of the survey questionnaires completed by experts and scholars, the weight coefficient for each indicator was calculated. Indicators with a coefficient of variation exceeding 0.21 were eliminated. The remaining indicators were then ranked, and the top five were selected as the test indicators for this paper.

***Table 2.*** *Table of Mean and Coefficient of Variation Results from Expert Survey Questionnaire on Lower Limb Explosive Power Test Indicators.*

| Test Indicator | Mean | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| Standing Long Jump | 4.4 | 0.70 | 0.16 |
| Standing Triple Jump | 3.8 | 0.63 | 0.17 |
| 30-Meter Accelerated Sprint | 2.9 | 0.99 | 0.34 |
| 20-Meter Hop Jump | 4.3 | 0.67 | 0.16 |
| Vertical Jump | 4.1 | 0.74 | 0.18 |
| 50-Meter Sprint | 4.5 | 0.71 | 0.16 |

| Test Indicator | Mean | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| Two-Handed Medicine Ball Throw | 2.6 | 1.17 | 0.45 |
| Triple Leap Frog | 4.0 | 0.67 | 0.17 |
| Approach Vertical Jump Reach | 3.9 | 0.74 | 0.19 |
| 5×10-Meter Shuttle Run | 3.2 | 0.92 | 0.29 |
| T-Shape Run | 3.1 | 0.88 | 0.28 |

Note: Test indicators with a coefficient of variation exceeding 0.21 are marked with an underline character. Based on the statistical results, test indicators with lower mean values, higher degrees of dispersion, and coefficients of variation above 0.21 are excluded from the table. The means from Table are ranked in descending order, and the test indicators for lower limb explosive power in this experiment are confirmed accordingly.

Five key indices were measured to assess lower limb explosive power:

1) *50-meter Sprint:* Measures speed and acceleration.
2) *20-meter Hop Jump:* Assesses horizontal explosive power.
3) *Vertical Jump:* Evaluates vertical explosive power.
4) *Triple Leap Frog:* Tests coordination and explosive power in a multi-jump task.
5) *Standing Long Jump:* Measures lower limb strength and power.

### 2.3.2. InterventionProtocol

1) *Duration:* 8 weeks, with training sessions conducted 3 times per week.
2) *Training Programs:*
   a) *CLT Group:* Performed conventional lower limb strength training (e.g., squats, lunges, and step-ups).
   b) *BPT Group:* Engaged in bilateral plyometric training (e.g., box jumps, squat jumps, and bilateral hops).
   c) *UPT Group:* Performed unilateral plyometric training (e.g., single-leg hops, lateral bounds, and single-leg box jumps).
3) *Progression:* Training intensity and volume were gradually increased over the 8 weeks to ensure adaptation and avoid overtraining.

### 2.3.3. DataAnalysis

1) *Descriptive Statistics:* Mean and standard deviation were calculated for all baseline and post-test measures.
2) *One-Way ANOVA:* Used to compare the pre-test and post-test results across the three groups (CLT, BPT, and UPT) to determine if there were significant differences in the five explosive power indices.
3) *Paired-Samples T-Tests:* Conducted within each group to assess the changes in explosive power indices from pre-test to post-test.
4) *Post-Hoc Analysis:* If significant differences were found in the ANOVA, post-hoc tests (e.g., Tukey's HSD) were performed to identify specific group differences.
5) *Statistical Significance:* A p-value of $<0.01$ was set as the threshold for statistical significance.

## 3. Results

### 3.1. Pre-Test Comparisons

No significant differences were found among the three groups in baseline explosive power indices ($p > 0.01$), confirming group comparability.

***Table 3.*** *Comparison results of the baseline characteristics and lower limb explosive power indicators among the three groups of male participants before the experiment.*

| Pre-test Indicators | UPT | BPT | CLT | F | P |
|---|---|---|---|---|---|
| Height (cm) | 172.2±8.24 | 171.67±9.86 | 174.2±5.49 | 0.41 | 0.67 |
| Weight (kg) | 62.73±14.90 | 67.07±21.32 | 70.13±14.28 | 0.71 | 0.50 |
| 50-Meter Sprint (s) | 8.39±0.93 | 7.95±0.70 | 8.54±1.01 | 1.76 | 0.19 |
| Standing Long Jump (cm) | 194.73±21.31 | 194.93±18.96 | 189.93±16.54 | 0.33 | 0.72 |
| Vertical jump (cm) | 251.6±8.16 | 251.8±7.99 | 247.47±7.94 | 1.39 | 0.26 |

| Pre-test Indicators | UPT | BPT | CLT | F | P |
|---|---|---|---|---|---|
| 20-Meter Hop Jump (m) | 6.9±0.54 | 7.12±0.48 | 7.04±0.45 | 0.74 | 0.49 |
| Triple Leap Frog (m) | 5.63±0.655 | 5.66±0.51 | 5.50±0.52 | 0.33 | 0.72 |

*Post-Test Comparisons:*

a) Significant improvements were observed in all five explosive power indices across the three groups ($p < 0.01$).
b) *UPT Group:* Showed the greatest improvement in the 50-meter sprint and 20-meter hop jump indices compared to the BPT and CLT groups.
c) *BPT Group:* Demonstrated superior performance in the vertical jump and triple leap frog indices compared to the UPT and CLT groups.
d) *CLT Group:* Improved in all indices but to a lesser extent compared to the UPT and BPT groups.

## 3.2. Within-Group Changes

All groups showed significant improvements in explosive power indices from pre-test to post-test ($p < 0.01$), indicating the effectiveness of all training methods.

***Table 4.*** *Test results of lower limb explosive power indicators for male participants in the UPT group before and after the experiment.*

| UPT group (N=15) | The test results (X±S) | | Difference | ES | T | P |
|---|---|---|---|---|---|---|
| | before | after | | | | |
| 50-Meter Sprint (s) | 8.39±0.93 | 7.87±0.54 | 0.52 | 0.71 | 4.71 | 0.00 |
| Standing Long Jump (cm) | 194.73±21.31 | 205.27±18.15 | 10.53 | 0.53 | -8.73 | 0.00 |
| Vertical jump (cm) | 251.6±8.16 | 257.47±6.13 | 5.87 | 0.82 | -8.35 | 0.00 |
| 20-Meter Hop Jump (m) | 6.9±0.54 | 6.43±0.43 | 0.47 | 0.97 | 10.59 | 0.00 |
| Triple Leap Frog (m) | 5.63±0.65 | 6.05±0.58 | 0.42 | 0.69 | -16.15 | 0.00 |

Note: An effect size of 0.2 to 0.3 is considered small, 0.5 is considered a medium effect size, and an effect size above 0.8 is considered large.

Before and after the experiment, male participants in the UPT group exhibited highly significant differences (T=4.71, p<0.01 for the 50-meter sprint; T=-8.73, p<0.01 for the standing long jump; T=-8.35, p<0.01 for the vertical jump; T=10.59, p<0.01 for the 20-meter hop jump; T=-16.15, p<0.01 for the triple leap frog) across all five tested indicators of lower limb explosive power. Specifically, the vertical jump (ES=0.82) and the 20-meter hop jump (ES=0.97) demonstrated large effect sizes, indicating substantial intergroup differences for these two indicators. The 50-meter sprint (ES=0.71), standing long jump (ES=0.53), and triple leap frog (ES=0.69) showed medium effect sizes, suggesting moderate intergroup differences for these three indicators. Notably, the male participants in the UPT group achieved significant improvements in all five tested indicators of lower limb explosive power following the experiment.

Test results of lower limb explosive power indicators for male participants in the BPT group before and after the experiment.

***Table 5.*** *Test results of lower limb explosive power indicators for male participants in the BPT group before and after the experiment.*

| BPT group (N=15) | The test results (X±S) | | Difference | ES | T | P |
|---|---|---|---|---|---|---|
| | before | after | | | | |
| 50-Meter Sprint (s) | 7.95±0.70 | 7.57±0.44 | 0.39 | 0.68 | 5.14 | 0.00 |
| Standing Long Jump (cm) | 194.93±18.16 | 210.60±14.91 | 15.67 | 0.93 | -12.22 | 0.00 |
| Vertical jump (cm) | 251.8±7.99 | 258.53±5.91 | 6.73 | 0.97 | -9.71 | 0.00 |

| BPT group (N=15) | The test results (X ±S) | | Difference | ES | T | P |
|---|---|---|---|---|---|---|
| | before | after | | | | |
| 20-Meter Hop Jump (m) | 7.12 ±0.48 | 6.81 ±0.42 | 0.30 | 0.67 | 9.34 | 0.00 |
| Triple Leap Frog (m) | 5.66 ±0.51 | 6.21 ±0.38 | 0.55 | 1.24 | -14.23 | 0.00 |

Note: An effect size of 0.2 to 0.3 is considered small, 0.5 is considered a medium effect size, and an effect size above 0.8 is considered large.

Before and after the experiment, the male participants in the BPT group showed highly significant differences in all five experimental indicators. Specifically, four indicators—standing long jump (ES=0.93), vertical jump (ES=0.97), and triple leap frog (ES=1.24)—demonstrated large effect sizes. Notably, the effect sizes for standing long jump, vertical jump, and triple leap frog exceeded 0.9, indicating substantial intergroup variability for these four indicators. The 50-meter sprint (ES=0.68) and 20-meter hop jump (ES=0.67) showed moderate effect sizes, suggesting moderate intergroup differences for these two indicators. Notably, the male participants in the BPT group achieved significant improvements in all five lower limb explosive power indicators after the experiment.

*Table 6. Test results of lower limb explosive power indicators for male participants in the CLT group before and after the experiment.*

| CLT group (N=15) | The test results (X ±S) | | Difference | ES | T | P |
|---|---|---|---|---|---|---|
| | before | after | | | | |
| 50-Meter Sprint (s) | 8.54 ±1.01 | 8.30 ±0.39 | 0.24 | 0.26 | 6.25 | 0.00 |
| Standing Long Jump (cm) | 189.93 ±16.54 | 194.93 ±16.37 | 5 | 0.304 | -8.20 | 0.00 |
| Vertical jump (cm) | 247.46.8 ±7.94 | 251.4 ±7.23 | 3.93 | 0.52 | -9.93 | 0.00 |
| 20-Meter Hop Jump (m) | 7.04 ±0.45 | 6.84 ±0.40 | 0.20 | 0.46 | 6.48 | 0.00 |
| Triple Leap Frog (m) | 5.50 ±0.52 | 5.76 ±0.46 | 0.27 | 0.61 | -15.57 | 0.00 |

Note: An effect size of 0.2 to 0.3 is considered small, 0.5 is considered a medium effect size, and an effect size above 0.8 is considered large.

Before and after the experiment, the male participants in the CLT group showed highly significant differences in all five experimental indicators. The four indicators, including standing long jump (ES=0.304), vertical jump (ES=0.52), 20-meter hop jump test (ES=0.46) and triple leap frog (ES=0.61) possess moderate effect sizes, indicating moderate inter-group differences among these four experimental indicators. The 50-meter sprint (ES=0.243) has an effect size less than 0.3, suggesting limited inter-group differences for this experimental indicator.

## 4. Discussion

### 4.1. Effectiveness of Plyometric Training

The results confirm that both unilateral and bilateral plyometric trainingare effective in enhancing lower limb explosive power in male junior high school students. This aligns with previous research highlighting the benefits of plyometric exercises for neuromuscular development and power output.

### 4.2. Superiority of Unilateral Training

The UPT group outperformed the BPT and CLT groups in the 50- meter sprint and 20-meter hop jump, suggesting that unilateral training may be particularly effective for improving horizontal explosive power and speed. This could be attributed to the unilateral focus on muscle imbalances and stability, which are critical for running and hopping tasks.

### 4.3. Advantages of Bilateral Training

The BPT group excelled in the vertical jump and triple leap frog, indicatingthat bilateral training may be more effective for tasks requiring vertical power and multi-jump coordination. This is consistent with the biomechanical demands of bilateral exercises, which emphasize simultaneous force production from both limbs.

### 4.4. Practical Implications

The findings suggest that incorporating both unilateral and bilateralplyometric exercises into training programs for junior high school students can optimize lower limb explosive power development. Coaches and physical educators should consider the specific demands of different sports or activities when designing training protocols.

## 5. Conclusion

After an 8-week intervention, Unilateral Plyometric Training (UPT), Bilateral Plyometric Training (BPT), and Conventional Lower Limb Explosive Power Training (CLT) were all effective in enhancing the lower limb explosive power of male junior high school students. However, UPT demonstrated superior improvements in horizontal explosive power (50-meter sprint and 20-meter hop jump), while BPT was more effective for vertical power and multi-jump tasks (vertical jump and triple leap frog). These findings highlight the importance of tailoring training programs to the specific needs and goals of young athletes, with a combination of unilateral and bilateral exercises potentially offering the most comprehensive benefits. Future research should explore the long-term effects of these training methods and their applicability to other populations.

## Abbreviations

| | |
|---|---|
| CLT | Conventional Lower Limbs Explosive Power Training |
| BPT | Bilateral Plyometric Training |
| UPT | Unilateral Plyometric Training |

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## Author Contributions

**Yu Wang:** Writing-Original Draft Preparation, Writing-Review&Editing, Methodology, Validation

**Yuxiu Jiang:** Supervision, Validation

## Ethics Approval and Consent to Participate

All procedures of the study involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee, as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study. Participants were informed about the purpose of the research, the procedures involved, and their right to withdraw at any time without penalty. Written consent was obtained prior to their participation. For participants under the age of 18, written consent was obtained from their parents or legal guardians.

In cases where data were collected retrospectively or anonymized, the requirement for informed consent was waived by the Ethics Committee of Northeast Normal University (date: [20/09/2024]), as the research involved no more than minimal risk to participants and the waiver did not adversely affect their rights and welfare.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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