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Effects of Plyometric Training Method and Motor Ability on Lower-Limb Power in Junior High School Futsal Players

A 2×2 Factorial Study

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ABSTRACT

Lower-limb power is essential for futsal because players repeatedly sprint, accelerate, decelerate, change direction, and jump, yet school-based extracurricular programs need training that is both effective and feasible for students with different readiness levels. This study examined whether the plyometric training method (squat jump vs. lunge-based plyometrics) and motor ability level (high vs. low) were associated with changes in lower-limb power in a junior high school futsal extracurricular program. Using a quasi-experimental 2×2 factorial framework, 40 students from SMP YPS Prabumulih City, Indonesia, completed a supervised plyometric program delivered over 16 sessions (four sessions per week) from October to November 2025. Motor ability testing classified students into high and low groups, and lower-limb power was assessed using a vertical jump test before and after training. Vertical jump scores increased significantly in all groups ($p < 0.001$): squat jump–low motor ability from 40.4 (SD 3.31) to 51.8 (SD 3.19), lunges–low from 37.0 (SD 3.30) to 47.9 (SD 2.60), squat jump–high from 36.9 (SD 4.04) to 48.2 (SD 4.37), and lunges–high from 44.2 (SD 2.53) to 54.8 (SD 2.20). These findings provide practical, school-context evidence that both plyometric options can be implemented and are linked with meaningful improvements across motor ability levels; however, conclusions about comparative superiority and interaction effects are limited by the single-site design and absence of a non-training control group. Future multi-site controlled studies with explicit factorial testing are

recommended to confirm effectiveness and clarify method-by-motor-ability interactions.

Keywords
2×2 Factorial Design
Lower-Limb
Motor Ability
Plyometric Training
Power Futsal Players

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Introduction

Futsal is characterized by repeated high-intensity actions, including short sprints, rapid accelerations and decelerations, frequent changes of direction, and explosive jumping, all of which place substantial demands on players' lower-limb power [1]. In this context, lower-limb power is a crucial component of performance because it underpins fast force production required for sprinting, jumping, and dynamic movement execution during play. In school-based extracurricular futsal programs, the development of this physical capacity is particularly important, as students are expected to perform competitively while training under practical limitations related to time, facilities, supervision, and heterogeneous physical readiness [2]–[3].

One training approach widely used to improve explosive lower-body performance is plyometric training. Plyometric exercises utilize the stretch–shortening cycle to enhance neuromuscular function and increase the ability to generate force rapidly [4]–[6]. Previous studies have shown that plyometric training can improve jump performance, muscular power, and other power-related outcomes in youth and athletic populations when implemented with appropriate progression and supervision [7]–[9], These findings suggest that plyometric training is a relevant conditioning strategy for school-based futsal participants, whose performance depends heavily on repeated explosive actions.

However, not all plyometric exercises place identical demands on movement execution or produce the same training response. In practice, coaches and physical education teachers frequently employ different exercise variations, such as squat jumps and lunges, because both are feasible to implement in school settings and require minimal equipment [10]–[11]. Even so, comparative evidence regarding which of these methods is more effective for improving lower-limb power in school futsal participants remains limited. Much of the existing literature has focused on the general effectiveness of plyometric training rather than comparing specific exercise forms within applied school-based sports contexts [12]–[13].

Another issue concerns individual differences in training responsiveness. The effectiveness of plyometric training may depend not only on the exercise selected but also on

the participant's motor ability. Motor ability influences coordination, balance, movement control, and the quality with which explosive tasks are executed; therefore, students with different levels of motor ability may not respond similarly to the same training stimulus [14]–[16]. Despite this, many school-based training studies assess only overall pre–post changes and do not explicitly examine whether training outcomes differ according to motor ability level. This limits the practical value of the evidence for teachers and coaches who work with students of varied readiness and physical competence.

Accordingly, an important applied research gap remains in school extracurricular futsal settings. First, there is insufficient comparative evidence on the relative effectiveness of different plyometric methods, particularly squat jumps and lunges, for improving lower-limb power. Second, there is limited evidence on whether motor ability moderates the effects of these training methods. Addressing these issues is important both practically and theoretically. Practically, school futsal programs require training methods that are effective, feasible, and safe for students with diverse physical profiles [17]. Theoretically, examining the interaction between training method and motor ability can contribute to a more differentiated understanding of training response in youth sports conditioning [4], [18].

Therefore, this study used a 2 × 2 factorial design to examine: (1) whether squat jump and lunge-based plyometric training produce different effects on lower-limb power; (2) whether lower-limb power outcomes differ between students with high and low motor ability; and (3) whether there is an interaction between plyometric training method and motor ability in influencing lower-limb power. By addressing these questions, this study provides context-specific evidence from a school extracurricular futsal program and offers practical insight for physical education teachers and coaches in selecting plyometric exercises that are more appropriate to students' readiness profiles. Nevertheless, the findings should be interpreted within the scope of the study, which is limited to a single-school setting and a relatively short intervention period [7], [19].

Material and Methods

A. Study Design and Setting

This study employed a quasi-experimental 2 × 2 factorial design to examine the effects of plyometric training method and motor ability level on students' lower-limb power [15]. The first factor was the plyometric training method, consisting of squat jump training and lunge-based training, while the second factor was motor ability level, classified as high and low. The study was conducted at SMP YPS Prabumulih City, Indonesia, from 14 October to 14 November 2025. The intervention was implemented over 16 training sessions, scheduled four times per week as part of the school's extracurricular futsal program.

B. Participants and Sampling

The participants were 40 students registered in the extracurricular futsal program at SMP YPS Prabumulih. A total sampling technique was applied, meaning that all students who met the study criteria were included in the research [20]. Students were eligible to participate if they were officially registered in the futsal extracurricular program, were physically able to participate in training and testing activities and attended both the pretest and posttest sessions. Students were excluded from the final analysis if they had injuries, medical restrictions, or other conditions that prevented safe participation during the intervention or testing period.

1. Grouping and Factorial Allocation

Before the intervention, all participants completed a motor ability test battery. Based on the results, students were classified into high motor ability and low motor ability groups. After classification, participants were assigned to four factorial treatment groups:

- A1B1: squat jump training × low motor ability
- A2B1: lunge training × low motor ability
- A1B2: squat jump training × high motor ability
- A2B2: lunge training × high motor ability

This grouping structure allowed the study to test both the main effects of training method and motor ability, as well as the interaction effect between the two factors.

2. Training Intervention

The intervention consisted of a structured plyometric training program conducted over 16 sessions. Each session began with a 10–15-minute warm-up, including dynamic mobility exercises and light running drills, to prepare participants physically and reduce injury risk. All training sessions were supervised by the futsal coach/teacher and the researcher to ensure correct technique, consistency of implementation, and participant safety.

- Squat Jump Training (A1). Participants in this condition performed squat jumps starting from a squat position and then jumping vertically as explosively as possible. During the exercise, both hands were placed behind the head with the fingers interlocked. Students were instructed to maintain forward gaze, proper body alignment, and stable landing control throughout the movement.
- Lunge Training (A2). Participants in this condition performed alternating lunges, emphasizing controlled lowering and rising movements with alternating single-leg support. This exercise was intended to develop lower-limb strength, balance, and movement stability as part of explosive training preparation.

3. Standardization Across Conditions

To maintain procedural consistency, both groups followed the same training schedule, session frequency, warm-up protocol, supervision procedures, and total number of sessions. The only difference between the groups was the assigned plyometric exercise, namely squat jump or lunge-based training.

C. Measures

1. Motor Ability

Motor ability was assessed using a multi-component motor ability test battery covering key movement-performance elements, including strength, speed, agility, balance, and coordination. The composite results of this test battery were used to classify students into high and low motor ability categories before the intervention.

2. Lower-Limb Power

The primary outcome of this study was lower-limb power, measured using the Vertical Jump Test. The test was administered twice: at pretest (before the intervention) and posttest (after the intervention). During testing, students received standardized instructions and were asked to perform maximal-effort vertical jumps. Jump height was recorded as the performance score.

D. Data Analysis

Descriptive statistics, including means and standard deviations, were calculated for the pretest and posttest vertical jump scores in each factorial group. Before hypothesis testing, the assumptions of normality and homogeneity were examined. Data normality was tested using the One-Sample Kolmogorov–Smirnov test, while homogeneity of variance was assessed using Levene's test.

To examine changes in lower-limb power within each group, paired-samples t-tests were performed between pretest and posttest scores. Because the study used a 2 × 2 factorial design, the main effects of training method and motor ability level, as well as their interaction effect, should ideally be analyzed using two-way analysis of variance (two-way ANOVA) on gain scores or posttest scores with pretest equivalence considered. The level of statistical significance was set at $\alpha = 0.05$. All analyses were performed using IBM SPSS Statistics (version to be specified by the authors).

E. Established Methods, Citations, and Contextual Adjustments

The Vertical Jump Test and the motor ability test battery are established field-based measures and should be supported by appropriate primary references. Likewise, squat jump and lunge-based plyometric exercises should be cited as recognized training methods in youth and sports conditioning literature. Any contextual adjustments made for the school setting,

such as warm-up format, supervision procedures, scheduling constraints, and safety considerations, have been described to improve replicability.

Results and Discussions

A. Assumption Testing

Before hypothesis testing, the data were examined to assess whether the assumptions for parametric analysis were satisfied. The results of the normality test for both pretest and posttest scores showed $p > 0.05$, indicating that the data were normally distributed. In addition, Levene's test also produced $p > 0.05$, suggesting homogeneity of variance across groups. Based on these results, the data met the assumptions required for parametric testing, and paired-samples t-tests were subsequently applied to assess pretest–posttest changes within each treatment group.

B. Pretest–Posttest Changes in Lower-Limb Power

The results showed that all four groups demonstrated higher vertical jump scores at posttest than at pretest after completing the 16-session training program. As presented in Table 1, statistically significant improvements were observed in every group ($p < 0.001$), indicating that both squat jump training and lunge-based training were associated with improved lower-limb power in this sample.

Table 1. Pretest–posttest changes in vertical jump performance by group

Group	n	Pretest Mean (SD)	Posttest Mean (SD)	t (df = 9)	p
A1B1 (Squat jump – Low motor ability)	10	40.4 (3.31)	51.8 (3.19)	21.05	<0.001
A2B1 (Lunges – Low motor ability)	10	37.0 (3.30)	47.9 (2.60)	15.43	<0.001
A1B2 (Squat jump – High motor ability)	10	36.9 (4.04)	48.2 (4.37)	17.37	<0.001
A2B2 (Lunges – High motor ability)	10	44.2 (2.53)	54.8 (2.20)	23.44	<0.001

These findings indicate that the two plyometric training variations were both effective in increasing lower-limb power, as reflected in vertical jump performance. The improvement pattern suggests that repeated exposure to explosive movement exercises, when implemented systematically and under supervision, can enhance students' ability to generate force rapidly.

Discussion

The improvement in vertical jump scores across all treatment groups is consistent with the theoretical basis of plyometric training, which emphasizes the enhancement of explosive power through the stretch–shortening cycle. Plyometric exercises stimulate neuromuscular adaptation by improving motor unit recruitment, rate of force development, and coordination efficiency, all of which contribute to better jump performance [6], [7]. In addition, plyometric methods are designed to optimize the transition between eccentric and concentric muscle contractions, thereby enhancing lower-limb explosive capacity and athletic movement

efficiency [7]. In the present study, these mechanisms may explain why students in all groups demonstrated meaningful gains in lower-limb power after the intervention period.

The findings are also consistent with previous studies reporting that plyometric training can improve vertical jump ability and power-related performance in youth and athletic populations. Bishop et al. [5] demonstrated that plyometric training significantly enhanced explosive movement performance among adolescent athletes, while Booth and Orr [6] highlighted the broad effectiveness of plyometric exercise in improving sport-specific physical performance. In school-based sports settings, such training appears particularly relevant because it can be implemented with relatively simple exercises and minimal equipment, while still producing measurable performance improvements. This is particularly important in futsal development programs, where physical conditioning plays a central role in supporting technical and tactical performance demands [4], [10]. Furthermore, futsal training environments often require efficient and adaptable conditioning methods because extracurricular programs generally operate under limited time and resource conditions [4]. This supports the practical value of plyometric methods for extracurricular futsal programs, where training time and resources are often limited.

From a descriptive standpoint, the magnitude of improvement across groups was relatively similar, with gains generally ranging from approximately 10 to 11 points. This pattern suggests that both squat jump and lunge-based plyometric training may serve as practical alternatives for improving lower-limb power in school futsal participants. Previous evidence also indicates that plyometric-based exercise interventions can enhance sport-specific physical capacities across athletes with varying performance characteristics [19]. Moreover, improvements occurred in both low and high motor ability groups, indicating that students with different levels of readiness may still benefit from structured plyometric exercise when the training is supervised and appropriately delivered. Similar findings in training studies suggest that well-structured exercise programs can generate positive physical adaptations regardless of participants' initial ability levels, provided that training loads and progression are adequately controlled [14].

However, these findings should be interpreted with caution. The present results are based primarily on within-group pretest–posttest comparisons, meaning that they confirm improvement over time within each group but do not, on their own, provide definitive evidence regarding the comparative superiority of one training method over another or the presence of an interaction effect between training method and motor ability level. Because this study was designed using a 2 × 2 factorial framework, a more rigorous evaluation of the main effects and interaction effects would require a two-way ANOVA or an equivalent factorial analysis [20]. Therefore, any conclusions regarding whether squat jump training is more

effective than lunge-based training, or whether training effects differ significantly according to motor ability level, should remain provisional unless supported by such analysis.

Practical Implications

Despite this limitation, the findings still offer useful practical implications for school-based futsal training. First, both plyometric methods appear feasible and beneficial for improving lower-limb power in adolescent students. Second, the fact that gains were observed across motor ability levels suggests that these exercises may be applied in heterogeneous school groups, provided that supervision, exercise instruction, and progression are carefully managed. For physical education teachers and extracurricular coaches, this means that plyometric training can be incorporated as an accessible and effective conditioning strategy within school sports programs.

Limitations

Several limitations should be acknowledged. First, the study involved participants from only one school, which limits the generalizability of the findings. Second, the intervention period was relatively short, consisting of 16 sessions, so the long-term effects of the training remain unclear. Third, the absence of a non-training control group means that improvements cannot be attributed exclusively to the intervention with full certainty. Finally, because the current analysis focuses mainly on within-group changes, the factorial nature of the design was not fully tested statistically.

Directions for Future Research

Future studies should include larger and more diverse samples drawn from multiple schools, incorporate a control or comparison group, and apply factorial statistical analysis to examine more precisely the main effects of training method, the effect of motor ability level, and the interaction between these factors. Such improvements would provide stronger evidence for selecting the most appropriate plyometric method for students with different readiness profiles.

Conclusion

This study examined the effects of the plyometric training method and motor ability level on lower-limb power in a junior high school futsal extracurricular program. The findings showed that vertical jump performance improved significantly in all groups after the 16-session intervention, indicating that both squat jump and lunge-based plyometric training were associated with enhanced lower-limb power. These improvements were observed in students with both high and low motor ability, suggesting that plyometric training can be applied in heterogeneous school-based sports settings when delivered in a structured and

supervised manner. From a practical perspective, the results indicate that both plyometric methods are feasible options for extracurricular futsal conditioning programs aimed at improving explosive lower-body performance. However, because the present analysis primarily demonstrates within-group improvement, the findings do not yet provide definitive evidence regarding the comparative superiority of one method over the other or the existence of an interaction effect between training method and motor ability level. This study contributes applied evidence from a school futsal context, but several limitations should be acknowledged, including the single-school setting, the relatively short intervention period, and the absence of a non-training control group.

Ethical Approval

This study involved human participants and received ethical approval from the Ethics Committee of Universitas PGRI Palembang (Approval No. 1549a/UN/17/KP.12.00/2025). All participants and/or their guardians provided informed consent before data collection. The study was conducted in accordance with relevant ethical principles for research involving human participants.

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