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Integrating circuit training into physical education: effects on javelin throwing performance in junior high school students

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ABSTRACT

Background: Javelin throwing is a complex athletic skill that requires strength, speed, balance, and proper release mechanics. In school settings, many students struggle to master these fundamentals due to limited practice time, lack of effective learning media, and insufficient development of the physical abilities needed to support throwing performance. **Objectives**: This study aimed to examine the association between circuit training and improvements in javelin throwing performance among junior high school students. **Methods:** A quasi-experimental one-group pretest–posttest design was employed involving 60 junior high school students in Makassar. Javelin throwing performance was assessed using a validated rubric covering technique, power, distance, and rule compliance. An eight-week circuit training programme was implemented, and data were analysed using descriptive statistics and paired-samples t-tests. **Results:** The findings showed that the mean javelin throwing score increased from 73.00 ± 13.72 (pretest) to 82.10 ± 13.28 (posttest). Paired-samples t-test results indicated a statistically significant difference ($t(59) = -20.83$, $p < 0.001$), with a mean improvement of 9.10 points and a moderate-to-large effect size (Cohen's $d = 0.68$). This magnitude suggests a practically meaningful improvement in students' throwing performance within a school-based context. **Conclusion:** Circuit training was associated with improvements in javelin throwing performance and shows potential as an instructional strategy in physical education. However, the absence of a control group limits causal inference, and future research should employ controlled designs to confirm these findings and examine long-term skill retention. Practically, the results support the use of structured circuit-based activities to optimise limited instructional time in school physical education settings.

Keywords: Integration; circuit training; exercise media; learning; javelin throwing

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INTRODUCTION

Javelin throwing is a complex motor skill that requires the integration of strength, coordination, speed, and proper release mechanics. However, in school settings, students often experience difficulties in mastering

these technical components due to limited practice time and insufficient physical conditioning support. Through physical activity, students learn to master motor skills and develop physical, mental, social and emotional fitness in balance (Mulya & Millah, 2019; Mustafa, 2022). In the context of modern education, physical education is seen as an integral part of the learning process, aimed at improving quality of life and 21st-century competencies such as collaboration, self-discipline, and sportsmanship. To achieve this, physical education teachers must be able to design innovative and varied learning that adapts to developments in sports science and the needs of learners. An engaging and effective approach to learning can increase student engagement and contribute to improved learning outcomes and motivation to participate in sports activities.

One training approach that has proven effective in improving fitness and motor performance is circuit training. This form of exercise combines several types of physical activity in a certain sequence, with relatively short rest periods between stations. This method allows the simultaneous development of various components of physical fitness, such as strength, speed, endurance, and coordination. Studies have shown that circuit training can significantly improve physical capacity, including increasing VO_2 max, a key indicator of aerobic performance (Annasai et al., 2023; Rocero, 2024; Sukendro, 2021). In addition, this method has been proven to increase student motivation and improve sporting outcomes compared to conventional exercise (Betaubun & Tahapary, 2023; Maulana et al., 2023; Yuliawan & Arsil, 2024). In the context of javelin throwing, circuit training is highly relevant as it strengthens the arm and shoulder muscles, improves movement speed and body coordination, and increases explosive power all of which are key components of effective throwing techniques.

Several previous studies have focused on developing models and learning media for teaching the javelin throw in schools (Haqi et al., 2023; Syahrianursaifi et al., 2024), as well as emphasising the importance of teaching variations to improve student achievement (Arianto et al., 2023; Bancin & Tantri, 2022). Although previous studies have explored instructional models and modified learning media for javelin throwing, limited research has examined the integration of structured physical conditioning approaches, such as circuit training, within skill-based instruction in school settings. Furthermore, most existing studies focus either on technical instruction or physical training separately, rather than combining both within a unified pedagogical framework. Integrating learning models with modern physical training methods could provide students with a more comprehensive learning experience, emphasising both fitness and engineering skills. This research gap highlights the need to explore the application of circuit training in javelin throwing in a school setting. There is an urgent need to modernise physical education to bring it more in line with the latest developments in sports science, while addressing the challenges of low motivation and poor learning outcomes in athletic activities. This study is novel in that it integrates elements of strength, speed and endurance into a unified learning framework through circuit training methods.

Based on these findings, this study aims to examine the association and practical applicability of integrating circuit training into javelin throwing instruction in school settings. The study focuses on how circuit training can be systematically applied to improve physical fitness and javelin-throwing technique, as well as student motivation. The results of this study are expected to provide theoretical and practical contributions to physical education teachers, particularly with regard to designing more innovative and efficient learning models. In practical terms, the study can serve as a reference for schools looking to implement an exercise approach that emphasises not only the achievement of technical skills but also the development of students' physical capacity and character. Thus, this study has the potential to contribute to the development of more comprehensive, adaptive and relevant physical education for today's learners.

METHOD

Design

This study employed a quasi-experimental one-group pretest–posttest design. A total of 60 junior high school students in Makassar were selected as participants using purposive sampling based on established inclusion criteria.

Participants

This study screened 300 junior high school students enrolled in physical education classes in Makassar as the initial population frame. Using purposive sampling, inclusion criteria were applied: active participation in physical education, no prior specialised javelin training, good health, and no history of musculoskeletal injury, resulting in the exclusion of 240 students. The final sample consisted of 60 students (mean age = 14.2 ± 0.8 years), including 32 males and 28 females. The sample was drawn from three junior high schools and selected proportionally based on grade level and gender, ensuring representative participation and minimising sampling bias.

Procedures

This research was carried out in several systematic stages. The first stage was preparation, which included coordinating with the school, selecting samples and implementing the validity and reliability of the research instruments. A pretest was also carried out to measure the participants' javelin throwing ability before the intervention. In the next stage, students underwent circuit training in accordance with the exercise programme design. Each session lasted approximately 60 minutes, including warm-up (10 min), circuit training (40 min), and cool-down (10 min). After the intervention was completed, a posttest was conducted to re-measure the participants' javelin-throwing ability. The final stage was data analysis, involving processing the pretest and posttest results using SPSS software, version 23.

Intervention/Treatment

The intervention was carried out over eight weeks, with exercise performed twice per week. Exercise intensity was progressively increased by adjusting repetitions and movement complexity across weeks. This duration and frequency are based on previous studies which show that an exercise period of 6-8 weeks, at an intensity of twice per week, is effective in causing physiological adaptation and measurable improvement in motor skills. Eight weeks is considered sufficient to bring about significant changes in muscle strength and endurance, as well as the coordination of movements required for the javelin throwing technique, without causing excessive fatigue in high school students.

The exercise parameters in the circuit programme are designed according to the principles of specificity and progressiveness. Each training session includes a series of exercises that target the strength of the arms, shoulders and legs, as well as the coordination and explosive power of the muscles relevant to the javelin throwing motion. The work-to-rest ratio is set at 40 : 20 seconds and is adjusted according to the students' physical abilities and the results of previous research on the effectiveness of interval training with adolescent students. This approach is expected to provide a sufficient training stimulus to improve performance without causing excessive fatigue.

Table 1. Circuit Training Exercise Programme

Week	Training Focus	Components of the Exercise (Circuit)	Frequency
1-2	Technique & basic introduction	1. Throw the ball lightly. 2. Squat jump. 3. Push-ups. 4. Wall throw. 5. Plank. 6. Zigzag run.	2x / week
3-4	Core & arm muscle strengthening	1. Medicine ball throw. 2. Burpee. 3. Light weight (1-2 kg). 4. Side plank. 5. Overhead throw. 6. Skipping.	2x / week
5-6	Throwing technique & speed	1. Sprint 20 m. 2. Overhead throw. 3. Core twist. 4. Skater jump. 5. Dummy javelins throw. 6. Ladder drill.	2x / week
7-8	Full simulation & reinforcement	1. Running-throwing combination. 2. Jump squat. 3. Maximum-effort throw (within safe technique limits). 4. Side lunges. 5. Core hold. 6. Race engineering simulation.	2x / week

Table 2. Assessment Aspects and Indicators

No	Assessment Aspects	Definition	Rating Indicators	Maximum Score
1	Throwing Technique	The ability to perform a sequence of javelin throwing movements correctly and efficiently.	1) starting position (grip, posture). 2) Step prefixes and transitions 3) throwing movements. 4) Follow-through (continued after the throw)	20
2	Power Throw	The thrust generated when making a throw.	1) the muscles of the hands and shoulders appear active. 2) The Throw looks strong and powerful. 3)the Javelin is thrown stably without falling prematurely	20
3	Throw Distance	The farthest valid distance result achieved by a javelin.	1) measured from the throwing line to the point of falling of the javelin tip that first touches the ground. 2) take the best throw of. 3) take the best of 3	50
4	Observance of the rules	Compliance with the Basic Rules of javelin throwing by athletic standards.	1) Do not cross the boundary line when throwing. 2.) The javelin lands with the spearhead first. 3) No cheating throws	10

Table 3. Rating Scale per Aspect

Score	Criteria
16-20	Perfect movement, according to the order of technique, excellent body coordination
11-15	Movement is quite good, there are few technical errors, but they do not significantly affect the effectiveness of the throw
6-10	Movement is less precise, the sequence of techniques is not complete, appear hesitant or lack of confidence
1-5	Totally wrong movement, out of order, looks doubtful and dangerous

Data Measurement and Analysis

The measuring instrument is a javelin throwing ability test that was developed with the help of two certified athletic trainers (each with a minimum of five years of experience in athletics coaching) and two licensed physical education teachers. The assessment scale covers four domains: throwing technique (maximum 20 points), power throw (maximum 20 points), throw distance (maximum 50 points), and observance of rules (maximum 10 points), yielding a total maximum score of 100 points. The validity of the contents was tested using Aiken's V, achieving results in the valid category (0.86-0.95). Reliability was tested using the Intraclass Correlation Coefficient (ICC), achieving a value of 0.89 (very reliable category). To reduce assessor bias, test results are evaluated by two independent assessors using the same scoring guidelines. If there are significant differences, discussions are held to reach a consensus. Data analysis in this study includes two main stages. First, a descriptive analysis was carried out to describe the characteristics of the participants and the distribution of javelin throwing ability test scores. Secondly, a paired t-test was used to analyse the difference between the average pretest and posttest results in order to determine the effectiveness of the circuit training intervention in improving students' javelin throwing skills.

Data analysis was conducted by comparing pre- and posttest scores using paired t-tests to determine the significance of improvements in javelin throwing ability following treatment. Additionally, Cohen's d was used to calculate the effect size and interpret the magnitude of the changes that occurred. A value of d = 0.80 was categorised as a large effect, indicating that the intervention had a substantial impact on students' abilities.

Research Ethics

Ethical approval was obtained from the Institutional Review Board. Written informed consent was obtained from all participants and their parents/guardians prior to commencing the study. Participant data were treated confidentially and used solely for academic research purposes.

RESULTS AND DISCUSSION

Results

This study examined changes in students' javelin throwing performance by comparing pretest and posttest scores following the implementation of a circuit learning method. Data were obtained from 60 participants who completed both tests. The pretest mean score was 73.00 (minimum = 51; maximum = 96; SD = 13.72). After the intervention, the posttest mean score increased to 82.10 (minimum = 57; maximum = 100; SD = 13.28). All participants demonstrated improvement, with score increases ranging from 4 to 15 points, indicating a consistent upward trend in performance.

Normality testing using the Kolmogorov–Smirnov method showed that both pretest and Posttest data were normally distributed ($p = 0.200$ for both), meeting the assumptions required for parametric analysis. Consequently, a paired-samples t-test was conducted to compare pretest and posttest scores. The results indicated a mean difference of -9.10, with $t = -20.83$, $df = 59$, and $p < 0.001$, demonstrating a statistically significant difference between pretest and posttest performance.

Table 4. Learning Outcomes Throwing Circuit Method

Test	N	Min	Max	Mean	SD
Pretest	60	51	96	73.00	13.72
Posttest	60	57	100	82.10	13.28

Table 5. Normality Test-(Kolmogorov-Smirnov)

Variable	Statistic	df	Sig. (p-value)	Interpretation
Pretest	0.092	60	0.200	Normal
Posttest	0.085	60	0.200	Normal

Based on the results of the normality test in **Table 5**, using the Kolmogorov–Smirnov method, it can be concluded that the pretest and posttest data are normally distributed, as both amount to a significance value (p-value) of 0.200. As both significance values are greater than the significance level of 0.05, it can be concluded that the pretest and posttest data are normally distributed. Therefore, the normality assumption is met, and the data can be analysed using further parametric tests.

Table 6. T-test Paired-Samples Test (Pretest vs Postest)

Data Pairs	Average Difference	t	df	Sig. (2-tailed)
Pretest – Postest	-9.10	-20.83	59	0.000

A paired samples t-test was conducted to determine whether there was a significant difference between the pretest and posttest results after circuit learning methods were applied to the javelin throwing material. Based on the analysis, the average difference was found to be -9.10, with a t-value of -20.83, a degree of freedom (df) of 59, and a two-tailed significance value of 0.000.

As the significance value is less than 0.05 ($p < 0.05$), it can be concluded that there is a significant difference between the pretest and posttest values. This suggests that the circuit learning method significantly improves participants' javelin throwing ability.

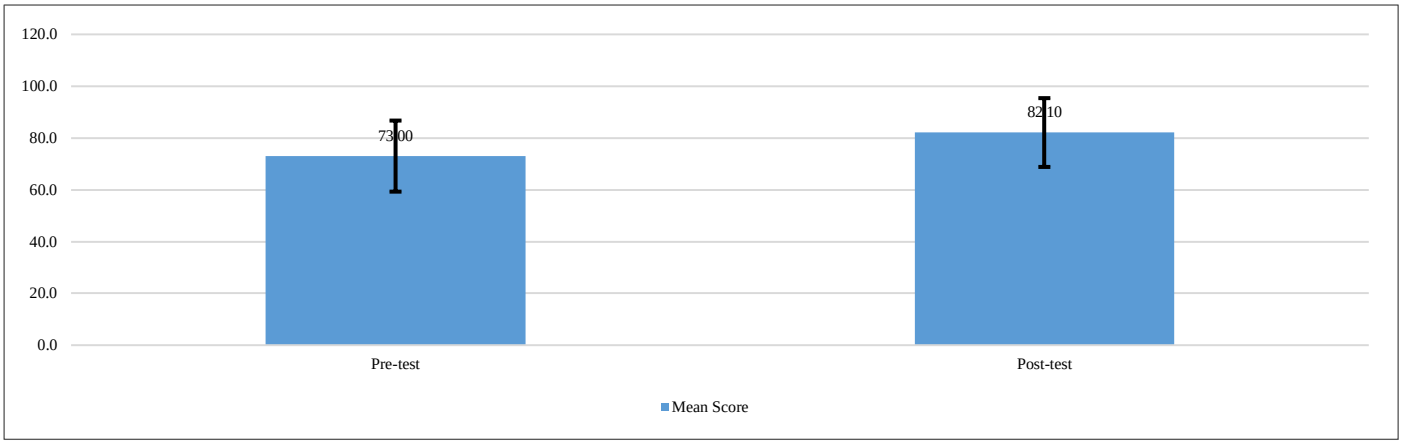

Figure 1. Mean Javelin Throwing Performance Scores in Pretest and Posttest with Standard Deviation Error Bars

Discussion

The results showed a significant improvement in javelin-throwing ability among students who received the circuit-training intervention ($t = -20.83$, $df = 59$, $p < 0.001$), with a mean difference of 9.10 points and a moderate-to-large effect size (Cohen's $d = 0.68$), demonstrating that the method had a tangible impact on the students' skills. The observed improvement in javelin-throwing performance should be interpreted in relation to the composite performance score used in this study, which assessed technique execution, power expression, throwing distance, and rule compliance, rather than direct physiological or biomechanical measurements. Accordingly, the improvement may be associated with several performance-related aspects reflected in the scoring rubric. Firstly, enhanced expression of power during throwing movements, as indicated by higher distance and execution scores, may reflect improved functional strength developed through circuit training exercises such as push-ups, squat jumps, and medicine ball throws. Secondly, improvements in movement coordination and rhythm, inferred from smoother transitions between throwing phases and better technical execution, may be linked to the repetitive and varied nature of the circuit activities. Richards and Gaynor (2022) emphasised the importance of movement rhythm in achieving a stable javelin release, which aligns with the observed improvements in technique-related scoring components in this study. Thirdly, greater awareness and consistency in release technique, reflected in improved accuracy and rule compliance scores, may have been facilitated by repeated exposure to throwing-related tasks performed at varying intensities within the circuit programme. These interpretations remain inferential and should be viewed as performance-related explanations rather than direct evidence of changes in underlying physical capacities. According to Bondarenko et al. (2022), this phase is the main determinant of success in terms of distance.

While these results align with several prior studies (Aulia & Mongsidi, 2022; Samsudin, 2023), notable differences exist. Most previous studies have focused on advanced athletes, whereas this study confirms that similar methods are also effective with junior high school students who have limited experience of javelin throwing. This comparison demonstrates the flexibility of circuit training, but the context of the participants (athletes vs. students) must be considered when applying it.

These findings are consistent with previous studies emphasising the importance of mastering the release technique and biomechanical parameters such as release angle and speed in achieving success in javelin throwing (Dong & Wang, 2022; Hussein, 2023; Ketlerova, 2023). Circuit training, combining strength and coordination in a repetitive format, helps students to improve their movement rhythm and body control during the throwing phase. William (2021) also asserts that rhythmic movement patterns play an important role in adolescent javelin throwing performance. Meanwhile, Makino et al. (2025) suggests that progressive exercises such as circuit training can improve the development of arm muscle strength and control, as well as efficient movement transitions. Thus, the results of this study reinforce the evidence that circuit training is an effective approach to developing students' technical skills and physical fitness.

From a pedagogical perspective, improving student performance through circuit training supports the constructivist principle of physical education, whereby active, repetitive, experience-orientated, hands-on learning enables students to develop an understanding of motor skills through reflective practice. According to Loibl and Leukel (2023), motor exercises that allow for independence and variety encourage students to self-regulate their learning process, increasing engagement and strengthening skill retention. By applying these principles to javelin throwing lessons, teachers can foster students' awareness of bodily processes and effective movements, as well as teaching techniques.

Furthermore, this study demonstrates the broad potential of circuit training in the development of physical education curricula. Programmes focusing on strength, coordination and endurance can be adapted for various sports, including javelin, discus and shot put, as suggested by (Auriemma & de Luigi, 2024). This approach enables teachers to design more structured, varied and challenging learning activities while maintaining student engagement through a dynamic combination of exercises. However, the training load must be adapted to the learners' physical condition and age, and technical feedback must be provided continuously to improve movement quality and prevent injury.

Nevertheless, some limitations of the study should be noted. The one-group pretest–posttest design without a control group restricts the study's internal validity, as improvements in scores can be influenced by external factors, such as individual motivation or teacher support. Additionally, the absence of a detailed biomechanical analysis meant that measurable improvement was only seen in the final result of the throw rather than in the quality of the motion technique itself. The intensity of students' motivation during the programme could not be quantified, although this factor may have contributed to the difference in results. Therefore, further research should involve a control group, observation of movement using kinematic analysis and measurement of students' motivation and perception of exercise.

CONCLUSION

This study demonstrates that circuit training was associated with improvements in javelin throwing performance among junior high school students. The findings suggest the potential value of integrating structured physical conditioning with sport-specific skill instruction, contributing to both physical fitness development and motor skill acquisition. In practical terms, the results indicate that circuit-based activities may support more structured and engaging learning experiences in physical education settings, particularly when instructional time is limited. However, given the one-group pretest–posttest design, the findings should be interpreted with caution, as causal relationships cannot be fully established. Further research using controlled experimental designs and biomechanical analysis is recommended to strengthen the validity of the findings and to better understand the mechanisms underlying performance improvements.

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CONFLICT OF INTEREST

No conflict of interest.

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