JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 69-74 (November 2025) | DOI: 10.17509/jtikor.v10i2.85697

Development and Effectiveness of the Bosco Training Model to Improve Students Physical Fitness

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Article Info

Article History

Submitted: June 10, 2025
Accepted: November 21, 2025
Published: November 25, 2025

Article Access

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Abstract

This study focuses on creating a physical fitness training model for students, evaluating its validity, and assessing how the training model affects students' physical fitness. The research follows a research and development (R&D) approach at the limited trial stage, based on the Borg and Gall model. The study involved 89 high school students. Data was collected through questionnaires, direct observation, and documentation. The result of the research and development process was the Bosco physical fitness training model, which includes shuttle run exercises in a W-shape and triceps push-ups. The training was conducted four times a week, with three trials per session, and the highest score from each session was recorded. There was a noticeable improvement from the pre-test to the post-test results, with a significance level of 0.000, which is less than 0.05. As a result, the null hypothesis (H0) was rejected, indicating a significant difference in the average scores before and after implementing the Bosco training model. The Bosco model is classified as “appropriate” and is suitable for use as a physical fitness training model for students. It can be integrated into physical education programs to enhance students' overall physical fitness.

Keywords: bosco training model, physical fitness, shuttle run, training development
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Introduction

The most recent report from the World Health Organization (WHO) in 2024 reveals that approximately 81% of teenagers between the ages of 11 and 17 worldwide are not getting enough physical activity, leading to poor physical fitness among adolescents. This issue poses a significant challenge to the health of future generations globally. The situation is also present in Indonesia. According to data from the 2021 National Sport Development Index (SDI), published by the Ministry of Youth and Sports (Kemenpora 2021), the physical fitness level of students in Indonesia is classified as very low. This information was later updated in the 2022 report, which shows that 83.9% of high school students fall into the "poor" or "very poor" categories regarding their fitness. These results emphasize the importance of increasing efforts to enhance the physical fitness of students in Indonesia.

According to Ardian and Yasin (2024), physical fitness plays a key role in overall well-being, going beyond just physical endurance to include energy levels, stamina, and mental health. Through Physical Education (PE), students have the opportunity to form healthy lifestyle habits, enhance their motor skills, and cultivate strong character traits (Nasution & Tarigan, 2021). Additionally, physical fitness is closely linked to an individual's ability to carry out daily tasks efficiently without experiencing undue tiredness (Pranata, 2022).

However, several studies have indicated that the physical fitness levels of students in Indonesia are still low and are not adequately addressed by the lack of systematic and practical training programs in schools. This situation highlights a gap between the need to enhance physical fitness and the current approaches used in physical education.

Several earlier studies have tried to create training models to boost physical fitness. Bile et al. (2021) made a training model using traditional games, and it was shown to improve students' fitness and increase their interest in learning. On the other hand, Lismana et al. (2022) discovered that the 2018 Healthy Heart Gymnastics Series V greatly enhanced endurance and muscle strength in female students from junior high school. However, there is still a lack of research focused on developing a physical fitness training model tailored for senior high school students, using a method that is easy to measure, simple, and suitable for students.

The Bosco fitness training model provides a practical and easy to implement training program even with limited facilities. The main objective of developing this training model is to produce innovations that support physical education learning activities to improve students' physical fitness. The results of this study are expected to contribute to improving the quality of teaching and serve as a reference for teachers when designing training programs that are applicable, effective, and enjoyable for students.

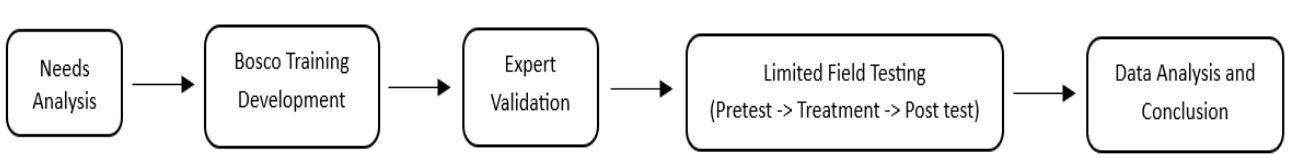
Methods

Research Design

This study uses the Research and Development (R&D) method, which is rooted in the Borg & Gall model and is applied in a restricted Level 3 trial. This approach is widely utilized in research focused on development. Generally, researchers modify certain phases of the process according to the specific goals of the study and the level of the investigation (Borg & Gall, as cited in Putri, 2023). In this study, the following steps were implemented throughout the development process.

Figure 1

Research Procedure



First, a needs analysis was carried out by gathering initial data through questionnaires and initial fitness assessments using TKSI (Tes Kebugaran Siswa Indonesia) to evaluate the physical condition of the students. Next, the model development phase involved creating the Bosco Training Model based on the findings from the needs analysis. Then came the expert validation stage, where physical education experts reviewed the design and content to ensure it was both technically and pedagogically sound. Following this, there was a revision stage to improve the model based on the experts' feedback. The final step was a limited field test, which involved implementing the model with a selected group of participants, following a pre-test, 16 weeks of intervention, and a post-test, to assess its feasibility and effectiveness.

Participants

The study involved all senior high school students, with a total of 89 participants. Among them, 45 were male and 44 were female, with ages ranging from 14 to 17 years. The research used a total sampling method, meaning every member of the population was included in the sample. Data collection took place during physical education lessons, specifically in five classes: three classes from the 10th grade and two classes from the 11th grade.

Instrument

The research tools used to assess students' physical fitness in this study included a questionnaire delivered through Google Forms, which had 10 questions focusing on students' physical fitness and 10 more questions given after the post-test. Additionally, documentation and observations were conducted using the TKSI test battery. The TKSI comprised various test components, all of which have proven validity and reliability.

The Hand and Eye Coordination Test showed a validity value of 0.751, which is higher than 0.103 (r calculated > r table), indicating very high validity. It also had a reliability coefficient of 0.689, which is considered high reliability. The Vertical Jump Test had a validity value of 0.805, which is greater than 0.103, classifying it as high validity, and a reliability value of 0.683, also indicating high reliability. The T Test resulted in a validity value of 0.714, which is above 0.103, showing high validity, and a reliability coefficient of 0.693, which is high reliability. The Hand Touch Reaction Test had a validity value of 0.323, which is above 0.103, categorized as low validity, although it demonstrated high reliability. The Dipping Test produced a validity value of 0.520, which is higher than 0.103, indicating moderate validity, and a reliability coefficient of 0.714, considered high reliability. Lastly, the Beep Test showed a validity value of 0.257, which is above 0.103, classified as low validity, but had a reliability coefficient of 0.738, which is high reliability.

Procedure

The research procedure consisted of three main stages, structured according the Borg & Gall Level 3 development model: needs analysis, model development and validation, and limited field testing. In the needs analysis stage, the researcher distributed a questionnaire containing 10 questions to obtain preliminary information related to student physical fitness levels, lifestyle habits, exercise intensity, dietary patterns, and sleep quality. These data were used to obtain a comprehensive overview of student initial physical fitness condition.

The next step was creating and checking the Bosco fitness training model. This model was made using the findings from the needs analysis. It was then reviewed by physical education experts who checked its content and design to make sure it was practical for teaching and matched the students' needs.

The final part of the process was a limited field test, which had three stages.

First, a pre-test was done using the TKSI to measure the students' current level of physical fitness. Then, the Bosco training model was implemented for 16 weeks, with sessions held three to five times a week, each lasting 90 minutes. Research by Panggraita and Mega (2020) shows that this training model significantly improves physical fitness. After the training period, a post-test was conducted to assess the improvement in fitness levels. Additionally, students' views on how effective the Bosco model was were gathered through an evaluation questionnaire along with quantitative data.

The efficacy of the intervention was then assessed by analyzing and comparing the post-test results with the pre-test data. Data triangulation was used as a complementary strategy by merging quantitative information from TKSI with qualitative information from the survey. Figure 1 shows how this method allowed for a more thorough and in-depth evaluation of the developed research workflow's efficacy.

Data Analysis

To make sure the developed training model's content and design were appropriate, an expert validation process was carried out prior to its implementation with the students. An expert in physical education completed this validation by evaluating the training model's design and content

Table 1

Normality Test of Results Pre-test and Post-test Variables

Variable	Statistic	df	Sig.
Pre-test Hand Eye Coordination	.183	89	.000
Post-test Hand Eye Coordination	.123	89	.002
Pre-test Vertical Jump Test	.167	89	.000
Post-test Vertical Jump Test	.175	89	.000
Pre-test T Test	.093	89	.056
Post-test T Test	.145	89	.000
Pre-test Hand Touch Reaction	.107	89	.014
Post-test Hand Touch Reaction	.430	89	.000
Pre-test Dipping Test	.069	89	.200*
Post-test Dipping Test	.114	89	.006
Pre-test Beep Test	.118	89	.004
Post-test Beep test	.063	89	.200*

Table 2

Hypothesis Test

Test Statistics	Z	*Asymp.Sig. (2-tailed)*
Post-test Hand Eye Coordination – Pre-test Hand Eye Coordination	-5.488[b]	.000
Post-test Vertical Jump – Pre-test Vertical Jump	-5.460[b]	.000
Post-test T Test – Pre-test T Test	-7.905[b]	.000
Post-test Hand Touch Reaction – Pre-test Hand Touch Reaction	-5.822[c]	.000
Post-test Dipping Test – Pre-test Dipping Test	-8.148[b]	.000
Post-test Beep Test- Pre-test Beep Test	-8.181[b]	.000

(Mardapi, 2023). In order to verify the validity of the employed instrument, the validation process was carried out methodically by gathering theoretical and empirical data. Following the completion of the data collection procedure, a normality test was used to start the analysis and ascertain whether the data could be distributed normally. The Wilcoxon Signed Rank Test non-parametric test was used to continue the analysis after the test results demonstrated that the data did not satisfy the assumptions of normality and homogeneity.

In the last phase, the researcher tested hypotheses and examined the variations between the pre-test and post-test outcomes following the intervention. The impact of training on the students' overall improvement in physical fitness was determined using the results of the hypothesis testing.

Results

Before deciding on the statistical methods, the researcher first checked for normality to assess how the data was distributed. Table 1 presents the results of the normality test, showing that most of the data, except for the pre-test Dipping Test, had a significance value greater than 0.05. A significance value less than 0.05 indicates that the data is not normally distributed. Therefore, it is evident that most of the data does not meet the assumption of normality, particularly the pre-test T Test, pre-test Dipping Test, and post-test Beep Test. Based on this, the Wilcoxon Signed Rank Test was chosen as the appropriate non-parametric statistical method, since the pre-test and post-test data did not follow a normal distribution.

In a scientific context, a hypothesis offers an initial answer to specific research questions that are clearly defined as problem statements (Sugiyono, 2018 as cited in Gea et al., 2023). The importance of the hypothesis testing results shown in Table 2 is that all the variables examined in the study — Hand Eye Coordination, Vertical Jump Test, the T Test, Hand and Touch Reaction Test, Dipping Test, and Beep Test — have p-values of 0.000. These values are all below the critical threshold of 0.05, indicating statistical significance.

Also, the average comparisons indicated an improvement from the initial exam to the final exam in all measured variables. Hand Eye Coordination increased by 35.45%. The Vertical Jump Test showed an improvement of 5.64%, while the T Test showed a decrease of 9.83%. The Hand and Touch Reaction Test increased by 15.24%. The

Dipping Test showed a relatively high increase of 39.82%, and the Beep Test improved by 6.04%. The overall average improvement across all treatment variables was 15.40%. These findings further support the idea that the Bosco training program can lead to statistically significant improvements in students' physical fitness.

Discussion

The findings from the research confirm that the Bosco training model positively changes the physical fitness of students across different dimensions. As shown by the gained score in the post-test result from each component of the TKSI variables. The largest increase was in the Dipping Test (39.82%), followed by Hand and Eye Coordination (35.45%) and Hand Touch Reaction (15.42%). Moderate improvements were also seen in the Vertical Jump Test (5.64%) and Beep Test (6.04%). However, one component, the T Test, experienced a decline of 9.83%. Overall, the average increase reached 15.40%. These results illustrate that the Bosco training model is effective in improving the physical fitness of high school students, especially in terms of coordination, reaction speed, and endurance.

The progress School-Based Interventions Reported 2021 is in line with previous findings that pointed out active training programs improve multiple domains within fitness. A good number of literature that examined school-based physical activities demonstrate that participation in physical activities improves the level of fitness and enhances the different domains of fitness (Vaquero-Solis et al., 2020). Also, comparative studies have shown that different sorts of training programs, for instance, resistance training, and interval training, have significant influence on the particular fitness components that get improved (Wu et al., 2023).

These results also support evidence showing explosive training to improve jumping performance, sprint ability and change of direction speed (Ramirez-Campillo et al., 2023; Zheng et al., 2025). In addition, Shuttle Run training has demonstrated to be significantly effective for the development of cardiorespiratory fitness in adolescents (Jovanovic et al., 2024). Conversely, when it comes to upper body strength related exercises like the triceps pushup in connection with resistance training a meta-analytic study has demonstrated that resistance training significantly enhances incremental both of the upper (upper and lower limbs).

To endorse the acceptance of the research hypothesis, the model`s effectiveness in improving student physical fitness is enhanced by the pre-test and post-test data. As a result, Bosco training model should be recognized as a valid and reliable alternative training program that is impactful in improving physical fitness and applicable in the case of senior high school students.

Conclusions

As such, this work establishes an appropriate Bosco physical fitness training model for senior high school students. The training model based on Shuttle Run and Tricep Push Up exercises, has shown to be an efficient way to enhance significantly physical fitness level in students as a whole, taking into account different evaluated dimensions (Hand Shape Coordination, Dip Test and Hand & Touch Reaction Time). The model was considered as a valid and applicable model in physical education lessons influenced students to interest in motivation to practice.

The Bosco Training Model can be actually generalizable by the physical education teachers as a simple and effective modality for an alternative training program aiming at augmenting participant's in school activities or participation and increasing their physical fitness performance, Considering that it may be a model adapted to health -related activities or athletics programs introduced within educational institutions, this could make more substantial contribution on promoting students' general health condition with no underestimating enhancing their overall quality of physical fitness.

Acknowledgment

I would like to thank to support by PGRI Adi Buana Surabaya University in conducting this research. I would like to thank also the students and Colleagues who collaborated in the preparation and implementation of this research.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)
e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle JTIKOR 10(2): 75-79 (November 2025) | DOI: 10.17509/jtikor.v10i2.86870

Effects of Target-Game Training on Shooting Accuracy in Futsal Players

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Article Info

Article History

Submitted: June 25, 2025
Accepted: November 21, 2025
Published: November 25, 2025

Article Access

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Abstract

Shooting accuracy is a fundamental skill in futsal and remains a common performance limitation among amateur players. This study aims to examine the effect of target-game training on the shooting accuracy of THE BOS Futsal Club players. A one-group pretest–posttest experimental design was implemented with 20 male athletes aged 14–18 years. Shooting accuracy was assessed using a standardized shooting test, and data were analyzed using normality testing, homogeneity testing, and a paired sample t-test. The results showed a significant improvement in shooting accuracy after the intervention, with mean scores increasing from 13.1 ± 1.81 to 15.5 ± 1.53 points. Statistical analysis indicated a significant effect of target-game training on shooting accuracy ($t = 12.352$, $p < 0.001$), with an improvement rate of 18.7%. These findings suggest that target-game training is an effective and engaging method for enhancing shooting accuracy in futsal players. The novelty of this study lies in applying a game-based accuracy model specifically tailored for amateur club athletes, offering evidence-based recommendations for futsal coaching practice.

Keywords: futsal, shooting, target training, training intervention.

Introduction

Futsal is one of the most rapidly developing team sports due to its fast tempo and high technical demands. The sport requires frequent high-intensity actions, rapid decision-making, and precise technical execution, making shooting accuracy a critical performance component (Castagna et al., 2009). Futsal has also become increasingly competitive at regional and national levels (Kharisma & Mubarok, 2020), and its accessibility allows many youth athletes to train in smaller indoor spaces (Zainuddin & Yusuf, 2021). These contextual factors highlight the importance of developing sport-specific technical skills such as shooting.

Shooting accuracy is a decisive factor for scoring success in futsal. Players must execute precise shots under time pressure, limited space, and defensive constraints. According to Iyakrus (2023), accuracy reflects an athlete's ability to direct movement toward a target, which directly influences goal-scoring effectiveness. This is supported by biomechanical research showing that proper foot placement, striking technique, and body coordination significantly affect shooting outcomes (Katis & Kellis, 2009). Despite its importance, both empirical studies and coaching reports indicate that shooting accuracy remains underdeveloped among amateur players.

Field observations in November 2024 confirmed similar issues in THE BOS Futsal Club, where players frequently produced weak or off-target shots. Such limitations negatively affect goal conversion, attacking efficiency, and overall match success. Improving shooting accuracy is therefore essential for enhancing athlete development and team performance.

Previous studies have explored training methods to enhance shooting performance. Target-game drills, for example, have been shown to improve precision and maintain player engagement (Buya et al., 2021). Game-based practice can also enhance decision-making and technical execution by simulating realistic match contexts (Travassos et al., 2012; Davids et al., 2013). However, there is still limited research examining how target-game training specifically affects shooting accuracy among amateur futsal players in competitive club settings.

Target games emphasize accuracy, focus, and control through structured scoring zones, offering immediate feedback and replicating competitive shooting scenarios. This approach may provide a more engaging and effective method than monotonous repetitive drills.

Based on this rationale, the present study aims to evaluate the effect of target-game training on shooting accuracy among players of THE BOS Futsal Club. The main research question is:

"Does target-game training significantly improve shooting accuracy among amateur futsal players?"

Methods

This type of research is experimental. The experimental method is defined as a systematic approach used to establish relationships that involve cause-and-effect phenomena (causal-effect relationship).

Research Design

This study employed a *One-Group Pretest–Posttest Design*, in which participants were measured before and after the intervention. This design was chosen because the research population consisted of a single intact team, making random assignment or the use of a control group impractical in the club's training environment. Although the absence of a control group limits internal validity, this design allows researchers to detect changes directly attributable to the intervention when the population is homogeneous (Munir et al., 2022).

The training program lasted four weeks, with three sessions per week, for a total of 12 training sessions. Each session lasted approximately 60 minutes, consisting of warm-up, target-game shooting drills, and cool-down. All sessions were supervised by the researchers and the team coach to ensure consistency of implementation.

The study was conducted at THE BOS Futsal Club, located in Prabumulih City, South Sumatra.

Participants

The participants were 20 male futsal athletes, aged 14–18 years, who were active members of THE BOS Futsal Club. A total sampling technique was used because the entire population met the characteristics required for the study (Azizah et al., 2022).

Inclusion criteria

1. Active club member for at least six months
2. Participated in routine weekly training
3. No lower-limb injury within the last three months
4. Able to complete all training sessions

Exclusion criteria

1. Players with current musculoskeletal injuries
2. Players absent for more than two training sessions
3. Players who did not complete pretest or posttest measurements

Ethical Considerations

Ethical approval was obtained from the Institutional Research Ethics Committee (insert

approval number if available). All participants and their guardians (for those under 18) provided informed consent before participating in the study.

Instrument

The instrument used to measure shooting accuracy was a standardized futsal shooting accuracy test, adapted from Miftahul & Sin (2019). The goal area was divided into scoring zones with predetermined point values. Each participant performed five instep shots from a distance of 10 meters.

Validity and Reliability

1. The test has been commonly used in futsal training assessments and demonstrated content validity based on expert evaluations (Miftahul & Sin, 2019).
2. Reliability testing in previous research showed r = 0.82, indicating high measurement stability.
3. Prior to data collection, the test was pilot-tested on five players from another local club, showing consistent scoring across repeated trials.

Scoring Zones

A diagram illustrating the scoring areas should be included to facilitate clarity for international readers.

Procedure

Data collection followed several key stages:

Pretest

Players performed five instep shots toward the target-zone goal. Scores were recorded according to the standardized scoring sheet.

Training Intervention

1. Duration: 12 sessions (4 weeks)
2. Frequency: 3× per week
3. Content: Target-game shooting drills emphasizing precision, visual targets, and decision-making
4. Supervision: Conducted under the researcher and head coach to maintain consistency
5. Drills used included:
   a. Corner target shots
   b. Moving-ball target shots
   c. Zone-based scoring challenges Training focused on accuracy development, not volume-based or conditioning-based shooting.

Posttest

After the intervention period, participants performed the same five-shot accuracy test under identical conditions.

Simplified Scoring System

1. 2 points → center
2. 3 points → upper/lower middle
3. 4 points → between tire and cone
4. 5 points → cone or tire target
5. 0 points → misses, post hits, or hitting barrier strings

Norm categories (Miftahul & Sin, 2019) were applied to classify results.

Data Analysis

The data were analyzed using SPSS 26. Prior to hypothesis testing:

1. Normality test (Shapiro-Wilk)
2. Homogeneity test (Levene test)

A paired sample t-test was used to compare pretest and posttest scores.

Effect size was calculated using Cohen's d, with the following interpretation:

1. 0.2 = small
2. 0.5 = medium
3. 0.8 = large

Confidence intervals (95% CI) were reported to increase the analytical rigor of the study.

Results

The results of this study present descriptive statistics, assumption testing, and hypothesis testing related to the effect of target-game training on shooting accuracy among THE BOS Futsal Club players. All analyses were conducted using SPSS 26.

Table 1

Descriptive Statistics of Shooting Accuracy Scores

Statistik	Pretest	Posttest
N	20	20
Mean	13.10	15.55
Median	13	15
Mode	12	15
Std. Deviation	1.81	1.53
Minimum	10	13
Maximum	16	18

Table 2

Paired Sample t-Test Results

Parameter	Value
Mean Difference	–2.450
Standard Deviation	0.887
Standard Error Mean	0.198
95% CI Lower	–2.865
95% CI Upper	–2.035
t(19)	–12.352
p-value	< .001

Descriptive data for pretest and posttest shooting accuracy scores are presented in Table 1.

As shown in Table 1, the mean shooting accuracy improved from 13.10 (pretest) to 15.55 (posttest), representing an increase of 2.45 points (18.7%). Minimum and maximum scores also increased, indicating improvement among both lower- and higher-performing players. The reduction in standard deviation suggests more consistent shooting performance following the intervention.

The results of the paired-sample t-test comparing pretest and posttest shooting accuracy are shown in Table 2.

The paired-sample t-test indicated a statistically significant increase in shooting accuracy following target-game training, $t(19) = -12.352$, $p < .001$.

To complement significance testing, the effect size was calculated using Cohen's *d*, resulting in $d = 2.76$, which represents a very large effect. This indicates that the training produced a meaningful and substantial improvement in players' shooting accuracy.

Discussion

The findings of this study demonstrate that target-game training significantly improved the shooting accuracy of THE BOS Futsal Club players. The increase in mean scores from 13.1 (pretest) to 15.5 (posttest) indicates a meaningful enhancement in players' ability to direct shots toward the target. This improvement aligns with the characteristics of game-based training, which integrates perceptual–motor demands, decision-making, and precision under dynamic conditions. Such characteristics have been shown to enhance shooting performance in futsal and football settings (Travassos et al., 2012; Katis & Kellis, 2009).

The effectiveness of target-game training in this study is consistent with the findings of Buya et al. (2021), who reported that target-based drills improve shooting precision by providing specific visual cues and performance feedback. Similarly, Prasetyo (2019) found that training with predetermined target zones increases players' accuracy due to heightened concentration and the development of shot-placement strategies. These parallels suggest that shooting accuracy improves when training incorporates structured scoring zones rather than monotonous repetitive drills.

From a performance-analysis perspective, shooting accuracy is a critical determinant of successful offensive play in futsal, owing to the fast pace and spatial constraints of the game (Castagna et al., 2009). Players must make rapid decisions while maintaining technical control, making targeted accuracy training particularly relevant. Improved shooting accuracy not only increases goal-scoring chances but also enhances a player's tactical confidence in tight match situations. This is especially important for amateur players, who often struggle with composure and decision-making under pressure.

The descriptive data further supports the quantitative findings. In the pretest, although most players were classified in the "good" and "very good" categories, their accuracy still exhibited variability. Following the intervention, all players achieved the "very good" category, indicating a more consistent level of performance across the team. This aligns with the aim of structured target-based training, which reduces performance inconsistency by reinforcing motor patterns and shot-placement strategies.

The results of the present study are also in line with another study by Sari Br P (2022), who examined the effects of target training among female futsal athletes and reported a 21.06% improvement in shooting accuracy, similar to the 18.7% improvement found in this study. These converging results strengthen the evidence that target-oriented drills are effective across different populations, regardless of age or gender.

Shooting accuracy is influenced by several factors, including kicking technique, foot–eye coordination, body alignment, focus, and tactical awareness. Target-based drills train these aspects simultaneously by providing immediate feedback and requiring players to execute precise shots in controlled scenarios. This supports the theoretical perspective proposed by Davids et al. (2013), which emphasizes that skill acquisition improves when training environments replicate the perceptual demands of actual gameplay.

Despite the positive outcomes, several limitations must be noted. First, the sample size was relatively small ($n = 20$) and derived from a single club, which may limit generalizability. Second, the players were not in a controlled training environment, allowing possible additional unmonitored practice outside of the intervention. Third, the study did not assess biomechanical variables such as foot placement or body orientation, which may provide deeper insights into the mechanism of improvement. Future studies should include a control group, larger participant samples, and possibly a biomechanical analysis to better understand how target-based methods influence shooting kinematics.

Overall, this study supports the use of target-game training as an effective approach to enhancing shooting accuracy in futsal players. The integration of accuracy-focused tasks, structured target zones, and repeated practice within game-like scenarios contributes to improvements in both shot precision and player confidence. These

findings provide practical implications for coaches seeking evidence-based methods to improve offensive performance in futsal.

Conclusions

Based on the research findings, it can be concluded that accuracy training can be effectively used to improve the shooting accuracy of players from The Bos Futsal Club Prabumulih. This is evidenced by the increase in scores from the pretest to the posttest after the players underwent shooting practice as an intervention. The average pretest score was 13.1, which rose to 15.5 in the posttest, indicating measurable improvement. The analysis results show that targeted training had a significant effect, with an impact of 18.7% on the shooting accuracy of the players. These findings are in line with previous studies, which also demonstrated that shooting drills can positively influence shooting accuracy when compared to performance prior to such training interventions.

Acknowledgment

The researcher would like to express sincere gratitude to THE BOS Futsal Club, Prabumulih, for granting permission and providing full support during the data collection process. Appreciation is also extended to the athletes who participated enthusiastically throughout the training intervention and testing sessions.

The researcher would like to thank the coaching staff for their assistance in supervising the training program and ensuring the consistency of its implementation. Special thanks are also given to colleagues and academic mentors who provided valuable feedback and guidance throughout the completion of this study.

Finally, the researcher acknowledges the support of the institution for facilitating this research and providing the necessary resources to complete this work.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)
e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle JTIKOR 10(2): 80-86 (November 2025) | DOI: 10.17509/jtikor.v10i2.90910

The Effect of Training in Improving the Ability of Side-Style Shot Put Technique

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Article Info

Article History

Submitted: October 6, 2025
Accepted: November 19, 2025
Published: November 25, 2025

Article Access

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Abstract

This study examined the impact of a structured side-style (glide) shot-put training program on the technical skills of eighth-grade students at SMP Maniamas Ngabang. Employing a one-group pretest–posttest experimental design, the research involved 30 participants whose performances were assessed using a validated rubric and shot distance test. The results showed an increase in mean scores from 61.67 (SD = 4.81) to 70.20 (SD = 4.48), representing an improvement of about 13.83%. Statistical analysis confirmed data normality and homogeneity, while the paired sample t-test revealed a significant difference between pretest and posttest ($t = -40.065$; $p < 0.05$). These findings demonstrate that a well-structured and repetitive training model effectively enhances students' coordination, strength, and mastery of technique. Furthermore, this research contributes to physical education pedagogy by offering an evidence-based framework for designing innovative and feedback-oriented training programs that improve technical proficiency and motor learning in school-based sports activities.

Keywords: motor coordination, physical education, shot put, side-style technique, training program.

Introduction

Shot put is one of the oldest athletics disciplines in the world, having been contested at the first modern Olympic Games in 1896 in Athens, Greece. Shot put performance is determined not only by muscle strength but also by the ability to transfer power from the lower extremities to the upper extremities through the kinetic chain during the acceleration phase of the throw. Therefore, learning proper technique through systematic and continuous training is crucial for optimal performance (Mappanyukkl & Anwar, 2025). Furthermore, numerous biomechanical factors have been identified as the most influential variables in successful shot put performance: release velocity, angle, and coordination time (Huang, 2014).

This understanding of biomechanics is important not only for elite athletes but also informs material in physical education. Physical education: Shot put is introduced in physical education for the development of motor skills, strength, and coordination. However, many students encounter challenges in learning the sidestroke (gliding) shot put technique, where they struggle with balance, timing, and control during the push phase (Landolsi et al., 2018). These challenges can be caused by insufficient practice time, the absence of formal technical feedback, and an inadequate understanding of movement mechanics (Putra et al., 2022). A similar issue was highlighted by (Bosse et al., 2015), who noted that student performance declines when training is not repetitive, incremental, and corrective. These biomechanical and instructional aspects are closely related, meaning that the (motor) learning process in schools must also incorporate the principles of coordination and feedback-oriented learning.

Several training schemes have been proposed to address these limitations. (Munandar et al., 2022) determined that a target-throw game model was effective in improving student technique and motivation in learning the side-stroke shot put. Similarly, (Ismail & Nuryastuti, 2023) implemented a power-position training program that significantly improved student performance ($t = 21.464$; $p < 0.05$), suggesting that a combination of technical development and instruction can result in more consistent and powerful throws. On the other hand, biomechanical differences in rotational and gliding forces indicate that gliding forces are more stable due to less variable kinematic patterns (Mastalerz & Sadowski, 2022). Despite this, the effects of structured gliding force training programs on junior high school students in Indonesia are still limited. Most previous studies have focused on athletes or general physical education, and little attention has been paid to the pedagogical use of biomechanical training models for physical education in schools.

(Zaras et al., 2021), efficient performance of shot-put strongly depends on the coupling between manipulation of hand action force and the Kinematics of body motion. Likewise (Mastalerz & Sadowski, 2022) stressed that biomechanical variables like release angle and velocity have great potential to contribute on throwing distance. These results are consistent with the assumption that repetition of movement and correction of technique are bases for formal training programs even in unskilled population (Mappanyukkl & Anwar, 2025). There have been studies, which contributed useful perspectives but they are often descriptive instead of integrative and hence emphasised for need to develop a model that bridges biomechanical understanding with pedagogical application. Integration of structured training elements involving repetition, loading progressions and performance feedback may optimize technical skill development and student engagement.

Side-style Shot Put throw (Gaya Menyamping) is often taught to Indonesian students in secondary school, meanwhile, this style is easier to learn and more appropriate in terms of the physical development of students as opposed to can be done by the course (Putratana & Hariyanto, 2022). However, from initial observations held at the SMP Maniamas Ngabang, especially to students which sit in class VIII, most of them still show not good movesothers poor arm push while their feet are not right when they undergo the pushing phase. These results suggest that the learning methods currently being used in schools may not be sufficiently successful in technical skill development.

It follows that this research is conducted with the purpose of, investigating the influence of a structured side-style shot put training program through technical skill development in eighth graders students at SMP Maniamas Ngabang. We speculate that feedback-based and systematic training regimen would greatly enhance the students' coordination, technical ability, and the pushing strength. The proposed results will help to design evidence-based training programme for PE teachers and sports coaches, offering a simple yet innovative approach to improve students' throwing performance and, ultimately, sport success.

Methods

Research Design

The present study adopted a quantitative experimental design throughout employing one-

group pretest–posttest. This project intended to verify how much a training model influences performance gains by students in the side-style shot put. This design was chosen because it is appropriate for measuring change that occurs after an intervention without a control group, as is frequently used in educational and sports performance research (Özlem Orhan et al., 2021). While this single-group pretest–posttest design has been instrumental in assessing within-subject change, it inherently lacks a comparison group. Lack of a control group is recognized as a methodological limitation that can affect internal validity. Nonetheless, a second control class was not possible, due to the organization of the school and the scheduled physical education lessons for all classes in one particular morning. All students in grade 8 were exposed to the same curriculum with the same class teachers, so there was no comparable non-treatment group. Even with this drawback, the design is still well-suited to a preliminary investigation of the immediate effects of structured training in an actual classroom condition and has been common in educational intervention research.

Participants

The respondents in this study were 30 eighth-grade students from Maniamas Junior High School, Ngabang, West Kalimantan, selected using a purposive sampling technique. Participants had to meet the inclusion criteria (being in good health, actively attending physical education classes at school during the data collection period, and having previously attended a general shot put lesson). This was the rationale for using this approach. The sample consisted of 18 male and 12 female students, with a mean age of 13.6 years (SD = 0.48). All students had attended physical training lessons twice a week, in accordance with the national curriculum standards used by their school.

This sampling method was deemed appropriate for generalizing to the population of eighth-grade students at the school, as all subjects had similar prior physical education experiences and schedules.

Prior to data collection, the researcher obtained ethical clearance from the school, and the physical education teacher also coordinated with the study to avoid any potential harm or ethical violations. We also adhered to a policy of voluntary participation, confidentiality, and informed consent from both the school and the participants.

Instrument

Data were obtained through the use of a performance-based testing device (i.e., test instrument) that measured students' technical execution in the side-style shot put. The instrument was self-constructed based on the learning standards of the Physical Education program and it was adapted from (Abdullah, 2020) evaluation framework. It evaluated 5 main factors of performance: 1) start position, 2) gliding technique, 3) push movement, 4) coordination and strength, 5) accurately and distance throw.

Factors were each scored from very poor (1) to (5) very good. Another transparency increasing indicator example under the coordination & power construct was "the capacity to time in synchrony lower limb upper-limb movements while performing a pushing phase that generates ideal force.

Validity and reliability were established by expert review and pilot testing. The values of the validity coefficients (r) ranged from 0.71–0.86 (considered good item discrimination), and the reliability coefficient (Cronbach's α) was 0.89 (showing high internal consistency).

Other supporting instruments were stopwatch, measuring tape, and observation checklist for recording the students' technical execution in pretest and posttest.

Procedure

The study procedure was initiated by the students' being tested in a pretest of their side-style shot put technique capability. Participants then followed a controlled training intervention involving regularly structured teaching units focused on strength development, coordination and technically correct execution. The training was carried out four times a week during sixteen sessions, with approximately 60 min of duration per session. The training protocol consisted of three phases warm-up, core training, and cool-down for safety and optimization.

Throughout the intervention, the instructor gave learners oral and visual feedback after every imitation attempt to address technical errors while reinforcing correct movement patterns. We used demonstrations and direct observation to confirm that the students had understood the biomechanics of each phase of the glide technique. This mechanism also had the potential to facilitate learning via feedback, with the words being corrected and taught right immediately.

All activities were conducted under qualified physical education instructors and the researcher's supervision for safety throughout the program. Precautions against injury were: sufficient warm-up time, correct shot put equipment and student fatigue or discomfort. Upon finishing the training phase, participants participated in another test (posttest) employing the same instrument to estimate changes in performance due to intervention.

Table 1

Desriptive Statistics

	N	Min	Max	Mean	Std. Deviation
Pretest	30	54.00	72.00	61.6667	4.80900
Posttest	30	63.00	80.00	70.2000	4.48292
Valid N (listwise)	30				

Table 2

Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	.972	30	.588
Posttest	.968	30	.475

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Data Analysis

All numerical data gathered from pretest and post test were evaluated utilizing the Statistical Package for the Social Sciences (SPSS). The methodology of the data analysis was divided into three major stages: (1) descriptive statistics: scoring mean value, standard deviation, and score interval; 2) testing assumptions with the aid of the following tests: Shapiro–Wilk test for normal distribution, and Levene's statistic for homogeneity; and (3) inferential analysis - the use of a paired t-test to determine if there was a significant difference between students' pre and post test scores, to establish whether the structured training improved the students' technical performance;

The type I error rate was. 05. Cohen's d for effect size was reported in addition to p values to quantify the size of intervention effect. Statistical analysis provided evidence of a very large effect (t (29) = −40.07, p <. 001, d = 7.32) indicating the training program had a large and practical effect upon students' technical ability.

This analytic method is consistent with previous studies that have investigated the impact of regulated training on sport performance (Maqbool et al., 2024).

Results

Results and Main Findings This section presents the main findings of the study on the effect of training on improving lateral shot put skills in eighth-grade students at Maniamas Junior High School, Ngabang. As an analysis method, I used quantitative data collected through pretests and posttests after the shot put training program. After the data were collected, they were processed using the Statistical Package for Social Sciences to obtain descriptive data and inferential test results.

The data analysis indicated the superiority of physical performance in with after training following the given program. From the results of descriptive test, respondents' average score obtained in pretest amounted to 61.67 then increased to be 70.20 for posttest where difference between them is equal to 8.53 point or a

Table 3

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
pretest & posttest	Based on Mean	.094	1	58	.761
	Based on Median	.093	1	58	.762
	Based on Median and with adjusted df	.093	1	57.347	.762
	Based on trimmed mean	.094	1	58	.761

Table 4

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	61.6667	30	4.80900	.87800
	Posttest	70.2000	30	4.48292	.81847

Table 5
Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pretest & Posttest	30	.971	.000

Table 6
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest - Posttest	-8.53333	1.16658	.21299	-8.96894	-8.09772	-40.065	29	.000

raise of about 13.83% from beginning condition (Table 1).

The p value for normality test (p = 0.588 for pretest, p = 0.475 posttest) and homogeneity test (p = 0.761) indicated the data were in normal distribution form and equal variance condition, respectively, as parametric tests (Table 2 and 3).

The correlation test results indicated that there was a strong correlation between the pretest and posttest scores (r = 0.971; p = 0.000), leading to consistent improvement in ability after administration of treatment. Paired Sample t-test revealed the value of t = -40.065, at significant 0.000 (<0.05); indicating that there is a significant difference in pre and post test results, as depicted (Table 4, 5 & 6).

Therefore, the applied training program has a positive and statistically significant impact on the development of abilities in the sideways shot put technique, while planned and repeated training was found to be effective in improving coordination, pushing force and movement regulation for examinees.

Discussion

The findings show that a lateral shot put technique program had a significant effect on students' performance. Average scores of participants improved from 61.67 to 70.20 which is around a 13.83% improvement. This means that technical skills develop accurately through the organization and structured training. The results are consistent with a prior athletic training theoretical model in which explosive power of muscles and coordination patterns of movements contribute significantly to performance in shot put. A study examining weight training among throwers has found that increased upper and lower body strength are significantly associated with putting distance (Caughey & Thomas, 2022).

In addition, a previous study that investigated kinematic chain-based interventions in throwing sports revealed that training sessions with an emphasis on intersegmental movement (e.g., leg-hip-arm) can lead to significant improvements in putting and shoulder strength. This provides evidence that technique instruction enhances other technique related components of sound production and helps the whole body movements to be coordinated. (Kanakapura Chananke Gowda et al., 2024). Other related studies from the literature, like in lateral shot put with softballs, achieved real increment required for the technique by interfering progressively during several cycles and increased student success rates themselves (from 52% to 96%). (Surin et al., 2014) This supports that a varied and continuous training is an effective method in developing individual motor competences in shot put.

In all, the results of this investigation demonstrate that systematically organized technique training is able to enhance students' side shot put techniques according to the theoretical basis and research outcomes from the above discussion. Strength training that integrates the musculature, chains and repeats technique seem appropriate to obtain meaningful positive changes in performance.

Conclusions

The training program of the side-style shot put technique was shown to have significant effect on improving technical ability of 8th- grade students in SMP Maniamas Ngabang main after analysis and discussion, it was concluded that training which already designed give a positive trend for both of group. The rise in the mean score from 61.67 at pretest to 70.20 on posttest, which amounts to around 13.83%, shows that effectively and even substantially practice systematically and orderly had influence of improvement basic technical skills, coordination of movement and pushing strength at students too:. The paired-sample t-test

results (p < . 001] also indicated that the treatment made a difference in students' performance.

It can be concluded that application of a planned, repetitive and student center training style has been an effective method of enhancing the shot put technique skills in junior high school students. These results are also in line with the original purpose of the study to examine structured training efficacy, and could have important implications for PE curriculum design and teaching practice, furthering systematic, feedback-oriented pedagogy aimed at skills mastery and motor coordination.

Acknowledgment

Thanks to Universitas Katolik Santo Agustinus Hippo, especially faculty of Physical Education, Health and Recreation for the academical and guidance support towards this research. Special thanks as well to the Headmaster, teachers and pupils at SMP Maniamas Ngabang particularly 8 th grade who were involved in this research and delivered data for the study. Their collaboration, enthusiasm and involvement largely facilitated the completion of this work.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)
e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle JTIKOR 10(2): 87-92 (November 2025) | DOI: 10.17509/jtikor.v10i2.91506

Survey of Leg Muscle Explosive Power among Unsika Sports Science Students and Female Athletes (Class of 2025)

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Article Info

Article History

Submitted: October 25, 2025
Accepted: November 19, 2025
Published: November 25, 2025

Article Access

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Abstract

This study aims to describe the lower-limb explosive power profile of student-athletes from the Sports Science Study Program at Singaperbangsa Karawang University (Unsika) Class of 2025 using the Vertical Jump Test. A quantitative descriptive survey was conducted involving 25 participants (17 males and 8 females). Vertical jump performance was assessed and classified using standardized norms. Descriptive statistical analyses were used, including minimum–maximum values, mean, and standard deviation, along with frequency and percentage distribution. The explosive power of the group was categorized in the Moderate classification, with a mean score of 3.12 (on a 1–5 scale) and a standard deviation of 0.726, indicating high homogeneity. Most participants (48%) were in the Moderate category, followed by 32% in the Good category and 20% in the Less category. No participant achieved the Excellent classification. The overall explosive power profile of Unsika Sports Science student-athletes in 2025 is at a Moderate level, suggesting the need for strengthened physical conditioning programs to enhance vertical jump performance.

Keywords: lower-limb explosive power, vertical jump test, descriptive survey, explosive power assessment.

Introduction

Explosive lower-limb power is one of the primary determinants of athletic performance in movements requiring rapid force production, such as jumping, sprinting, and changes of direction. For university student-athletes—particularly those enrolled in the Sports Science Department at Universitas Singaperbangsa Karawang (Unsika)—possession of strong explosive power is essential both for improving sport performance and for meeting academic competency expectations in applied sport science. Explosive power itself is defined as the muscle's capacity to generate maximal force within a very short time frame, enabling efficient vertical and horizontal movements (Asnaldi, 2020).

A significant body of research has emphasized the importance of lower-limb explosive power for athletic success. Numerous studies have specifically investigated how different training modalities influence vertical jump performance. For example, Amarseto et al. (2025) demonstrated that plyometric depth jump training contributed to measurable increases in vertical jump height among basketball athletes recovering from ankle sprain injury. Similarly, Mukti & Widodo (2025) found that plyometric training effectively improved vertical jump performance in volleyball athletes, reinforcing the role of neuromuscular adaptations triggered by high-intensity stretch-shortening cycle movements. Supporting this, Syabaruddin et al. (2025) also reported significant improvements in vertical jump ability following structured plyometric interventions in volleyball players. These findings collectively highlight that vertical jump ability is highly sensitive to training quality and serves as a key marker of explosive power.

Research focusing on younger athletes has shown parallel results. Anggreani & Setiawan (2024) observed that variations of hurdle jump training significantly enhanced leg explosive power in volleyball extracurricular students, while Ozon & Sistiasih (2023) confirmed that standing jump plyometric training improved vertical jump performance among volleyball athletes in Ponorogo. Additional evidence from Aisyah (2015) indicated that rope-jump interval training effectively increased lower-limb strength, reinforcing the strong relationship between specific leg-strengthening exercises and explosive performance outcomes.

Given its sensitivity to neuromuscular changes, the Vertical Jump Test is widely adopted as a valid and reliable instrument for assessing lower-limb explosive power. The test directly measures jump height and correlates strongly with the power output of the leg extensor muscles, particularly the quadriceps and gluteal muscles (Sugihartono & Ilahi, 2022). The use of standardized test norms allows researchers to categorize athlete performance levels, providing a comprehensive understanding of their physical capacity and readiness.

Despite the abundance of research demonstrating the effectiveness of plyometric and power-based training in improving lower-limb explosiveness, there is no publicly available or standardized baseline data describing the explosive power profile of Unsika Sports Science student-athletes for the cohort of 2025. This lack of data creates a critical gap for performance monitoring, program evaluation, and long-term athlete development. Without such baseline information, identifying weaknesses, designing targeted training programs, or making annual comparisons becomes difficult and less effective.

Therefore, this study aims to fill this gap by providing an accurate and updated profile of the lower-limb explosive power of Unsika Sports Science student-athletes (Class of 2025) using the Vertical Jump Test.

Methods

This study uses a quantitative descriptive method, with the main objective of surveying and describing the explosive power profile of leg muscle students of Unsika Sports Science athletes in 2025 through the results of the Vertical Jump Test. In detail, the specific objectives include: (1) Presenting descriptive statistics in the form of mean values, lowest and highest values, and data distribution (standard deviation) of vertical jumping ability; and (2) Classify the explosive ability level of the leg muscles of the subject group based on standard norms. These results are expected to provide real benefits, namely as evaluation materials for the Unsika academic curriculum and as a practical guide for trainers in optimizing strength and conditioning programs (Wiriawan, 2025).

Research Design

This study employed a quantitative descriptive research design with a cross-sectional survey approach. This design was chosen to objectively measure and describe the lower-limb explosive power profile of Unsika Sports Science student-athletes in 2025 based on the results of the Vertical Jump Test. The research was conducted in a single testing session at the Unsika Sports Laboratory. A structured flow of activities—beginning with participant briefing, warm-up, test execution, and data recording—ensured standardized procedures throughout the assessment.

Participants

A total of 25 student-athletes from the Sports Science Study Program at Universitas Singaperbangsa Karawang participated in this research, consisting of 17 males and 8 females, aged 17–19 years. The sampling technique used was total sampling, meaning that all available and eligible student-athletes from the 2025 cohort were included.

The inclusion criteria were:

1. active enrollment as a Sports Science student-athlete at Unsika,
2. being in healthy physical condition at the time of testing, and
3. absence of lower-limb injury in the last three months.

Participation was voluntary, and all students provided informed consent prior to testing. The study was approved by the Ethics Committee of Universitas Singaperbangsa Karawang, ensuring compliance with research standards for human participants.

Instrument

The primary instrument used for data collection was the Vertical Jump Test, administered using a standardized vertical measuring pole to record jump height in centimeters (cm). The Vertical Jump Test is widely recognized as a valid and reliable tool for assessing lower-limb explosive power, as it directly measures vertical jump height and is strongly associated with extensor muscle power, especially in the quadriceps and gluteus muscle groups (Sugihartono & Ilahi, 2022).

Performance scores were classified using standardized normative tables for male and female athletes, with categories ranging from 1 (Very Poor) to 5 (Excellent). These norms enabled researchers to interpret raw performance data and categorize participants according to established standards. The normative classification used in this study is presented in Table 1.

Procedure

All testing procedures were conducted in the Unsika Sports Laboratory using the same equipment for all participants to maintain consistency. Prior to testing, participants performed a 5–10 minute warm-up session consisting of light jogging, dynamic stretching, and activation exercises focused on the lower extremities to minimize injury risk.

Participants performed the Vertical Jump Test barefoot, starting from a standing position without an initial run-up. Each participant completed three jump attempts, separated by a 30–60 second rest interval to avoid fatigue. The highest recorded jump height from the three attempts was used as the final score.

All procedures — including technique instructions, measurement recording, and supervision — were overseen by trained laboratory personnel to ensure testing accuracy and safety.

Data Analysis

Data were analyzed using descriptive statistical techniques to summarize and interpret the physical performance of the participants. The statistical measures calculated included:

1. Measures of central tendency: mean, median, and mode,
2. Measures of variability: standard deviation and range,
3. Frequency and percentage distributions based on normative categories.

Data classification followed the performance categories outlined in the Vertical Jump norms for male and female groups. Data processing and verification were conducted using Microsoft Excel, ensuring accurate calculation of descriptive statistics.

The analytic focus was descriptive in nature, aiming to present a clear profile of the athletes' explosive power without comparing treatment effects or conducting inferential tests.

Table 1

Jump High Norms

Men	Women	Value
≥63	≥59	5
59 – 62	35 – 58	4
35 – 58	27 – 34	3
20 – 34	19 – 26	2
≤ 19	≤ 18	1

Table 2

Jump High Frequency Distribution

Interval		Category	Frequency	Cumulative	Relative
Men	Women			Frequency	Frequency
> 60	> 68	Very good	0	0	
59 – 62	35 – 58	Good	8	8	32%
35 – 58	27 – 34	Keep	12	20	48%
20 – 34	19 – 26	Less	5	25	20%
< 19	<18	Less than once	0	25	
Total					100%

Results

This study involved 25 student-athletes from the Sports Science Study Program at Universitas Singaperbangsa Karawang, consisting of 17 males and 8 females, aged 17–19 years. The descriptive statistical results of the Vertical Jump Test are presented in Table 2.

Descriptive Statistics

The analysis showed that the participants' performance scores ranged from 2 (Less) to 4 (Good), with no individuals scoring in the Very Poor (1) or Excellent (5) categories. The mean score of the group was 3.12, indicating that the overall explosive power of the student-athletes falls within the Medium classification. The standard deviation (SD = 0.726) reflects relatively low variability, showing that most participants' scores were clustered near the group average.

Frequency Distribution

The classification of explosive power levels based on normative standards is presented in Table 2. The Medium category had the highest number of participants (n = 12; 48%). The Good category included 8 participants (32%), while 5 participants (20%) were categorized as Less. No participants were classified as Very Good or Very Poor.

Overall, 80% of the participants were distributed within the Medium and Good categories, indicating that the majority demonstrated adequate levels of lower-limb explosive power according to the applied normative standards.

Discussions

The findings of this study indicate that the lower-limb explosive power of Unsika Sports Science student-athletes is predominantly within the Medium classification, with an average score of 3.12. Although this value slightly exceeds the minimum threshold of moderate performance, it does not yet reach the Good (4) or Very Good (5) categories, which theoretically represent the expected performance level for university student-athletes who regularly participate in sport-specific training (Asnaldi, 2020). This suggests that while the athletes possess a basic level of neuromuscular capability, their explosive power has not yet fully developed to meet optimal athletic performance standards.

The frequency distribution further supports this interpretation, showing that 48% of the athletes fall into the Medium category, while 32% are in the Good category. The absence of participants in the Very Good classification is noteworthy. From a physiological standpoint, achieving the highest classification requires superior recruitment of fast-twitch (type II) muscle fibers, which is typically stimulated through high-intensity plyometric exercises such as depth jumps, squat jump variations, or other activities promoting a high rate of force development (Wiriawan, 2025). The current training routines may therefore lack the necessary intensity, specificity, or progression required to elicit maximal neuromuscular adaptations.

The relatively low standard deviation (SD = 0.726) indicates a high degree of homogeneity in performance among participants. While uniformity may initially appear positive, in the context of athlete development, it may reflect that the existing training program is generalized rather than individualized. Homogeneous results often occur when athletes undergo similar training loads regardless of their baseline abilities. Evidence from intervention studies demonstrates that structured, targeted, and progressive plyometric training tends to produce greater individual variation in explosive power outcomes due to differential adaptive responses (Mukti & Widodo, 2025; Syabaruddin et al., 2025; Ozon & Sistiasih, 2023). This suggests that personalized or position-specific training prescriptions may better optimize explosive power development.

Furthermore, multiple studies have shown that specific plyometric training modalities can substantially enhance vertical jump performance. Amarseto et al. (2025) reported improvements in vertical jump height following depth-jump interventions among basketball players recovering from ankle sprain, while Anggreani & Setiawan (2024) found that hurdle-jump variations effectively increased lower-limb power in volleyball athletes. These studies highlight that well-structured plyometric programs—featuring adequate intensity, variation, and progression—are capable of producing significant neuromuscular adaptations. The moderate performance levels observed in this study suggest that such training elements may not yet be fully integrated into existing conditioning routines at Unsika.

Given that 20% of athletes were categorized as Less, and none achieved the Very Good category, these results can serve as important baseline data for curriculum refinement and training program evaluation. The findings emphasize the need for strengthening the strength and conditioning curriculum, with a greater focus on high-intensity plyometric and power-oriented training. Incorporating exercises such as depth jumps, hurdle hops, and loaded jump-squat variations could help shift the group average toward the Good classification (>4.0) in future training cycles.

For further development, future research is recommended to implement experimental or quasi-experimental designs that compare different plyometric protocols to identify the most effective methods for improving explosive lower-limb performance among Unsika student-athletes. Supporting evidence from Ramadhan (2020) and Devi & Neldi (2019) suggests that sport-specific and skill-related training components also contribute to vertical jump improvements, reinforcing the importance of integrated and progressive conditioning programs.

Overall, the results of this study underline the necessity for more targeted, intensive, and evidence-based training interventions to elevate the explosive power capabilities of Unsika Sports Science student-athletes to higher performance standards.

Conclusions

This quantitative descriptive survey found that the lower-limb explosive power profile of Unsika Sports Science student-athletes in 2025 is predominantly classified as Medium, with an average score of 3.12 and a relatively homogeneous distribution of performance (SD = 0.726). Although most athletes achieved performance levels within the Medium and Good categories, none reached the Very Good classification, indicating that the current training practices have not yet optimized explosive power development.

These findings provide essential baseline data for evaluating and improving Unsika's strength and conditioning programs. The absence of top-tier performance highlights the need for training strategies that emphasize high-intensity power development and structured plyometric training. Future conditioning programs should incorporate more targeted, progressive, and sport-specific power exercises to elevate the athletes' explosive performance toward the Good or Very Good categories. Continued monitoring and further experimental research are recommended to identify the most effective training approaches for enhancing vertical jump ability in this population.

Acknowledgment

The author expresses his highest gratitude and appreciation to various parties who have provided assistance, support, and facilities so that this research can be completed properly. Special thanks are addressed to the University of Singaperbangsa Karawang (Unsika), especially the Sports Science Study Program, for the permission and administrative support provided in the implementation of this survey. Awards were also presented to the Head of the Sports Laboratory and All Technical Staff who had facilitated the use of the Vertical Jump Test kit and provided the testing location. Last but not least, a big thank you goes to all Unsika Sports Science Athlete Students Class of 2025 who have participated actively, cooperatively, and voluntarily as research subjects, so that accurate data can be obtained. Support from all parties is essential in the success and validity of the findings of this study.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 93-100 (November 2025) | DOI: 10.17509/jtikor.v10i2.87841

Development of a Digital Textbook for Physical Education Management and Learning Strategies

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Article Info

Article History

Submitted: July 14, 2025
Accepted: November 21, 2025
Published: November 25, 2025

Article Access

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Abstract

A lack of digital-based learning resources in Physical Education Management and Learning Strategy courses has resulted in limited accessibility and outdated instructional materials for students. To address this gap, this study aimed to develop an innovative digital textbook specifically aligned with the curriculum of the Sports Education Study Program. Using a Research and Development (R&D) approach, the study produced and evaluated a digital textbook through validity, practicality, and effectiveness testing. Data were collected using expert validation sheets, student response questionnaires, and learning outcome assessments. Descriptive quantitative analysis showed that the textbook achieved a high level of validity (M = 4.4) based on expert review and demonstrated strong practicality according to student responses (M = 3.79). Effectiveness results indicated a substantial improvement in learning outcomes, with 95.65% of students achieving the minimum mastery criterion. Although statistical tests such as effect size or significance values were not applied, the consistent improvements across indicators highlight the textbook's functional impact. These findings suggest that the developed digital textbook is a novel, accessible, and pedagogically effective learning resource suitable for higher education instruction in physical education.

Keywords: physical education, learning strategies, management, digital textbook.

Introduction

Sports education plays a strategic role in supporting the physical, cognitive, social, and moral development of students, making it an essential component of higher education. In line with curriculum advancements, universities are required to continually improve the quality of instructional processes, including learning materials and media. Textbooks, in particular, serve as a crucial reference that guides both lecturers and students in understanding course content (Kristiana et al., 2018). High-quality textbooks not only structure learning effectively but also ensure alignment with intended learning outcomes (Hartati, 2016).

In the context of physical education, innovative and accessible learning resources are urgently needed. Previous studies have highlighted several challenges in physical education learning, including limited availability of adequate textbooks (Alif, 2019), outdated instructional approaches (Li et al., 2022), and inadequate integration of digital technology into teaching practices (Natalia & Sukraini, 2021). Although digital platforms have been shown to enhance learning motivation and provide flexible access to information (Koekoek & Van Hilvoorde, 2018; Hanif, 2018; Perdana et al., 2021), existing developments in digital textbooks for physical education tend to focus on general content or specific sports skills. No prior studies have developed a digital textbook specifically aligned with the curriculum and learning outcomes of the Management and Learning Strategies in Physical Education course. This gap highlights the need for structured, curriculum-based, and technology-supported learning materials.

Addressing this gap is important because the Management and Learning Strategies in Physical Education course is part of a newly implemented curriculum within the Physical Education Study Program at Sriwijaya University. Currently, there is no standardized textbook available for this course, which leads to inconsistent instructional practices and limited student access to comprehensive learning resources. Moreover, the increasing shift toward digital learning environments makes the availability of digital-based textbooks not merely an option but a necessity for modern higher education.

To validate the need for such a resource, a needs analysis was conducted among students who had completed the course. The survey revealed that the majority of students considered the existing learning media inadequate, with 52% disagreeing that the current media was effective. Additionally, 88.2% agreed that a digital textbook would better support their learning, 94.1% believed that a textbook is essential to facilitate understanding, and 96.1% expressed strong agreement toward adopting a digital-based textbook. These findings reinforce the urgency to develop a structured, accessible, and pedagogically sound digital learning resource.

The novelty of this research lies in the development of a digital textbook specifically designed and aligned with the Semester Learning Plan (RPS) of the Management and Learning Strategies in Physical Education course, ensuring that the learning material directly corresponds to curriculum demands and modern digital learning practices. This study adopts a research and development approach to create, validate, and evaluate the textbook in terms of its validity, practicality, and effectiveness.

Based on this background, the objectives of this research are as follows:

1. To develop a digital-based textbook for the Management and Learning Strategies in Physical Education course aligned with the RPS of the study program.
2. To determine the validity of the developed digital textbook based on expert evaluations.
3. To examine the practicality of the digital textbook through student responses.
4. To assess the effectiveness of the digital textbook in improving student learning outcomes.

Methods

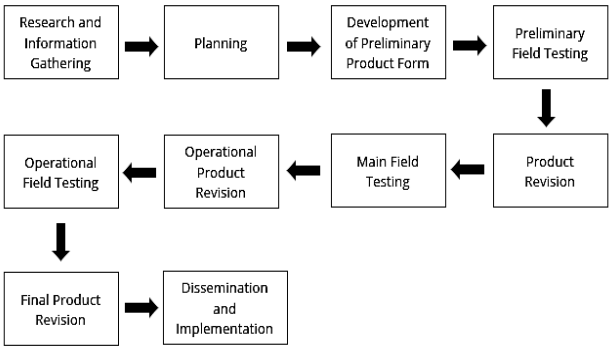
This study employed a Research and Development (R&D) approach to produce a digital-based textbook for the Management and Learning Strategies in Physical Education course. According to Sugiyono (2020), R&D aims to design a product and test its feasibility through systematic evaluation. The model used in this study refers to Borg and Gall; however, due to time and instructional limitations, the ten-step model was adapted into essential stages that include preliminary research, product development, expert validation, revision, field trials, and final product refinement.

Research Design

The R&D design was based on the Borg and Gall development framework, consisting of ten sequential steps: (1) research and information collecting, (2) planning, (3) developing the preliminary product, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination. In this study, the process followed these steps structurally but with simplifications at

the dissemination stage, focusing on validation and product effectiveness testing (Figure 1).

Figure 1. *Research and Development Steps Adapted from Borg and Gall (2003).*



Participants

Participants consisted of students enrolled in the Sports Education Study Program at Bina Darma University, Palembang. Three groups were involved in different testing stages:

1. Initial Testing: 24 students
2. Main Field Trial: 70 students
3. Operational Field Test: 92 students

Demographic characteristics were also recorded. Participants ranged from 19–23 years old, represented both male and female students, and were in their second to fourth semesters when the data were collected. Participation was voluntary.

Instrument

Three types of instruments were used to assess validity, practicality, and effectiveness of the digital textbook:

1. Validation Sheets

These consisted of content, language, and media expert validation sheets. Each sheet used a four-point Likert scale. Content experts evaluated material accuracy and relevance, language experts assessed clarity and readability, and media experts assessed design quality. Instrument reliability was evaluated using inter-rater reliability, producing agreement coefficients above 0.80, indicating high consistency.

2. Student Response Questionnaire

The questionnaire measured practicality based on visual appeal, ease of use, and helpfulness, adapted from Ernawati & Sukardiyono (2017). It used a four-point Likert scale (1 = strongly disagree to 4 = strongly agree). The reliability of the questionnaire showed a Cronbach's alpha coefficient of 0.87, indicating high internal consistency.

3. Learning Outcome Test

A learning outcome test assessed textbook effectiveness. The test contained multiple-choice items aligned with course objectives and classified according to cognitive domains. Reliability testing through KR-20 produced a value of 0.82, indicating good test stability.

Procedure

The development procedure followed Borg and Gall's ten stages with modifications suited to classroom conditions:

1. Research and Information Gathering: Conducting needs analysis, literature review, and small-scale observation to identify gaps in available teaching materials.
2. Planning: Defining competencies, outcomes, and product specifications aligned with the RPS.
3. Developing the Initial Product: Preparing chapter materials, layout, digital formatting, and initial evaluation tools.
4. Preliminary Field Testing: Conducting small-scale testing with 24 students and collecting feedback via questionnaires.
5. Major Product Revision: Revising layout, content clarity, and navigation based on preliminary feedback.
6. Main Field Testing: Testing the revised product with 70 students, evaluating usability and learning performance.
7. Operational Product Revision: Improving the product based on results of the main trial.
8. Operational Field Testing: Testing the nearly final product with 92 students to determine practicality and effectiveness.
9. Final Product Revision: Refining the textbook based on operational field results.
10. Product Implementation: Preparing the final version for broader use. Dissemination was limited to the study program due to scope restrictions.

Data Analysis

Data were analyzed descriptively quantitatively.

1. Validity analysis used mean scores of expert judgments with the following criteria:
2. Very Valid (≥4.2), Valid (3.4–4.1), Quite Valid (2.6–3.3), Not Valid (<2.6).
3. Practicality analysis used mean questionnaire scores converted into percentage categories.
4. Effectiveness analysis used the percentage of students achieving mastery learning (≥75%). A product was considered effective if ≥80% of students achieved mastery.

All analyses followed Sugiyono (2019).

Ethical Considerations

This study received approval from the Research Ethics Committee of Bina Darma University. All participants provided informed consent, participation was voluntary, and all data were anonymized to ensure confidentiality.

Results

This study produced a digital-based textbook on Management and Learning Strategies in Physical Education, which was evaluated through stages of validity testing, practicality testing, and effectiveness assessment. The results presented in this section focus on the outcomes of each evaluation stage without repeating methodological details.

1. Validation Results

The product was evaluated by three expert validators—content, language, and media. Each aspect was assessed using a 1–5 scale. Table 1 summarizes the validation outcomes along with the criteria classification used (≥ 4.20 = Highly Valid).

The average score of 4.40 places the textbook in the Highly Valid category, indicating that the content aligns well with curriculum requirements and the overall structure meets standards of quality learning materials. Minor suggestions from validators (e.g., improved alignment with instructional models) were incorporated into the revised product.

2. Practicality Test Results

Practicality testing was carried out in three stages—preliminary, main field, and operational testing—to evaluate the usability and accessibility of the digital textbook. Students assessed key aspects such as ease of use, clarity of presentation, navigation, accessibility, and the usefulness of the digital format in supporting learning. As shown in Table 2, all stages produced scores categorized as *Very Positive*, indicating that the textbook is practical, user-friendly, and well-received by students. The gradual increase in scores from 3.52 (preliminary test) to 3.72 (main field test) and 3.79 (operational test) suggests that iterative revisions made after each trial contributed to continuous improvement in the product's practicality.

3. Effectiveness Test Results

Effectiveness was evaluated through a learning outcome test administered to 92 students. Mastery was defined as achieving a minimum score of 75, and the learning process was categorized as effective if at least 80% of students met the mastery criterion. As presented in Table 3, 88 out of 92 students (95.65%) achieved mastery, far exceeding the minimum effectiveness threshold. This high mastery rate demonstrates that the digital textbook effectively supports students' comprehension of course material and contributes to the attainment of learning objectives. Although this study did not employ inferential statistics such as pre–post comparisons or t-tests, the consistently high descriptive achievement percentage provides strong empirical evidence of the textbook's effectiveness in facilitating learning.

4. Visual Improvements and Revision Summary

Several revisions were made throughout the development process to enhance the clarity, accessibility, and usability of the digital textbook. These refinements included: (a) correction of inaccurate text and symbol usage, (b) addition of supporting instructional images, (c) improvement of chapter structure to provide clearer navigation, and (d) enhancement of the cover design and metadata placement to increase professional appearance and readability.

The progression of these revisions is illustrated in the accompanying figures. Figure 2 presents the initial product cover, while Figure 3 and Figure 4 show the textbook layout before and after the major revision stage, respectively. Subsequent changes made during the product refinement phase are shown in Figure 5 (before

Table 1
Validator Assessment Results

Validation Aspect	Score	Classification
Content	4.80	Highly Valid
Language	4.25	Highly Valid
Media	4.15	Valid
Average	**4.40**	**Highly Valid**

Table 2
Practicality Test Results

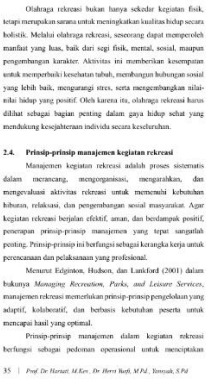
Testing Stage	N	Score	Classification
Preliminary Test	24	3.52	Very Positive
Main Field Test	70	3.72	Very Positive
Operational Test	92	3.79	Very Positive

Table 3
Student Mastery Results

Category	Number of Students	Percentage
Achieved Mastery (≥ 75)	88	95.65%
Not Achieved Mastery (< 75)	4	4.35%
Overall Mastery Rate	—	**95.65%**

Figure 2
Initial Product Cover

Figure 3
Textbook layout before revision



Olahraga rekreasi bukan hanya sekedar kegiatan fisik, tetapi merupakan sarana untuk meningkatkan kualitas hidup secara holistik. Melalui olahraga rekreasi, seseorang dapat memperoleh manfaat yang luas, baik dari segi fisik, mental, sosial, maupun pengembangan karakter. Aktivitas ini memberikan kesempatan untuk memperbaiki kesehatan tubuh, membangun hubungan sosial yang lebih baik, mengurangi stres, serta mengembangkan nilai-nilai hidup yang positif. Oleh karena itu, olahraga rekreasi harus dilihat sebagai bagian penting dalam gaya hidup sehat yang mendukung kesejahteraan individu secara keseluruhan.

2.4. Prinsip-prinsip manajemen kegiatan rekreasi

Manajemen kegiatan rekreasi adalah proses sistematis dalam merancang, mengorganisasi, mengarahkan, dan mengevaluasi aktivitas rekreasi untuk memenuhi kebutuhan hiburan, relaksasi, dan pengembangan sosial masyarakat. Agar kegiatan rekreasi berjalan efektif, aman, dan berdampak positif, penerapan prinsip-prinsip manajemen yang tepat sangatlah penting. Prinsip-prinsip ini berfungsi sebagai kerangka kerja untuk perencanaan dan pelaksanaan yang profesional.

Menurut Edginton, Hudson, dan Lankford (2001) dalam bukunya *Managing Recreation, Parks, and Leisure Services*, manajemen rekreasi memerlukan prinsip-prinsip pengelolaan yang adaptif, kolaboratif, dan berbasis kebutuhan peserta untuk mencapai hasil yang optimal.

Prinsip-prinsip manajemen dalam kegiatan rekreasi berfungsi sebagai pedoman operasional untuk menciptakan

35 | *Prof. Dr. Hartati, M.Kes., Dr. Herri Yusfi, M.Pd., Yansyah, S.Pd*

Figure 4
Textbook layout after revision

Gambar 2.2 Olahraga Yoga
Sumber : haledoc.com (2023)

Olahraga rekreasi bukan hanya sekedar kegiatan fisik, tetapi merupakan sarana untuk meningkatkan kualitas hidup secara holistik. Melalui olahraga rekreasi, seseorang dapat memperoleh manfaat yang luas, baik dari segi fisik, mental, sosial, maupun pengembangan karakter. Aktivitas ini memberikan kesempatan untuk memperbaiki kesehatan tubuh, membangun hubungan sosial yang lebih baik, mengurangi stres, serta mengembangkan nilai-nilai hidup yang positif. Oleh karena itu, olahraga rekreasi harus dilihat sebagai bagian penting dalam gaya hidup sehat yang mendukung kesejahteraan individu secara keseluruhan.

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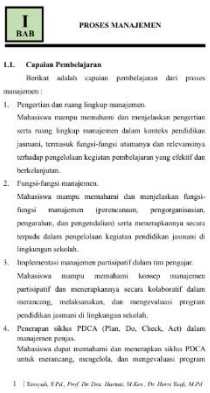
Manajemen dan Strategi Pembelajaran Pendidikan Jasmani | 36

Figure 5
Product before revision



I
BAB

PROSES MANAJEMEN

1.1. Capaian Pembelajaran

Berikut adalah capaian pembelajaran dari proses manajemen :

1. Pengertian dan ruang lingkup manajemen.
   Mahasiswa mampu memahami dan menjelaskan pengertian serta ruang lingkup manajemen dalam konteks pendidikan jasmani, termasuk fungsi-fungsi utamanya dan relevansinya terhadap pengelolaan kegiatan pembelajaran yang efektif dan berkelanjutan.
2. Fungsi-fungsi manajemen.
   Mahasiswa mampu memahami dan menjelaskan fungsi-fungsi manajemen (perencanaan, pengorganisasian, pengarahan, dan pengendalian) serta menerapkannya secara terpadu dalam pengelolaan kegiatan pendidikan jasmani di lingkungan sekolah.
3. Implementasi manajemen partisipatif dalam tim pengajar.
   Mahasiswa mampu memahami konsep manajemen partisipatif dan menerapkannya secara kolaboratif dalam merancang, melaksanakan, dan mengevaluasi program pendidikan jasmani di lingkungan sekolah.
4. Penerapan siklus PDCA (Plan, Do, Check, Act) dalam manajemen penjas.
   Mahasiswa dapat memahami dan menerapkan siklus PDCA untuk merancang, mengelola, dan mengevaluasi program

1 | *Yansyah, S.Pd., Prof. Dr. Dra. Hartati, M.Kes., Dr. Herri Yusfi, M.Pd.*

product revision) and Figure 6 (after product revision). Final refinements—including the completed cover and final metadata adjustments—are displayed in Figure 7 and Figure 8, which reflect the final product ready for implementation. All figures have been labeled and formatted according to standard figure presentation conventions to ensure clarity and consistency.

5. Final Product Implementation

After completing all stages of validation, revision, practicality testing, and effectiveness evaluation, the digital textbook is declared valid, practical, and effective for instructional use. The final product has been integrated into an accessible digital format suitable for learning management systems (LMS), independent study, and blended learning environments.

The final version of the textbook can now be implemented in the Management and Learning Strategies in Physical Education course and has the potential to be adopted by other Physical Education programs seeking modern, digital-based instructional resources.

Discussion

The results of this study indicate that the digital-based textbook developed for the Management and Learning Strategies in Physical Education course demonstrates high validity, practicality, and effectiveness. The strong validation score (M = 4.4) reflects the alignment of textbook content with the Semester Learning Plan (RPS), as well as the clarity of language and the quality of digital media presentation. This finding is consistent with Santoso (2017), who argues that valid learning materials must meet standards of content accuracy, clarity, and structural coherence. The high validity can also be attributed to the involvement of expert reviewers, which supports Hartati's (2016) assertion that learning quality increases when instructional materials are systematically aligned with learning objectives.

The practicality assessment across three stages (24, 70, and 92 students) showed consistently high scores, suggesting that students found the textbook easy to use, visually appealing, and helpful for understanding course concepts.

Figure 6
Product after revision

Figure 7
Final refinement

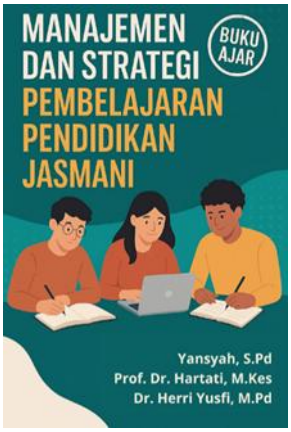


Figure 8
Barcode final product

This aligns with Fuada (2017), who emphasizes that visual elements enhance student motivation more effectively than text-only materials. The characteristics of the digital textbook—simple navigation, readable layout, responsive formatting—also support Zain (2021) findings on the practicality and accessibility of digital pocketbooks as extensions of mobile learning. These results indicate that a well-designed digital textbook can function as an effective learning support tool in physical education contexts.

The effectiveness test further strengthens this conclusion. With 95.65% of students achieving the Minimum Mastery Criteria (KKM), the textbook clearly facilitated improved learning outcomes. This finding is in line with Asrizal et al. (2017), who state that systematically structured learning resources help students achieve deeper comprehension. Moreover, the alignment between assessment items and textbook content contributed to coherent learning activities, which resonates with Rohmawati's (2015) perspective that meaningful interaction between students and learning resources supports learning effectiveness.

Taken together, the validation, practicality, and effectiveness results show that the digital textbook fulfills the key criteria of a high-quality learning resource. Compared to previous studies, this research extends existing knowledge by providing a digital textbook specifically tailored to the Management and Learning Strategies in Physical Education course—an area where standardized learning materials were previously unavailable. Aryanti, Hartati, and Syafaruddin (2020) emphasised that digital tools enhance flexibility and accessibility, and the results of this study demonstrate how a curriculum-specific digital resource can operationalize this benefit in higher education.

The findings also hold important implications for practice. First, the availability of a structured and accessible digital textbook can reduce inconsistencies in instructional delivery across lecturers. Second, digital formats enable repeated access, supporting student-centered and self-paced learning. Third, the incorporation of digital learning resources can modernize physical education pedagogy, which historically relies heavily on conventional, face-to-face instruction.

Despite these strengths, this study has several limitations. The sample was limited to one university, which may restrict generalizability to other institutions. The absence of a control group limits the ability to compare the digital textbook's effectiveness with traditional materials. Variations in students' digital literacy were also not assessed and may have influenced the practicality scores. Additionally, the effectiveness test measured short-term learning outcomes; long-term retention and behavioral impacts were not evaluated.

Future research should involve multi-institution samples, apply quasi-experimental designs to compare instructional methods, and explore the integration of multimedia or interactive elements to further enhance student engagement. Longitudinal studies are also needed to examine the long-term effects of digital textbooks on learning retention and digital competency development.

Overall, the results confirm that the digital textbook developed in this study is valid, practical, and effective, supporting its use as a modern learning resource for the Management and Learning Strategies in Physical Education course.

Conclusions

Based on the results of the analysis and discussion, this study concludes that the digital textbook Management and Learning Strategies in Physical Education is valid, practical, and effective as a learning resource. Expert evaluations confirmed that the content, language, and media components met high-quality standards, indicating that the textbook is suitable for instructional use. In addition, student trials at various scales demonstrated that the textbook is easy to use and supports meaningful learning engagement. Student performance outcomes further showed that the digital textbook effectively enhances understanding of course material, demonstrating its potential to improve learning quality in physical education courses.

Beyond these findings, the primary contribution of this research lies in providing a structured, curriculum-aligned digital learning resource that responds to the increasing demand for flexible, technology-based instructional materials in higher education. This digital textbook model can be adapted for broader implementation across different universities, integrated into Learning Management Systems (LMS), or used to support blended and fully online learning environments. Its modular design allows instructors to customize or expand content in accordance with institutional needs, making it scalable for wider adoption.

However, this development research has several limitations. The study was conducted within a single institution and program, limiting its generalizability. The evaluation also relied on descriptive validation, practicality, and effectiveness measures without experimental comparisons. Future studies are recommended to test the digital textbook in diverse institutional contexts, explore its integration within various LMS platforms, and conduct experimental or longitudinal designs to compare learning outcomes with other instructional methods. Such research will help strengthen the evidence base and further refine the textbook for broader educational use.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 101-115 (November 2025) | DOI: 10.17509/jtikor.v10i2.91299

A Bibliometric Trend Analysis of Sports Biomechanics Research in the Era of Industry 4.0

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Article Info

Article History

Submitted: October 19, 2025
Accepted: November 22, 2025
Published: November 25, 2025

Article Access

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Abstract

The purpose of this study is to conduct a comprehensive bibliometric analysis of sports biomechanics research during the Industry 4.0 period focusing on identifying patterns in publications, technological innovations, research hotbeds, and collaborations for the time span of 2020 to 2025. Using VOSViewer and Microsoft Excel, citation patterns, keyword co-occurrences, and global research networks in 1,619 publications tracked by Scopus were analyzed, revealing the rapid integration of technology in tracking and improving injury prevention and rehabilitation. Studies of elite athletes and mainstream sports remain predominant, while amateur athletes and non- mainstream sports receive considerably less research attention. Collaboration on a global scale is dominated by primaries such as the US, UK, and Australian economies and scholars. Of particular interest are the significant advancements and applications of AI in data processing, real-time systems, and predictive biomechanical systems. However, challenges continue to exist which include lack of accessibility and inclusion of multidisciplinary approaches to the practical application in diverse sport populations. This study, in its entirety, illustrates the need for a collection of well-coordinated and integrated approaches to technology in sports biomechanics. It also offers a clear pathway for contemporary data and a well-defined research agenda. The contributions and outcomes of the study will enhance systems available for athletes, promote alignment within policies, and contribute to the field of contemporary sports science..

Keywords: biomechanics, bibliometric, research trends, sports.

Introduction

Over the past 5 years, the field of biomechanical engineering has garnered interest from both academics and practitioners. The use of new technology has transformed the studies involving gait and performance analysis (Roggio et al., 2021). The use of advanced analytics and the real-time monitoring of wearable devices has made biomechanical parameter tracking and performance optimization in various sports, especially movement-dominating sports, easily accessible (Alzahrani & Ullah, 2024).

Artificial Intelligence (AI) and machine learning allow us to easily analyze complex datasets to provide real-time feedback to improve training, avoid injuries, and inform rehabilitation plans (Souaifi et al., 2025).

Wearable technology enables us to monitor our body's physical and mechanical components in real time. People can learn new things and get ready for mental challenges by employing immersive virtual reality (VR) and augmented reality (AR) environments that look like real world but are controlled (Alzahrani & Ullah, 2024). These modifications could help professional athletes, normal individuals, and even amateur athletes perform better, stay healthy, and get around more easily (Ali et al., 2025).

Technology has advanced significantly, however critical research deficiencies persist. Schumann and Doherty (2024) assert that a lot of studies look at elite athletes, which doesn't include a lot of people or less popular sports. Second, even if wearable technology may correctly collect biomechanical data, it is currently unable to evaluate the data in real time and give coaches and athletes relevant feedback based on the results (Alzahrani & Ullah, 2024). Third, current biomechanical technologies are still hard to get to and use, especially in places with few resources (McDevitt et al., 2022). It could even lead to better training and rehabilitation systems by combining ideas from biomechanics, physiology, psychology, and data science (Padulo, 2025). Integration across disciplines is still not good enough. We need to close these gaps so that more athletes can benefit from advances in biomechanics, sports science research can be more complete, and coaches and politicians can make decisions based on facts.

We desire a bibliometric framework to comprehensively evaluate the progression of sports biomechanics research as we go towards Industry 4.0. Bibliometric analysis enables the quantitative mapping of publishing trends, subject development, and research networks, so offering a holistic view of the knowledge framework and identifying domains necessitating further inquiry (Donthu et al., 2021).

A lot of bibliometric studies have looked at general trends in sports science or exercise physiology. However, there aren't many that focus specifically on sports biomechanics in the context of Industry 4.0, which encompasses AI, IoT, and data-driven analytics. The aim of this work is to rectify that shortcoming by providing a focused bibliometric synthesis of the most recent developments in this field.

This study does a thorough bibliometric analysis of sports biomechanics literature from 2020 to 2025. The analysis. encompasses trends in publications, modifications in keywords, citation networks, and the contributions of prominent authors, institutions, and countries to identify established themes and areas necessitating further research. This study combines patterns to create a framework for future research and practical ways to use new technologies in sports biomechanics to boost performance, avoid injuries, and help people recover.

This project aims to address the subsequent research questions:

1. What are the principal themes and trends in. the publication of sports biomechanics research from 2020 to 2025?
2. Which prominent writers and nations have significantly. contributed to the development of this field?
3. What new topics and areas of study need to be looked into more within the Industry 4.0 framework?

Methods

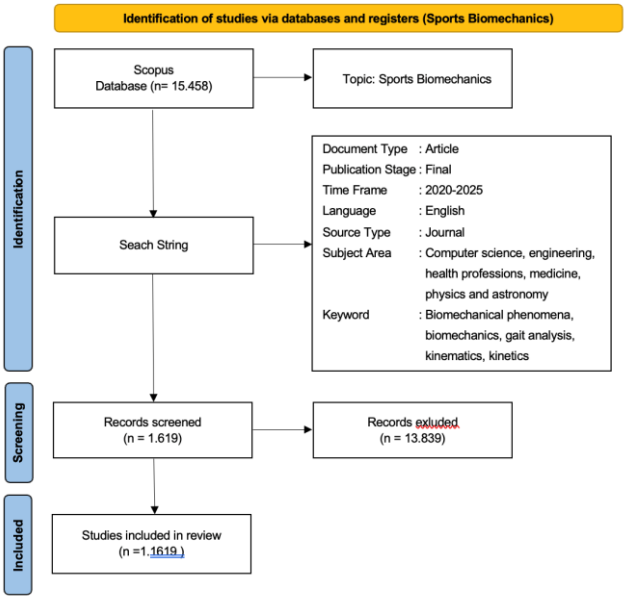
The research method is systematically organized to provide a clear picture of the approach, flow, and steps taken by researchers in answering the research questions (Fàbregues & Guetterman, 2025). The method is presented in a sequential manner so that the research can be understood, reviewed, and replicated by other researchers with the same level of reliability. Therefore, the description of the methods in this study is presented through five main components, namely: research design, participants and data sources, research instruments, research procedures, and data analysis techniques.

Research Design

This study employed a bibliometric design with a Citation Network Analysis (CNA) approach. This design allows for the tracing of specific research activities within the overall prism of internationalisation, dissemination, and networking in the field as structured by the citations. This study used Citation Network Analysis (CNA) as its bibliometric design. This design allows for the tracing of specific research activities within the

Figure 1

PRISMA Flowchart of Search and Screening Strategy



overall prism of internationalisation, dissemination and networking in the field, as structured by the citations. It allows for a complete evaluation of the state of the research in sports biomechanics. Bibliometric analysis can help assess the multiplicity of different types of scholarly output. Similar to a systematic review (Inoue et al., 2020), it aims to ensure a high degree of accuracy and reliability in the retrieved data and outcomes.

In this particular study, the analytical methodologies, and impact of the researched field(s) of study, and Citation Analysis (CNA) have underscored the novelty of this study. CNA employs network visualization with clustering to establish the most impactful authors, publications, and publications to assist in determining the thematic areas of focus. This technique outlines the links between said entities via citations and displays the organizations within the field as thematic clusters. Analyzing these clusters sheds light on the potential cited relationships and links in the particular field(s) of study. In this study, it allows:

1. recognize patterns in publications an thematic development across different time periods;
2. ascertain significant contributors and their collaboration networks; and
3. analyze scholarly domains that are currently insufficiently explored, or novel research fields that present future potential and relevance in an industrial context. Version 4.0.

This analytical approach guarantees the systematic alignment of the bibliometric data with the objectives of the study.

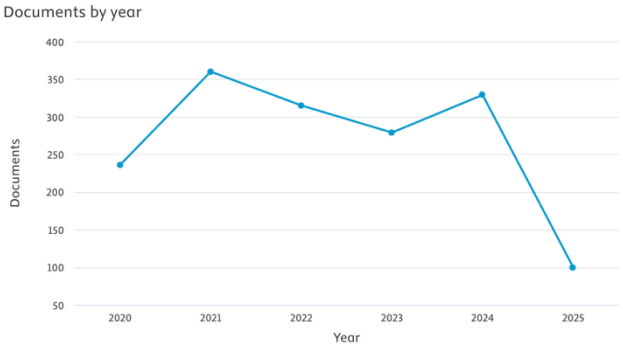
Data Sources

The bibliographical information regarding the research study was obtained from the Scopus (Elseviewer) database. Scopus was selected due to the database having the most comprehensive collection of information regarding peer-reviewed journals, proceedings of conferences, and book chapters across 1,000 subject areas. Scopus offers the best research collection to obtain a comprehensive perspective of research conducted across the globe. Scopus also exercises a stringent mechanism of quality control and indexing. For example, journals are required to self-assess the ethical standards of their publication process, citation metrics, and editorial policies. For the studies, Scopus was the most appropriate database to obtain the bibliometric and citation network analysis due to Scopus providing lower levels of duplicated data and higher levels of information.

We retained publications ranging from 2020 to 2025. There were 1,619 remaining from the original 15,458. To ensure dataset relevance to sports biomechanics, additional subfield specific filtering was performed at Scopus.com. This filtering process was based on the following index terms: sports biomechanics, motion analysis, kinematics, sports technology, and biomechanical performance.

Figure 2

Dokumen Published on Scopus Database



The design of the analysis is shown in Figure 1 which describes the steps of data harvesting, filtering and analysis.

Instrument

The main instruments used in this study are:

1. VOSviewer 1.6.20 was used to make maps of citation and co-occurrence networks, look at how topics are related, and show the intellectual structure of sports biomechanics research in the context of Industry 4.0. The software used the association strength normalization method, which makes sure that co-occurrence links between items are given the right amount of weight. To find a balance between network density and thematic interpretability, the clustering resolution was set to 1.0, which is the default value and the value that is most commonly used in bibliometric studies. Also, a minimum of five occurrences of a keyword and twenty citations of a document were set to make sure that only the most important and relevant items were included in the analysis.
2. Microsoft Excel is used to clean up data, combine terms, and prepare bibliometric metadata for display in VOSviewer.
3. Unlike other databases, Scopus (Elsevier) has more than 1000 subject categories and even had very good quality control, which is why we took to Scopus. Some of the keyword searches we used included kinematics, kinetics, biomechanical phenomena, biomechanics as well as gait analysis.

Procedure

In order to ensure reliability, accuracy, and replicability of the bibliometric analysis, this research process was divided into several (Donthu et al., 2021). This consisted of four main steps which included data collection, data processing, data analysis, and then the visualization and interpretation.

1. Data Collection

Metadata from the Scopus. database was gathered using keywords. related to sports biomechanics. The following query and filtering parameters were used to conduct the search. On

Figure 3

Influential Author generated using VOSviewer

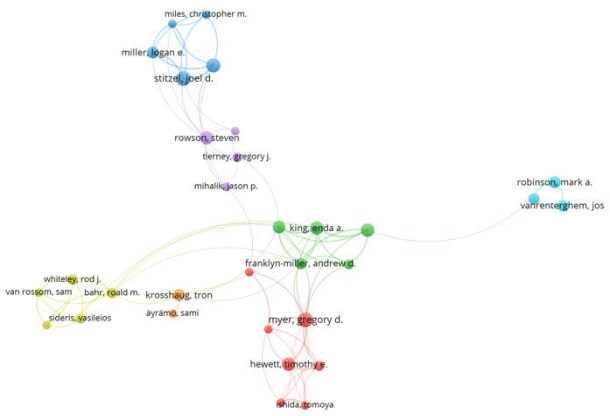


Table 1

Top Authors by Number of Publications in Sports Biomechanics (2020–2025)

Rank	Author by Document	Document
1	Gu, Yaodong	15
2	Myer, Gregory D.	14
3	Stitzel, Joel D.	14
4	Urban, Jillian E.	13
5	King, Enda A.	12
6	Hewett, Timothy E.	12
7	King, Mark A.	12
8	Daniels, Katherine A. J.	11
9	Rowson, Steven	11
10	Caparkapa, Ditrimije	11

The prevalence of writers like Gu and Myer indicates the existence of important research teams that continuously improve sports biomechanics.

TITLE-ABS KEY (sports AND biomechanics) AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "PHYS")) AND (LIMIT-TO (EXACTKEYWORD , "Biomechanics") OR LIMIT-TO (EXACTKEYWORD , "Biomechanical Phenomena") OR LIMIT-TO (EXACTKEYWORD , "Gait Analysis") OR LIMIT-TO (EXACTKEYWORD , "Kinematics") OR LIMIT-TO (EXACTKEYWORD , "Kinetics")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all")).

We collected information about. the article's title, authors, source journal, year of publication, number. of citations, abstract, keywords, and the authors' countries. To make sur. the data was correct and consistent before. analysis, Microsoft Excel. was used to find and fix. duplicate entries, incomplete records, and.differences.in author and keyword data.

2. Data Processing

We put the cleaned and checked metadata into Microsoft Excel so we could work with it. This step included:

1. Consolidating similar terms (e.g., “sports biomechanics” and “biomechanics in sports”);
2. Fixing differences in the names of authors and institutions;
3. Removing redundant entries and irrelevant records.

The most recent dataset was then imported to VOSViewer version 1.6.20 and used to conduct network analysis.

3. Data Analysis

The analysis of the dataset focused on the following bibliometric measures:

Table 2

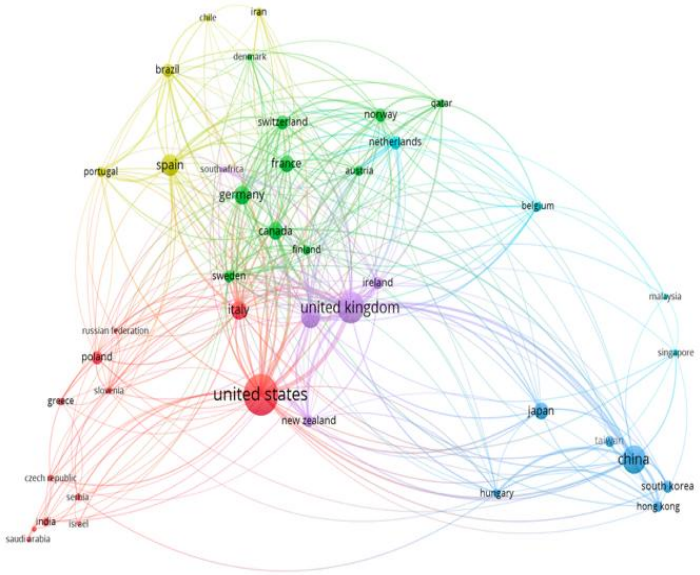
Top Authors by Number of Citations in Sports Biomechanics (2020–2025)

Rank	Author by Citations	Citations
1	Bahr, Roald M.	364
2	Whiteley, Rod J.	337
3	Sideris, Vasileios	337
4	Myer, Gregory D.	321
5	Stitzel, Joel D.	298
6	Jonkers, Ilse	286
7	Van Rossom, Sam	286
8	King, Enda A.	280
9	Robinson, Mark A.	267
10	Dos’Santos, Thomas	230

The substantial citation impact of authors like Bahr, Whiteley, and Myer is indicative of their pivotal role in shaping international sports biomechanics research trends.

Figure 4

Citation network analysis that determines the nation of origin of authors



1. The trend of publication over time — The number of articles published from 2020 to 2025 was tracked and displayed by year.
2. The analysis of co-authorship — the recognition of collaboration of research at the level of authors, organizations, and countries.
3. The analysis of co-occurring keywords — the identification of primary themes of research and the relationships between topics.

The strength of the relationships between the different keywords was measured using the association strength method and clique identification parameters set at 1.0. The minimum number of occurrences for a keyword was set at five and 20 for the number of times the document was cited to improve the quality of the analysis and the visibility of the themes.

4. Visualization and Interpretation

Network maps of authors, keywords, and cited documents were created and displayed using VOSViewer (Arifin et al., 2025). The pictures showed how problems got worse and how sports biomechanics research was organized.

The overall publication trend (2020–2025), shown in Figure 2, indicates a fluctuating growth pattern. Publications increased sharply from 236 documents in 2020 to 360 in 2021 (the highest within five years), followed by declines in 2022 (315) and 2023 (279). The trend rose again in 2024 (329) before dropping in 2025 (100), suggesting a possible data lag for the current publication year.

Table 3

Top 10 Nations by Sports Biomechanics Publications (2020–2025)

Rank	Country by Dokument	Document
1	United States	446
2	United Kingdom	256
3	China	201
4	Australia	136
5	Spain	127
6	Italy	95
7	Germany	93
8	Canada	88
9	Japan	79
10	France	76

The majority of publications are produced in the United States and the United Kingdom, which is indicative of their dominance in the field of sports biomechanics and their vast research infrastructure.

Table 4

Top 10 Countries by Number of Citations in Sports Biomechanics (2020–2025)

Rank	Country by Citations	Citations
1	United States	4720
2	United Kingdom	3245
3	Australia	1810
4	China	1344
5	Italy	1211
6	Spain	1036
7	Germany	1036
8	Canada	994
9	Norway	735
10	Switzerland	691

The dominance of the United States and the United Kingdom in both publication and citation metrics indicates their strong academic centrality and international collaboration in biomechanics research.

Results

Author's Analysis

Based on the results of bibliometric analysis of a total of 1,619 documents, a list of authors with the highest publication and citation contributions in the field of sports biomechanics was obtained (Figure 3). In the publication count category (Table 1), author Gu, Yaodong ranked first with 15 documents, followed by Myer, Gregory D. and Stiezel, Joel D., each with 14 documents. Next, Urban, Jillian E. is listed with 13 documents, as well as several other authors such as Kida, Einda A., Hewett, Timothy E., and King, Mark A. with 12 documents. Meanwhile, Daniels, Katherine A., Rowson, Steven, and Gaparbag, Dimitrije each produced 11 documents.

Meanwhile, in the citation count category (Table 2), the author with the highest number of citations was Bahr, Roald M. with a total of 364 citations, followed by Whiteley, Rod J. with 337 citations, and Sideris, Vasilios with 337 citations. Author Myer, Gregory D. also shows significant influence with 321 citations, while Stiezel, Joel D. is recorded as having 298 citations. Other important authors are Jonkers, Ilse, and Van Rossom, Sam, who each have 286 citations; King, Einda A., who has 280 citations; Robinson, Mark A., who has 257 citations; and Dos Santos, Thomas, who has 230 citations

Country Analysis

These results show the consistency of certain authors' contributions in terms of both the quantity of publications and the quality of their academic

Figure 5

Citation network analysis that identifies occurrences based on keywords

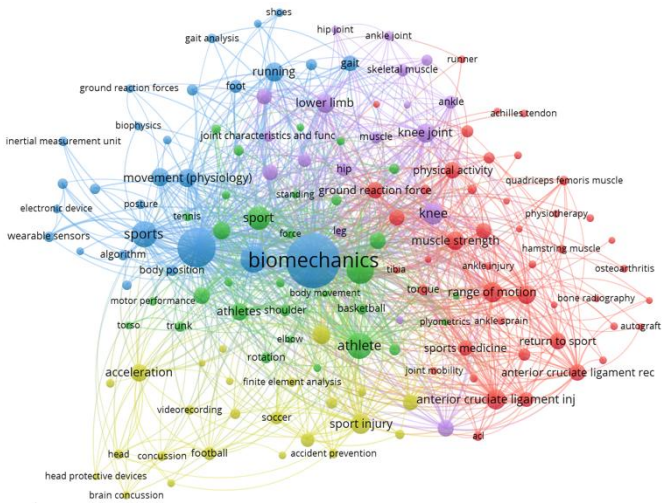


Table 5

Major Research Keyword Clusters Identified in Sports Biomechanics Publications (2020–2025)

Cluster	Item	Colour	Precentage	Total
1	Achilles tendon, acl, ankle injury, anckle sprain, anterior cruciate ligament, anterior cruciate ligament injury, anterior cruciate ligament reconstruction, autograft, body mass, bone radiography, electromyography, exercise, gastrocnemius muscle, grip strength, ground reaction force, hamstring muscle, joint mobility, knee function, knee injury, knee instability, knee meniscus rupture, knee osteoarthritis, muscle contraction, muscle isometric contraction, muscle strength, neuromuscular function, observational study, osteoarthritis, pain, patellofemoral joint, physical activity, physiotherapy, quadriceps femoris muscle, range of motion, rehabilitation, resistance training, return to sport, runner, shoulder injury, sports medicine, tendon graft, tibia, torque, treadmill exercise, weight bearing	Red	31%	45
2	anthropometry, athlete, athletes, athletic performance, baseball, basketball, basketball player, body height, body movement, body weight, controlled study, elbow, elite athlete, exercise test, fatigue, force, jumping, motor performance, pelvis, performance assessment, plyometrics, rotation, shoulder, sport, standing, tennis, torso, training, trunk, upper limb, velocity	Green	21%	31
3	algorithm, algorithms, biomechanical phenomena, biomechanics, biophysics, body position, electronic device, foot, gait, gait analysis, ground reaction forces, inertial measurement unit, joints (anatomy), kinematics, machine learning, motion capture, movement, movement (physiology), posture, running, shoe, shoes, skiing, sports, walking, wearable electronic devices, wearable sensors	Blue	19%	27
4	acceleration, accident prevention, athletic injuries, biological model, brain concussion, computer simulation, concussion, finite element analysis, football, football player, head, head injury, head protective devices, injury, injury prevention, risk assessment, risk factor, risk factors, simulation, soccer, soccer player, sport injury, sports equipment, videorecording	Yellow	17%	24
5	abduction, ankle, ankle joint, anterior cruciate ligament injuries, hip, hip joint, joint characteristics and functions, kinetics, knee, knee joint, leg, lower extremity, lower limb, muscle, muscle, skeletal, musculoskeletal system	Purple	12%	18

	parameters, range of motion, articular, skeletal muscle			
6	Achilles tendon, acl, ankle injury, anckle sprain, anterior cruciate ligament, anterior cruciate ligament injury, anterior cruciate ligament reconstruction, autograft, body mass, bone radiography, electromyography, exercise, gastrocnemius muscle, grip strength, ground reaction force, hamstring muscle, joint mobility, knee function, knee injury, knee instability, knee meniscus rupture, knee osteoarthritis, muscle contraction, muscle isometric contraction, muscle strength, neuromuscular function, observational study, osteoarthritis, pain, patellofemoral joint, physical activity, physiotherapy, quadriceps femoris muscle, range of motion, rehabilitation, resistance training, return to sport, runner, shoulder injury, sports medicine, tendon graft, tibia, torque, treadmill exercise, weight bearing	Red	31%	45
7	anthropometry, athlete, athletes, athletic performance, baseball, basketball, basketball player, body height, body movement, body weight, controlled study, elbow, elite athlete, exercise test, fatigue, force, jumping, motor performance, pelvis, performance assessment, plyometrics, rotation, shoulder, sport, standing, tennis, torso, training, trunk, upper limb, velocity	Green	21%	31
8	algorithm, algorithms, biomechanical phenomena, biomechanics, biophysics, body position, electronic device, foot, gait, gait analysis, ground reaction forces, inertial measurement unit, joints (anatomy), kinematics, machine learning, motion capture, movement, movement (physiology), posture, running, shoe, shoes, skiing, sports, walking, wearable electronic devices, wearable sensors	Blue	19%	27
9	acceleration, accident prevention, athletic injuries, biological model, brain concussion, computer simulation, concussion, finite element analysis, football, football player, head, head injury, head protective devices, injury, injury prevention, risk assessment, risk factor, risk factors, simulation, soccer, soccer player, sport injury, sports equipment, videorecording	Yellow	17%	24
10	abduction, ankle, ankle joint, anterior cruciate ligament injuries, hip, hip joint, joint characteristics and functions, kinetics, knee, knee joint, leg, lower extremity, lower limb, muscle, muscle, skeletal, musculoskeletal system parameters, range of motion, articular, skeletal muscle	Purple	12%	18

influence, as reflected in the citations they have received.

Table 3 shows the ten countries that have written the most papers. The US has 446 papers. With 256, the UK has the second most, and with 201, China has the third most. After the US, there are Canada (88 papers), Japan (79 papers), France (76 papers), Italy (95 papers), Germany (93 papers), Australia (136 papers), and Spain (127 papers).

The ten countries that get the most citations are shown in Table 4. The United States has the most citations (4720), followed by the United Kingdom (3245) and Australia (1810). The list also includes Canada (994 citations), Norway (735 citations), Switzerland (691 citations), Italy (1211 citations), Spain (1036 citations), Germany (1036 citations), and China (1344 citations). Figure 4 shows how networks of people who work together are getting bigger. The US is the most central, then the UK and Australia. Based on the centrality criteria, these states show strong international cooperation and strong academic involvement.

Analysis of co-occurrence of keywords

Table 6

Sports Biomechanics' Top 10 Most Cited Articles, 2020–2025

No	Title	Author	Year	Total Citation
1	Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes	(Kotsifaki, Van Rossom, et al., 2022)	2022	136
2	Sport biomechanics applications using inertial, force, and EMG Sensors: A literature overview	(Taborri et al., 2020)	2020	117
3	Prediction of lower limb kinetics and kinematics during walking by a single IMU on the lower back using machine learning	(Lim et al., 2020)	2020	117
4	A motion capturing and energy harvesting hybridized lower-limb system for rehabilitation and sports applications	(Gao et al., 2021)	2021	110
5	Real-time feedback by wearables in running: Current approaches, challenges and suggestions for improvements	(Van Hooren et al., 2020)	2020	102
6	Shear-stress sensing by PIEZO1 regulates tendon stiffness in rodents and influences jumping performance in humans	(Passini et al., 2021)	2021	97
7	(Kotsifaki, Whiteley, et al., 2022)	2022	93	
8	Test-retest reliability of a commercial linear position transducer (gymaware powertool) to measure velocity and power in the back squat and bench press	(Orange et al., 2020)	2020	93
9	Recent improvements in marathon run times are likely technological, not physiological	(Muniz-Pardos et al., 2021)	2021	83
10	Multidimensional ground reaction forces and moments from wearable sensor accelerations via deep learning	(Johnson et al., 2021)	2021	81

Table 7

Top 10 Most Cited Articles and Their Research Focus (2020–2025)

No	Title	Type of Study / Main Focus	Year	Total Citation
1	Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes	Cross-sectional biomechanical study / Knee deficits post-ACLR	2022	136
2	Sport biomechanics applications using inertial, force, and EMG Sensors: A literature overview	Literature review / Applications of sports biomechanics sensors	2020	117
3	Prediction of lower limb kinetics and kinematics during walking by a single IMU on the lower back using machine learning	Experimental study with machine learning / IMU-based Biomechanics Prediction	2020	117
4	A motion capturing and energy harvesting hybridized lower-limb system for rehabilitation and sports applications	Experimental system development / Hybrid Lower-Limb Motion Capture & Energy Harvesting	2021	110
5	Real-time feedback by wearables in running: Current approaches, challenges and suggestions for improvements	Review study on wearable feedback in running	2020	102
6	Shear-stress sensing by PIEZO1 regulates tendon stiffness in rodents and influences jumping performance in humans	Experimental mechanistic study on PIEZO1 and tendon stiffness	2021	97
7	Single leg hop for distance symmetry masks lower limb biomechanics: Time to discuss hop distance as decision criterion for return to sport after ACL reconstruction?	Experimental biomechanics study on ACLR hop symmetry	2022	93
8	Test-retest reliability of a commercial linear position transducer (gymaware powertool) to measure velocity and power in the back squat and bench press	Reliability study on GymAware measurements	2020	93
9	Recent improvements in marathon run times are likely technological, not physiological	Narrative review / Impact of shoe technology on running performance	2021	83
10	Multidimensional ground reaction forces and moments from wearable sensor accelerations via deep learning	Experimental study / Prediction of GRF/M from wearables	2021	81

The most frequently cited works highlight a paradigm shift toward data-driven and technologically enhanced sports science research by integrating biomechanics with digital technologies, especially sensors, artificial intelligence, and machine learning.

Researchers mapped the main factors contributing to publications, including authors, country of origin, and keywords. Keyword analysis was used to trace the direction of publication development and identify dominant themes. The size of the item labels in the visualization represents the frequency of publication, while the color differences represent specific fields of knowledge formed through software clustering techniques (Delmoral & João, 2024) . The citation relationship between documents is an important foundation in bibliometric studies, so the accuracy of citation data is a key requirement for the quality of the analysis (Wang et al., 2024).

In this study, keyword mapping was performed using VOSviewer software with a fractional counting approach. A minimum occurrence limit of 50 keywords was set, with author keywords selected as the unit of analysis. The clustering results are visualized in Figure 5 and then presented in Table 5 through cluster analysis.

Top 10 Most Cited Articles and Their Research Focus

According to bibliometric study using VOSviewer, wearable technology, data analysis, and smart sensors are used to evaluate athlete performance in the top ten sports biomechanics papers (Table 6). The most cited study is that of Kotsifaki et al. (2022) who used one-leg vertical jump performance to assess knee function impairments in male athletes following ACL surgery (136). These results show how important it is to use modern biomechanical methodologies and cutting-edge technology in clinical decision-making and data-based sports training.

In the top 10 articles, the most prevalent research types are cross-sectional biomechanical studies employing IMU sensors, EMG, force plates, and machine learning, experimental investigations, and literature reviews (Table 7). To forecast lower limb kinetics and kinematics, Lim et al. (2020) employed a single IMU and machine learning methods, whereas Taborri et al. (2020) Investigated the use of sensors in sports biomechanics. This trend shows how research on sports biomechanics is adopting digital technology and advanced data analysis, which are characteristics of the Industry 4.0 era.

A focus on improving athlete performance and rehabilitation effectiveness using wearable sensors, real-time input, and AI-based biomechanical predictions is shown by further study. While Samuel et al. (2020) evaluate the accuracy of speed and power measuring instruments, Passini et al. (2021) investigate the processes of shear stress on tendons. These results imply that in order to promote athlete development and evidence-based sports intervention, the research trend in sports biomechanics in the Industry 4.0 age will continue to include cutting-edge technology, smart sensors, and predictive assessment techniques.

Discussion

A bibliometric review focusing on the literature with respect to sports biomechanics between 2020 and 2025 indicates that there has been a steady development within the field owing to the increased use of augmented reality (AR), virtual reality (VR), Artificial Intelligence (AI), and portable devices. The rapid use of digital tracking technologies and the increase in publications within the field in 2021 indicates that there may have been a growing need on the part of coaches and researchers to more accurately and precisely assess an athlete's performance during the pandemic (Yu et al., 2020). The pattern shows that a significant number of people engage with the research contrary to the uneven distribution of ef fort which suggests that there are a number of barriers to the research such as a lack of proper research infrasturcture, inequity in available funding and acces to up to date technologies. These barriers are more pronounced in low and middle income countries (Godfrey et al., 2023).

According to the author's level analysis, it appears that there exists a very small and yet extremely productive and impactful group of academics, specifically Gu, Yaodong (volume of publication) and Bahr, Roald M. (impact of citation). This illustrates that a "scientific elite" is coming into existence, shaping the theory, methodology, and the research agenda in global biomechanics (Liu et al., 2022).

The concentration of output in the USA, UK, and Australia also illustrates long-standing disparities in scientific captivation which may narrow the variety of explored methodologies on a global scale. This trend shows that poor countries need to get more money, labs, and foreign partnerships in order to build research ecosystems.

The keyword and topic cluster analysis (Ciptaningrum et al., 2023) shows that smart sensors, real-time feedback, kinematic–kinetic integration, and AI-supported evaluation are all very important. Other studies have shown that force plates, EMG systems, IMUs, and machine learning algorithms are more useful for objectively measuring performance (Kotsifaki et al., 2022; Lim et al., 2020; Taborri et al., 2020). However, the majority of existing research continues to concentrate on elite athletes. Prior research corroborates this structural bias, indicating that amateur and youthful demographics are underrepresented due to the concentration of advanced biomechanical assessment equipment in high-performance training facilities (Galy et al., 2024). This difference makes us wonder about ecological validity and limits the usefulness of the current results to athletes at the community or school level.

The ten most cited articles that support this change in technology are Lim et al. (2020) on IMU-based prediction, Gao et al. (2021) on hybrid motion-capture systems, Van Hooren et al. (2020) on wearable-assisted feedback, and Passini et al. (2021) on tendon mechanobiology assessments. It seems that the research performed in biomechanics has shifted to more of a predictive and personalized focus as seen in the predominance of experimental and cross-sectional studies utilizing AI and sensor integration. This focus aligns with the justification for the injury prevention and return-to-sport frameworks and evaluations that aim to utilize evidence-based decision-making (Orange et al., 2020).

There are still a number of changes that still need to occur. One is that the demands of the amateur athletes, recreational exercisers, and para-athletes are unmet, and the elite focus makes it difficult to translate to the other groups. Another is that the differences in access to technology, especially in low-income countries, makes it so that advanced biomechanical methods are inaccessible to large portions of the population. A final one is the integration (especially with the disciplines of physiology, psychology, and data science) which, while pertinent to the construction of comprehensive performance and rehabilitation systems, still seems to be lacking (Zentgraf et al., 2024). These are the issues that we need to address in order to make biomechanical research more accessible and incorporate a greater degree of cultural sensitivity.

This research has several limitations. The study only used the Scopus database, which might not have included important papers that are indexed in Web of Science, PubMed, or regional databases. This could have led to selection bias. Also, contributions from countries where English is not spoken may not have been fully represented because only English-language texts were looked at. To encompass a broader spectrum of research impact, forthcoming studies should enhance database coverage, incorporate multilingual sources, and employ altmetric analysis. In addition, future bibliometric studies should look at subfields like youth biomechanics, adaptive sports, and low-cost sensor innovation to promote research development that is more inclusive and relevant to people all over the world.

Conclusions

This bibliometric study looks closely at sports biomechanics research from 2020 to 2025. It does this because technology is moving so quickly because of the use of wearable technologies, virtual and augmented environments, and AI-driven analytics. Mapping of publications, citation patterns, and network linkages shows that most scientific research is still done by a small number of authors, institutions, and countries. This is due to the significant disparities in research capability globally.

The results show that most of the current biomechanics research is focused on assessment and predictive evaluation models that use technology. However, the fact that amateur athletes, young people, and sports that aren't as well known are only included in a few studies shows that there is a big gap in the evidence that is available to everyone. Biomechanics could have a bigger effect on training, injury prevention, and rehabilitation if advanced tools were more evenly distributed and there were more interdisciplinary perspectives.

In theory, this study helps us better understand how the use of technology affects the growth of biomechanics research. The findings point to the need for more approachable techniques that can be applied in a variety of performance scenarios. The inclusion of people from different backgrounds, the affordability and accessibility of technological advancements, and the promotion of interdisciplinary professional collaboration should all be given top priority in future research.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 116-122 (November 2025) | DOI: 10.17509/jtikor.v10i2.88119

Assessment of Learning in the Topic of Karate Martial Arts Using the TKPN Test Application

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Article Info

Article History

Submitted: October 6, 2025
Accepted: November 19, 2025
Published: November 25, 2025

Article Access

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Abstract

This study examined students' physical fitness in the karate learning module using the TKPN test application. A quantitative descriptive cross-sectional design was employed, involving 30 Grade VIII students from SMP Negeri 16 Palembang (20 males and 10 females). Five components were assessed using TKPN: body mass index (BMI), flexibility (V sit-and-reach), muscular endurance (sit-ups), whole-body endurance (squat thrusts), and cardiorespiratory endurance (PACER). The results showed that 90% of both male and female students were categorized as having nutritional well-being. Flexibility levels were predominantly poor, with 80% of males and 90% of females classified in the poor category. Muscular endurance results indicated that 55% of males fell into the poor category, and only 5% reached the good category, while females demonstrated better performance, with 40% achieving good muscular endurance. Cardiorespiratory endurance was generally low, with 70% of males and 80% of females scoring in the poor category. Composite TKPN fitness scores placed both groups in the "fair" fitness category, with mean values of 2.2 for males and 2.6 for females. Overall, the TKPN application facilitated faster and more efficient data processing, providing teachers with a practical and systematic tool for monitoring students' physical fitness in karate learning. Digital-based assessment shows strong potential for supporting consistent and accurate evaluation in physical education, although further research with larger and more diverse samples is recommended to validate and expand these findings.

Keywords: assessment of learning, TKPN application, martial arts karate.

Introduction

Physical education is a branch of science aimed at influencing the physical and mental development of children by engaging them in well-structured physical activities. According to Rahmadani Fitri (2023), physical education is an integral part of the overall educational process. Its purpose is to develop physical fitness, motor skills, critical thinking abilities, social skills, reasoning, emotional stability, moral actions, healthy lifestyle habits, and environmental awareness through systematically planned physical, sports, and health-related activities. In other words, physical education is an effort by educators to enhance students' physical and mental well-being, while also supporting other aspects essential for social development.

According to Zebua (2024), assessment is the process of gathering data or information from learning activities. In physical education, assessment is a crucial component that must be conducted by teachers to evaluate the extent to which learning objectives have been achieved. Hart (in Kurniawati, 2017) defines assessment as the process of collecting data or information about students regarding what they know and what they can do. Based on these two perspectives, assessment can be concluded as a key element in physical education to evaluate the learning process and determine the success of student learning outcomes.

According to Anisah (2022), assessment of learning remains the dominant approach used in schools. The aim of this approach is to identify and confirm learning outcomes and to report them to students and their parents. This form of assessment is widely accepted by both parents and the broader community. Assessment of learning helps distinguish between students who have learned effectively and those who have not.

Good physical fitness is characterized by an individual's ability to engage in physical activity or exercise without experiencing excessive fatigue, and still having enough energy reserves to continue with the next activity without feeling overly tired. This aligns with Destriana et al. (2023), who state that physical fitness refers to the ability of an individual or group to perform daily physical activities optimally while still having enough strength to carry out subsequent tasks without any signs of fatigue.

According to Pramata (2016), karate is a form of martial arts that involves physical movements using both the hands and feet, such as punches, blocks, and kicks. Meanwhile, Purwaningtias Deasy describes karate as a traditional Japanese martial art that originated in Okinawa in 1896, where techniques known as *te* or *Okinawa-te* were first demonstrated. In 1929, many practitioners brought their own karate styles from Okinawa to mainland Japan, leading to its further development. Karate has been found to influence fitness levels; according to Maweikere et al. (2022), there is a significant relationship between physical fitness and nutritional status among karate athletes. However, fitness testing often still relies on outdated equipment, which affects the accuracy and duration of the assessments.

Instructional media refers to tools or elements used to deliver content that can be effectively received by students. In today's era, technology plays a major role in advancing the education sector. Through technological media, teachers can also carry out student assessments. In physical education, technology-based tools—such as applications or web platforms—can be used to evaluate learning or conduct fitness tests, provided they meet the required functional standards. According to Hartati, Destriana, and Aryanti (2016), the rapid and global development of science and technology has compelled higher education institutions to continuously improve the quality of teaching and learning in order to produce competent graduates. The digital transformation in education has accelerated the shift toward technology-based assessment tools, enabling more efficient data processing and learning analytics (Zain, 2021). From this statement, it can be inferred that technology is essential in achieving educational goals.

Based on the observations conducted at State Junior High School 16 Palembang, it was found that the school still uses manual methods for conducting physical fitness tests. The use of the TKPN application in assessing physical fitness is expected to assist teachers in saving time during the evaluation process. According to Hartati (2019), with the advancement of science and technology in the field of sports, significant progress has been made in both coaching knowledge and physical testing. In this era of globalization, it is recommended that test results be processed using computer-based applications or software that can record and calculate all test data and help determine the athlete's physical fitness level.

From the explanation above, it can be concluded that the TKPN application plays a vital role in managing both fitness assessments and technical aspects of martial arts, particularly karate. Lots of schools still stick with manual testing for physical education, even though it eats up time and mistakes slip through. Not many researchers have looked into how well digital TKPN works for karate classes in Indonesian junior high schools, especially when it comes to saving time. In this study, I set out to do two things: first, to show how students perform in karate when we use the TKPN app, and second, to see if the app actually

makes data processing faster and easier compared to the old manual way.

Methods

Research Design

This study employed a quantitative descriptive cross-sectional design to assess students' physical fitness during the karate learning module. The cross-sectional approach allowed data to be collected at a single point in time, providing an overview of students' fitness profiles based on the components measured using the Tes Kebugaran Pelajar Nusantara (TKPN) application. This design is commonly used in school-based physical education research to evaluate physical fitness status without implementing treatment or intervention.

Participants

The participants were 30 Grade VIII students (20 males and 10 females) from SMP Negeri 16 Palembang who were enrolled in the karate learning module. Purposive sampling was applied to include students who met the following criteria:

1. actively participated in physical education classes during the study period;
2. were present on the day of fitness testing; and
3. had no injuries or health conditions that prevented participation in physical fitness tests.

Students with recent acute injuries or medical limitations were excluded from testing. Prior to data collection, permission was obtained from the school administration, and written informed consent was collected from parents/guardians. All students also provided verbal assent. The study procedures adhered to school safety protocols and ethical principles for conducting research involving minors.

Instrument

The TKPN (Tes Kebugaran Pelajar Nusantara) application was used as the primary instrument for measuring physical fitness. TKPN is a digital platform developed to assess school-aged students' fitness through standardized national norms and automated scoring. Five test components were administered:

1. Body Mass Index (BMI): calculated from height and weight measurements to categorize nutritional status (malnutrition, normal, overnutrition, obesity).
2. Flexibility (V Sit-and-Reach): measures hamstring and lower back flexibility, categorized into very poor, poor, fair, good, and excellent.
3. Muscular Endurance (Sit-Up Test, 60 seconds): counts the number of sit-ups performed, classified into five performance levels.
4. Whole-Body Endurance (Squat Thrust Test, 30 seconds): assesses total-body endurance and coordination through repeated squat thrust movements.
5. Cardiorespiratory Endurance (PACER Test): conducted following the standardized 20-meter shuttle run protocol; TKPN converts total laps into category scores.

All raw scores were directly entered into TKPN, which automatically calculated performance categories and generated the composite fitness score.

Procedure

Data collection was carried out during scheduled physical education sessions. The procedure consisted of the following steps:

1. Preparation:
   The teacher and research team prepared the testing stations (BMI, sit-and-reach box, sit-up mat, squat thrust area, and PACER track). Students received instructions and demonstrations for each test component.
2. Warm-Up:
   A standardized 10-minute warm-up session was implemented consisting of light jogging, dynamic stretching, and mobility exercises to ensure readiness and reduce injury risk.
3. Testing Sequence:
   Tests were administered in the following order to minimize fatigue effects:
   (1) BMI measurement, (2) V sit-and-reach, (3) sit-up, (4) squat thrust, and (5) PACER test.
   Students rotated through stations in small groups under teacher supervision.
4. Data Input:
   All test results were recorded and entered into the TKPN application immediately after completion of each station. TKPN automatically generated individual and class-level reports.
5. Safety and Monitoring:
   Throughout the procedure, the teacher monitored test execution to ensure student safety and correct technique.

Data Analysis

Data exported from the TKPN application were analyzed descriptively using Microsoft Excel. Frequency distributions and percentages were calculated for each performance category within all fitness components. TKPN applies a weighted

scoring system to generate a composite fitness index, where each component contributes differently to the overall score:

1. PACER: 50%
2. Sit-up: 20%
3. Squat thrust: 20%
4. V Sit-and-reach: 10%

The composite fitness score for each student was calculated using the formula: $\text{Composite Score} = \sum(\text{Component Value} \times \text{Weight})$

The resulting scores were then classified according to the TKPN categories: >4 = excellent; 3–3.9 = good; 2–2.9 = fair; 1–1.9 = poor; <1 = very poor.

The final analysis focused on gender-based comparisons and overall fitness classification to describe students' fitness profiles within the karate learning module.

Results

The results of the application-based physical fitness assessment are presented in three tables. Table 1 shows the distribution of BMI categories for male and female students. Table 2 summarizes the classification outcomes for four fitness components (flexibility, muscular endurance, coordination/agility/balance, and cardiorespiratory endurance). Table 3 reports the composite TKPN fitness scores based on weighted proportions for each component.

Most students fell within the normal nutritional well-being category (90% male; 90% female). Overnutrition was identified in 10% of males and 10% of females, with no cases of underweight or obesity.

Flexibility scores were predominantly poor (80% male; 90% female). Muscular endurance showed a wider distribution: most males fell into poor or fair categories, while females showed higher percentages in good performance (40%). Cardiorespiratory endurance, assessed using the PACER, showed low performance for both sexes, with 70% of males and 80% of females classified as poor.

Composite scores indicated that both male (2.2) and female (2.6) students fall within the *fair* fitness category. The PACER component contributed the highest weight (50%) and had the greatest downward impact on total scores due to its predominantly poor classifications.

Discussion

Aligned with the study objective: "to analyze students' physical fitness using the TKPN digital assessment application and compare digital vs. manual assessment approaches.

The purpose of this study was to analyze the physical fitness levels of Grade VII students using the TKPN application and to evaluate how digital assessment improves the accuracy and efficiency of the fitness testing process compared with conventional manual assessment. Overall, the findings show that students at SMP Negeri 16 Palembang fall within the *fair* fitness category, while the use of the TKPN application substantially streamlined data processing and minimized human error. The discussion in the following sections connects the study's results with previous research and the broader context of assessment practices in physical education.

Manual assessment methods remain widely used in schools, including at SMP Negeri 16 Palembang. As described by Wikarya et al. (2018), conventional assessment relies on written tests, direct observations, and manual scoring. This method is simple, low-cost, and aligns with

Table 1

BMI Classification of Students by Sex

Category	Male (n = 20)	Female (n = 10)
Malnutrition	0 (0%)	0 (0%)
Nutritional well-being	18 (90%)	9 (90%)
Overnutrition	2 (10%)	1 (10%)
Obesity	0 (0%)	0 (0%)

Note. BMI classification based on TKPN standards.

Table 2

Fitness Component Classification by Sex Across Four TKPN Tests

Category	Flexibility n (%)		Sit-Up n (%)		Squat Thrust n (%)		PACER n (%)	
	Male	Female	Male	Female	Male	Female	Male	Female
Very Poor	0 (0%)	0 (0%)	1 (5%)	1 (10%)	0 (0%)	0 (0%)	6 (30%)	1 (10%)
Poor	16 (80%)	9 (90%)	11 (55%)	5 (50%)	11 (55%)	5 (50%)	14 (70%)	8 (80%)
Fair	4 (20%)	1 (10%)	7 (35%)	3 (30%)	5 (25%)	3 (30%)	0 (0%)	0 (0%)
Good	0 (0%)	0 (0%)	1 (5%)	4 (40%)	3 (15%)	2 (20%)	0 (0%)	1 (10%)
Excellent	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5%)	0 (0%)	0 (0%)	0 (0%)

Note. All test classifications follow TKPN normative scoring for each component.

Table 3

Composite TKPN Fitness Scores Based on Weighted Proportions

Component	Weight (%)	Male Score	Female Score
PACER	50%	1.0	1.0
Sit-Up	20%	0.4	0.8
Squat Thrust	20%	0.6	0.6
V Sit-and-Reach	10%	0.2	0.2
Total Composite Score	—	**2.2**	**2.6**
Fitness Category	—	**Fair**	**Fair**

Note. Composite scores follow the TKPN rubric: >4 = Excellent; 3–3.9 = Good; 2–2.9 = Fair; 1–1.9 = Poor; <1 = Very Poor.

teachers' current assessment competencies. These advantages are consistent with Sari (2019), who noted that traditional approaches allow learning objectives to be achieved effectively within the allotted instructional time.

However, manual assessment has notable limitations. The process is time-consuming, susceptible to scoring inconsistencies, and inefficient when used for testing multiple components across large groups of students. Kharizma et al. (2024) highlighted that such methods tend to reduce student engagement and may limit the meaningfulness of learning experiences. In this study, PE teachers reported similar challenges, particularly during the calculation and recording of fitness test outcomes.

igital assessment incorporates technology to record, calculate, store, and analyze fitness results. As Satria et al. (2021) stated, digital tools are increasingly essential in physical education, particularly for enhancing accuracy and accountability. The TKPN application used in this study offered several advantages—automated scoring, structured data storage, standardized norms, and immediate result processing.

These benefits mirror Kresnapati et al. (2020), who emphasized the superiority of digital systems in minimizing calculation errors and increasing assessment efficiency. Despite these advantages, digital assessment has challenges, including the need for adequate devices, stable internet, and teacher technological readiness. Adawiyah & Haolani (2021) reported similar obstacles in digital-based school assessment environments.

In this study, however, the TKPN app proved highly functional and significantly assisted the PE teacher in evaluating each student's fitness status efficiently and accurately.

The V Sit and Reach results indicate that most students fall within the poor–fair range. Flexibility is crucial in karate due to its influence on kicking range, body control, and injury prevention. Prior research supports this: Afrizal (2018) found that lumbar flexibility improves kicking accuracy, while Hasyim (2020) emphasized its importance for movement efficiency. Thus, students' low flexibility scores highlight a key area for instructional improvement in the karate module.

Sit-up results showed generally fair but not optimal endurance levels. Muscular endurance plays a significant role in karate, especially for maintaining technique consistency across rounds. Firmansah (2021) and Azhari et al. (2020) emphasized that stronger core muscles directly enhance kicking and punching power while reducing injury risk. The "poor" category obtained by many students suggests the need for strengthening interventions as part of the PE curriculum.

Squat Thrust performance fell mainly in the fair–poor categories. This result is important because these components—coordination, balance, agility—are foundational in karate. Marta (2020) and Nur Khofifah et al. (2023) highlight that efficient movement patterns in martial arts depend on well-developed coordination, allowing movements to be integrated smoothly while minimizing energy expenditure. Students' low scores indicate limited physical readiness for advanced skill execution.

PACER scores were the lowest across components, with most students falling into the poor and very poor categories. Endurance is essential in karate, as matches require sustained physical effort. Arridho (2021) and Sepriani (2019) emphasized that strong cardiovascular endurance is necessary for maintaining high-intensity performance. The low results observed suggest the need for more structured aerobic conditioning in PE.

The combined TKPN composite scores (male = 2.2; female = 2.6) classify students in the *fair* fitness category. This aligns with Sudirman (2024), who stressed that fitness and nutritional status significantly affect physical development during adolescence. The BMI results, mostly indicating normal nutritional well-being, support this finding—suggesting that students' fitness limitations are more related to physical activity patterns than nutritional issues.

The digital assessment provided clear, quantifiable evidence of students' fitness strengths and weaknesses. This supports the goal of the research: to use application-based assessment not only to measure fitness but also to

provide actionable insights for improving PE instruction, particularly in karate.

The findings reinforce Komariah et al. (2024), who argued that learning outcomes are strengthened when assessment aligns with objectives, uses student-centered approaches, and incorporates technology. In this study, the TKPN application helped the PE teacher more accurately monitor students' abilities, identify priority areas for training, and streamline evaluation.

Thus, application-based assessment aligns well with the current needs of physical education: accuracy, efficiency, and evidence-based decision-making. These findings support previous technological innovations in physical testing, where digital platforms improved the accuracy and efficiency of test administration (Hartati, Aryanti, & Victorian, 2020). The integration of TKPN in karate learning aligns with these developments, demonstrating that mobile-based measurement systems can streamline teacher workflow and improve data reliability.

This study demonstrates that Grade VII students show a moderate level of physical fitness, with particular weaknesses in flexibility and endurance. The use of the TKPN application significantly improved the assessment process, providing accurate, real-time analysis that would be difficult to achieve through manual evaluation.

Overall, the findings support the integration of digital assessment tools in PE classes, particularly in skill-intensive subjects like karate, where detailed monitoring of physical readiness is essential.

Conclusions

This study examined the physical fitness levels of Grade VII students at SMP Negeri 16 Palembang using the TKPN digital assessment application. The findings show that students generally demonstrated *moderate* fitness levels across BMI, flexibility, muscular endurance, coordination, and cardiorespiratory endurance components. The composite scores (male = 2.2; female = 2.6) placed both groups in the "fair" category based on TKPN standards. These results highlight specific areas—particularly flexibility and cardiovascular endurance—that require greater instructional attention within the karate module of physical education.

A key contribution of this study lies in demonstrating how digital assessment tools such as the TKPN application can significantly improve the efficiency, accuracy, and consistency of fitness evaluations in school settings. The app minimized human error, accelerated data processing, and offered standardized scoring aligned with national fitness norms. For teachers, this provides clearer insights for planning instructional interventions, monitoring student progress, and supporting data-driven physical education practices. For students, the digital feedback fosters greater awareness of their physical fitness status and encourages healthier habits and active participation in PE classes.

This research has several limitations. First, the sample size was relatively small (N = 30) and limited to a single school, which restricts the generalizability of the findings. Second, the study focused only on descriptive analysis, without examining causal factors that may influence fitness outcomes—such as physical activity habits, nutrition, lifestyle, or psychosocial variables. Third, the implementation relied on a single digital tool (TKPN), leaving unexplored how different assessment technologies may compare in terms of usability and accuracy.

Future research should involve larger and more diverse populations across multiple schools to strengthen external validity. Studies integrating digital assessment with intervention programs (e.g., flexibility training, endurance conditioning) would provide deeper insight into improving student fitness. Additionally, comparative studies examining various assessment applications could help identify the most effective digital tools for physical education.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 123-129 (November 2025) | DOI: 10.17509/jtikor.v10i2.91321

The Role of Traditional Games and Sports in Forming Social Solidarity among Physical Education Students

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Article Info

Article History

Submitted: October 20, 2025
Accepted: November 20, 2025
Published: November 25, 2025

Article Access

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Abstract

Traditional sports games are distinctive cultural characteristics of various regions in Indonesia and contain valuable social and educational elements. It is crucial to introduce and integrate these games as part of education to cultivate social solidarity among Physical Education students at the Catholic University of Saint Augustine Hippo. This study employed a mixed-methods approach (descriptive and quantitative). Data was collected through observation, interviews, and questionnaires covering five core aspects: social solidarity, cultural values, physical education, digital alternatives, and social character values. The research results indicated that all aspects scored highly, with the highest average score observed in the Physical Education (4.50) aspect, while the lowest score was found in the digital alternatives (4.20) aspect. These findings demonstrate that traditional games hold significant potential for strengthening students' cooperation, empathy, and sense of togetherness. Practically, this study recommends the integration of traditional games into the Physical Education curriculum as a vehicle for instilling character values and preserving local culture. The results further affirm that collaborative activities, such as traditional games, can effectively reinforce a sense of togetherness and social solidarity within higher education settings.

Keywords: traditional games, solidarity, culture, education.

Introduction

According to Restuina (2025), through playing, children not only get pleasure but also develop various important aspects in their lives. Playing helps improve motor, cognitive, linguistic, creativity, emotional, and social development. Through playing activities, individuals learn to interact, obey rules, and develop social skills that are important for social life (In the context of physical education, traditional games have pedagogical value because they encourage physical, emotional, and social engagement simultaneously). Traditional games are more than just recreational physical activities; traditional games are a medium for instilling social values that contribute to the formation of character and moral integrity of the younger generation.

According to Irwan (2020), traditional games, in the form of cooperation, solidarity, and teamwork, foster empathy in the games played in the community. The values of solidarity, implemented through games, become a habitual practice in the surrounding environment and in learning. Traditional sports games play a role in character building in higher education, physical education, health, and recreation. Traditional games foster sportsmanship and social solidarity in school-age children, suggesting that activities such as gobak sodor strengthen social relationships and a sense of community. However, most of this research focuses on primary and secondary education contexts.

The research gap lies in the lack of empirical studies at the higher education level, particularly regarding how Physical Education students internalize social values through traditional game practices. This phenomenon has the potential to weaken the social function of traditional games, which were previously based on face-to-face interactions, replacing them with virtual interactions with different characteristics. As Yogi Imam Hambali (2021) points out, this change reduces opportunities for building a sense of togetherness, cooperation, and empathy within groups, as the real-world interactions found in traditional games are increasingly replaced by virtual interactions. Furthermore, there is little research which relates these empirical results to Durkheim's theoretical framework of social solidarity, which distinguishes between solidarity and social solidarity. Solidarity mechanical solidarity (based on similarity and togetherness) and organic solidarity (based on differentiation and cooperation between roles). This conceptual relationship is important because it provides a sociological basis for understanding how collective physical activity can strengthen social cohesion in modern educational environments.

In today's digital age, students' shift in preference to online games and virtual activities has led to a reduction in face-to-face interactions and a potential decline in the sense of community. Traditional role play has long been recognized in literature. Muhamad Aris (2023) with games that stimulate cognitive development and improve movement skills and become more active, games in the form of competitions will provide more discipline and value in role play to shape character for the younger generation in the current digital era.

Sports game traditional in learning Physical education, health, and recreation involve more attitudes of solidarity, cooperation, and mutual trust. Andriani (2011) states that games can shape character for students in fostering a sense of mutual care in developing an attitude of sportsmanship in games and social interactions. Haku (2022) says that traditional sports games have an important role in instilling an attitude of solidarity among students in higher education. According to Khoiriyah (2024), games stimulate cognitive skills for the players, can hone attitudes of sportsmanship in social activities, and work together in teams.

Game Traditional games serve as a fun and effective learning medium that helps shape character and foster positive social interactions. Therefore, traditional games play a crucial role in shaping a generation that is not only physically healthy but also socially and emotionally mature. Traditional games have an important social function, namely fostering social solidarity among the younger generation.

Methods

Taking into account the existing background and gaps, this study aims to analyze how sports and sports games game traditional can teach and educate about social gaming and society with study method Mixed methods. This study uses a qualitative approach with sociological study methods. This approach was chosen because it aims to gain a deep understanding of the social meanings, interactions, and solidarity values that emerge through the practice of traditional games among Physical Education students. This study also uses a mixed methods approach, where a qualitative approach is applied to explore the social meanings contained in traditional games, while a quantitative approach is used to support the data through descriptive numerical results obtained from a social solidarity questionnaire.

Research Design

The use of a mixed methods approach in this research aims to obtain a more comprehensive and

in-depth understanding of the social phenomena being studied.

A qualitative approach was used because this research focuses on understanding the social meanings, interactions, and solidarity values that emerge in traditional game practices. This approach allowed researchers to directly explore the perspectives, experiences, and perceptions of Physical Education students through in-depth observations and interviews. Thus, researchers were able to capture social aspects that cannot be measured numerically.

A quantitative approach was used to complement the qualitative data by providing numerical or percentage support obtained from the social solidarity questionnaire. This quantitative data helped strengthen the qualitative findings and provided an objective and measurable picture of the level of social solidarity among students.

Quantitative data provides an objective and measurable picture of the level of social solidarity among college students. By combining these two approaches, this research is able to produce more valid, comprehensive, and meaningful findings, as explained in this study. Qualitative and quantitative data complement each other.

Participants

The subjects of this study were fifth-semester students in the Physical Education, Health, and Recreation Program at Saint Augustine Catholic University, Hippo. A total of 30 students participated, all enrolled in the Traditional Sports Games course

Instrument

The instruments used in this study consist of two types—qualitative instruments and quantitative instruments—in accordance with the mixed methods approach applied in this study.

Qualitative Instruments

The primary instrument in a qualitative approach is the researcher (human instrument). The researcher acts as the primary data collector through direct observation of traditional game practices and in-depth interviews with Physical Education students. To ensure data validity, researchers developed observation guidelines. And The interview protocol was based on indicators of social values and solidarity derived from Durkheim's sociological theory. This guideline was reviewed through expert assessment (content validation) by two expert lecturers specializing in the sociology of sport and physical education.

Quantitative Instruments

In the quantitative approach, the instrument used is the Social Solidarity Questionnaire developed by Researchers to measure the level of social solidarity of students after participating in traditional game activities.

Here is a clear and natural English translation of your work, while maintaining academic format and terminology: to measure the level of social solidarity of students after participating in traditional game activities.

Instrument Development

The steps for developing the instrument are as follows:

a) Determine indicators of social solidarity based on Durkheim's sociological theory. b) Develop questionnaire items using a Likert scale with five response options (Strongly Agree – Strongly Disagree). c) Conduct a pilot test of the questionnaire on 30 students outside the research sample.

Validity Test

Instrument validation is tested using validation tests content, which is assessed by experts and research the can used profit connect results linear data research for two data for interval or ratio the For results individual with score overall, with mark r value ≥ 0.30 in consider valid. The value as minimum limit.

Reliability test

Reliability test done For know how much consistent instrument study the in measure the variables to be examined. Testing done using For evaluate internal consistency is Cronbach's Alpha formula. Test results with results the α value is 0.87, mark the show reliability high, because in the range value 0.70-0.089. With thus questions on the instrument can said to be valid for measuring research variables. Respondents with the same characteristics can give no answer Lots changeable.

Procedure

This study uses a qualitative approach with a sociological study method. This approach was chosen because the purpose of this study is to deeply understand the social meaning, interaction, and solidarity values that emerge through the practice of traditional games among Physical Education students. This study also applies a mixed method approach, where a qualitative approach is used to understand the social meaning reflected in traditional games, while a quantitative approach is used to support the data with descriptive numerical results obtained from a social solidarity questionnaire. to understand the social meaning that emerges in traditional games, while a quantitative approach is used to support the data through descriptive numerical analysis obtained from a social solidarity questionnaire.

Data Analysis

Data analysis was carried out using qualitative methods. And method quantitative descriptive. In qualitative analysis, the process follows the model proposed by Miles & Huberman. (Aziza, 2023)

Table 1
Descriptive Statistics of Measured Aspects

Aspect	Mean	Standard Deviation	Interpretation
Social Solidarity	4.45	0.32	Very High
Cultural Values	4.35	0.40	High
Physical Education Learning	4.50	0.28	Very High
Digital Alternatives	4.20	0.35	High
Character & Social Values	4.40	0.30	Very High

which includes the following stages: Data Analysis = Data Reduction + Data Presentation + Conclusion Drawing/Verification.

Meanwhile, quantitative analysis uses simple statistical calculations as follows:

To calculate the average score of respondents (Sugiyono, 2020) and determine the reliability coefficient using the Cronbach's Alpha formula.

The results of the analysis are then interpreted according to the category of social solidarity levels based on the percentage range obtained from the calculations.

Results

A total of 30 students from the Physical Education, Health, and Recreation Study Program participated in this study. The descriptive analysis was conducted using actual quantitative data obtained from the Social Solidarity Questionnaire.

1. Descriptive Statistics of Social Solidarity Dimensions

The questionnaire measured five dimensions: Social Solidarity, Cultural Values, Physical Education Learning, Digital Alternatives, and Character & Social Values. The descriptive results are presented in Table 1.

The highest mean score was recorded for Physical Education Learning (4.50), suggesting that students perceived traditional games as highly effective learning tools. The lowest score, Digital Alternatives (4.20), was still categorized as high, indicating that traditional games remain valued even in the digital era. Standard deviations ranging from 0.28 to 0.40 show that responses were consistent and did not vary widely across participants.

2. Instrument Validity and Reliability

Instrument validation was performed using content and empirical validity testing.

Content validity was confirmed by two experts in sports sociology and research methodology, who validated all items as relevant and appropriate.

Empirical validity using Pearson Product Moment correlation showed that all items met the minimum requirement ($r \geq 0.30$).

Reliability testing produced a Cronbach's Alpha value of 0.87, indicating high internal consistency.

These results confirm that the instrument used to assess social solidarity is both valid and reliable.

3. Visualization of Findings

To support numerical interpretation, two visual representations were prepared:

A bar chart (Figure 1) showing the mean score of each aspect, and

A pie chart (Figure 2) illustrating each dimension's proportional contribution to overall solidarity.

These figures demonstrate that all aspects significantly contribute to the strengthening of social solidarity among students.

4. Narrative Summary of Findings

The findings show that traditional games play an important role in fostering social solidarity among university students. Participants reported that traditional games helped them build cooperation, mutual trust, appreciation of differences, and a stronger sense of group belonging. The very high score in the Social Solidarity aspect (4.45) indicates that traditional games effectively promote collective values and interpersonal bonds.

Meanwhile, the high score in Cultural Values (4.35) demonstrates that students recognize traditional games as carriers of cultural norms and heritage. The strong result for Character & Social Values (4.40) reinforces the role of traditional games in instilling discipline, empathy, respect, and teamwork.

Overall, the findings confirm that traditional games remain relevant as culturally rooted pedagogical tools that strengthen social relations and enhance learning experiences.

Discussion

1. Alignment with Theory

The results of this study strongly align with Durkheim's theory of mechanical solidarity, which emphasizes that collective activities produce shared values, emotional unity, and social cohesion. Traditional games require synchronous participation, mutual cooperation, and adherence

Figure 1
The bar chart below shows the average score for each aspect.

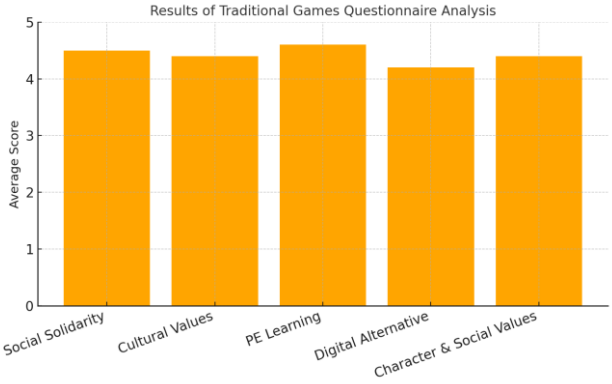
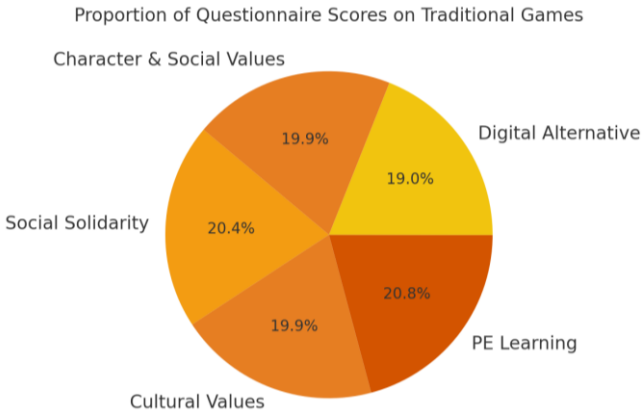


Figure 2
The pie chart depicts the proportion of contribution of each aspect to the overall score.



to collective norms—elements that Durkheim identified as foundations of social solidarity. The high scores across solidarity-related aspects (4.20–4.50) demonstrate that students naturally form stronger bonds through shared activities and collective goals.

Additionally, from a socio-constructivist perspective (Vygotsky, 1978), traditional games provide social interaction that facilitates learning within the "zone of proximal development." Through cooperation, mentoring among peers, and communication during the games, students gain not only motor skills but also social and emotional competencies. This supports findings from Rogoff (2003), who argued that learning is inherently social and shaped by culturally embedded activities.

Traditional games also reflect principles from Social Learning Theory (Bandura, 1986), where students learn social behaviors such as cooperation, empathy, and sportsmanship through observation, modeling, and reinforcement during gameplay.

2. Comparison with Previous Studies

The findings of this study are consistent with earlier research in Indonesia, such as Haku (2022) and Andriani (2011), which found that traditional games contribute to character development, cooperation, and discipline. Similar to Irwan (2020), this study also confirms that traditional games promote active learning and social interaction in educational settings.

When compared with international literature, the findings of this study are also strongly aligned with global evidence. Pellegrini and Smith (1998) demonstrated that traditional play activities enhance cooperation, conflict resolution, and social competence—outcomes that closely mirror the high levels of social solidarity reported by students in this research. Similarly, Berk and Meyers (2015) found that culturally rooted games support emotional regulation and strengthen peer relationships, which is consistent with the strong scores obtained in the Character and Social Values aspect. Opie and Opie (2018) further emphasized that traditional games embed social norms and cultural rules, reinforcing the present study's finding that Cultural Values remain well-preserved despite the rise of digital alternatives. More recent research by Marques et al. (2020) also showed that integrating traditional games into physical education significantly increases motivation, engagement, and group cohesion among university students. Together, these studies highlight that the social and cultural benefits of traditional games observed in this study are in line with international research trends and remain relevant across different educational contexts.

These international studies reinforce that the social functions of traditional games—cooperation, trust-building, conflict resolution, and cultural transmission—are universal, not limited to Indonesian contexts.

3. Educational Implications

In line with Marques et al. (2020) and Morgan & Hansen (2017), the findings suggest that traditional games should be integrated into physical education as a way to promote holistic learning that includes social, emotional, cultural, and physical dimensions. The very high score in the Physical Education Learning aspect (4.50) confirms that traditional games function as effective culturally relevant pedagogy.

The results also support Khoiriyah (2024) regarding the shift to digital play. Although digital alternatives received the lowest score (4.20), students still value traditional games as meaningful and socially rich experiences—indicating that traditional games retain strong educational relevance despite digitalization trends.

4. Social and Cultural Implications

Consistent with Durkheim and previous quantitative evidence, the study confirms that traditional games foster social bonds by requiring collaboration, rule-following, and shared emotional experiences. This mirrors Cortés et al. (2019), who found that collective physical activities strengthen group identity and social cohesion in youth communities.

Traditional games also support cultural continuity, aligning with UNESCO (2018), which identifies traditional sports as intangible cultural heritage that fosters identity, belonging, and intergenerational transmission of values. This is reflected in the high score for Cultural Values (4.35).

5. Practical Program Implications

The recommendation to integrate traditional games into the curriculum aligns with Morgan & Hansen (2017) and Bailey (2021), who argue that culturally based pedagogies increase student motivation and foster stronger learning communities. Regular traditional game festivals or competitions may reinforce peer relationships and a positive campus atmosphere.

6. Contribution to Literature

This study contributes to the literature by demonstrating that traditional games, even in higher education, continue to foster solidarity despite the dominance of digital games—a gap noted in prior research by Khoiriyah (2024) and UNESCO (2018). Furthermore, the study operationalizes Durkheim's classical theory within a modern university context, offering new insights into how traditional practices maintain relevance today.

Conclusions

This study concludes that traditional games play a significant role in fostering social solidarity among Physical Education students. Participation in traditional games promotes cooperation, empathy, communication skills, discipline, and mutual trust. These elements collectively contribute to developing strong social bonds in academic environments.

The results support Durkheim's theory that collective activities reinforce social cohesion, demonstrating that traditional games serve as both recreational and educational tools. They embed cultural values and strengthen character development, making them relevant for modern Physical Education programs.

Practically, the findings highlight the potential of traditional games to be integrated into university curricula as a strategy for enhancing social character and strengthening student relationships. The consistently high scores across aspects (4.20–4.50) confirm their effectiveness.

Theoretically, this research expands the understanding of mechanical solidarity in contemporary educational settings, especially amid increasing digital individualism. Future research is recommended to involve multiple universities, comparative designs, or longitudinal studies to examine long-term impacts on student behavior.

Acknowledgment

We offer all praise and gratitude to the presence of God Almighty, because with His abundant grace and blessings, this paper can be completed well.

The author would like to express his sincere appreciation and deepest gratitude to:

1. Physical Education Study Program, for the opportunity and support provided during the implementation of this research.
2. The students of Physical Education, Health, and Recreation, Class of 2023, Semester V, Class B, for their willingness to participate as participants and for their active involvement in research activities.
3. Family and friends, for their continued prayers, encouragement, and moral support throughout the research and writing process.

May all the help, prayers and support given be rewarded many times over by God Almighty.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)
e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle JTIKOR 10(2): 130-136 (November 2025) | DOI: 10.17509/jtikor.v10i2.91211

A Correlational Study of Body Mass Index (BMI) and Hemoglobin Levels with Cardiovascular Endurance in KOP Taekwondo Athletes at Universitas Negeri Jakarta

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Article Info

Article History

Submitted: October 16, 2025
Accepted: November 24, 2025
Published: November 25, 2025

Article Access

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Abstract

This cross-sectional correlational study aimed to analyze the relationship between Body Mass Index (BMI) and hemoglobin levels with cardiovascular endurance among athletes of the Achievement Sports Club (KOP) Taekwondo, State University of Jakarta. The research employed a quantitative approach with a correlational design. The sample consisted of 22 athletes selected through purposive sampling based on the inclusion criteria of being 19–21 years old and actively training for at least the last three months. BMI was obtained from body weight and height measurements, hemoglobin levels were measured using a digital EasyTouch GCHb device, and cardiovascular endurance was assessed using the Balke Test to estimate VO_2max values. Data analysis included the Kolmogorov–Smirnov normality test, linearity test, and Spearman and Pearson correlation tests according to the characteristics of the data. The results revealed no significant relationship between BMI and VO_2max ($r = -0.029$; $p = 0.900$) nor between hemoglobin levels and VO_2max ($r = 0.262$; $p = 0.238$). In conclusion, BMI and hemoglobin levels were not proven to significantly contribute to the cardiovascular endurance of KOP Taekwondo athletes. These findings suggest that coaches should monitor multiple physiological parameters beyond BMI and hemoglobin to optimize cardiovascular conditioning in taekwondo athletes.

Keywords: body mass index, cardiovascular endurance, hemoglobin, taekwondo.

Introduction

In combat sports like taekwondo, physiological factors such as BMI and hemoglobin play a critical role in performance, endurance, and recovery during multi round matches. Body Mass Index (BMI) or Indeks Massa Tubuh (IMT) is a simple indicator used to assess nutritional status based on the ratio of body weight to height. Although it has limitations, such as its inability to distinguish between muscle mass and fat, BMI remains one of the most widely used parameters in health and sports monitoring. In the athletic context, the use of BMI often sparks debate, as it may classify highly muscular athletes as overweight, even though physiologically they are healthy and fit (Nuttall, 2015). Recent studies have suggested adjusting BMI thresholds for athletic populations to more accurately represent their nutritional and health status (Nevill et al., 2021). Nevertheless, BMI continues to serve as a primary screening indicator due to its practicality, affordability, and ease of calculation, making it widely utilized in fitness and sports health research (García-Hermoso et al., 2019).

In the field of competitive sports, BMI is associated with muscle efficiency, body mass proportion, and athletic performance. Athletes with excessively high BMI may experience increased cardiac workload, limited mobility, and reduced metabolic efficiency. Conversely, a low BMI can indicate a lack of muscle mass and energy reserves, both essential for sustaining high-intensity activities (Salazar & Lankford, 2020). Research on collegiate athletes has shown that those with a normal BMI tend to demonstrate better fitness performance compared to those classified as obese or underweight (Li et al., 2022).

Aside from body composition, cardiovascular endurance or cardiorespiratory fitness is another crucial component of athletic performance. Cardiovascular endurance reflects the ability of the heart, lungs, and circulatory system to deliver oxygen to body tissues during physical activity. The primary indicator of this capacity is VO_2max, the maximum amount of oxygen the body can utilize during high-intensity exercise (Joyner & Coyle, 2018). In martial arts such as taekwondo, a high VO_2max is essential to support explosive movements, speed, and short recovery intervals. Athletes with low cardiovascular endurance tend to fatigue more quickly, leading to reduced technical accuracy and an increased risk of injury (Bridge et al., 2014). Recent studies also report that higher VO_2max values are a significant predictor of success for taekwondo athletes in multi-round competitions (Rocha et al., 2022).

Another physiological factor closely linked to cardiovascular endurance is hemoglobin concentration. Hemoglobin, a protein in red blood cells responsible for oxygen transport, plays a key role in delivering oxygen to muscle tissues. Higher hemoglobin levels increase the blood's oxygen-carrying capacity, thereby enhancing VO_2max (Faude et al., 2018). Conversely, low hemoglobin levels reduce oxygen supply to muscles, accelerating fatigue (Sharma & Marwaha, 2021). Studies on adolescent taekwondo athletes have demonstrated a positive relationship between hemoglobin concentration and cardiorespiratory fitness, with athletes possessing optimal hemoglobin levels performing better in fitness tests compared to those with lower levels (Istiqomah et al., 2022). This finding aligns with previous literature identifying hemoglobin as a key determinant of aerobic capacity and athletic performance (Burtscher et al., 2019).

In the context of university sports development, monitoring BMI and hemoglobin levels is crucial for designing safe and effective training programs. The Taekwondo Performance Sports Club (KOP) at Universitas Negeri Jakarta serves as a platform for nurturing student athletic talent and requires physiological data to ensure a structured training process. However, to date, there has been no specific study examining the relationship between BMI, hemoglobin levels, and cardiovascular endurance among collegiate taekwondo athletes. Such information is essential as a scientific foundation for developing training programs tailored to athletes' physiological needs (Tuan et al., 2020). Despite prior studies on general athletes, no study has specifically examined how BMI and hemoglobin levels related to cardiovascular endurance in collegiate taekwondo athletes, limiting evidence base training design. This study hypothesizes that BMI and hemoglobin levels are significantly related to cardiovascular endurance among taekwondo athletes.

Methods

Research Design

This study employed a quantitative approach with a cross-sectional correlational design, conducted from June to July. The purpose of this design was to analyze the relationship between Body Mass Index (BMI), hemoglobin levels, and cardiovascular endurance in athletes. Ethical approval was obtained from the Research Ethics Committee, Faculty of Sport Science, Universitas Negeri Jakarta.

Participants

The research population consisted of 50 active athletes registered in the Taekwondo Performance Sports Club (KOP) at Universitas Negeri Jakarta. The sample was selected using a purposive

sampling technique based on the following inclusion criteria: (1) active athletes aged 19–21 years, and (2) having participated in regular training for at least the past three months. Based on these criteria, a total of 22 athletes (7 males and 15 females) were included in the study.

Instrument

Body Mass Index (BMI), hemoglobin levels, and cardiovascular endurance were measured using validated and reliable instruments. Body weight was assessed using a digital scale, while body height was measured with a stadiometer (±0.1 cm), and BMI was calculated using the WHO (2004) formula. These anthropometric instruments demonstrate high reliability (ICC > 0.95) and the BMI formula has been widely validated in athletic populations. Hemoglobin levels were obtained using a portable EasyTouch GCHb device through fingertip capillary blood sampling, following WHO (2010) procedures. Portable hemoglobin analyzers have shown excellent reliability (ICC = 0.94–0.97) and strong validity when compared with laboratory hematology analyzers, with typical measurement bias below 1 g/dL (Von Schenck et al., 1986). Cardiovascular endurance was assessed using the Balke 15-minute running test, in which total distance covered was converted to VO_2max using the formula developed by McArdle, Katch, and Katch (2015). The Balke Test has been shown to possess high reliability (ICC = 0.86–0.90) and strong validity (r = 0.80–0.90) relative to direct gas analysis.

Procedure

Data collection followed a standardized chronological sequence. Participants first completed an informed consent form. Subsequently, anthropometric measurements (body weight and height) were recorded, followed by hemoglobin assessment and finally the Balke running test. All measurements were conducted between 15:00–17:00 WIB under stable environmental conditions (27–29°C, outdoor synthetic track). Athletes were instructed to avoid strenuous physical activity for 24 hours prior to testing and to maintain normal hydration.

Data Analysis

Data were analyzed using SPSS. The Kolmogorov–Smirnov test was used to examine data normality. Linearity between variables was tested using ANOVA-based regression analysis. Pearson correlation was used for normally distributed and linear variables, while Spearman correlation was applied to variables with non-normal distributions or non-linear relationships. Statistical significance was set at $p < 0.05$, and results were interpreted based on correlation coefficients (r) and significance values to determine the presence or absence of relationships among BMI, hemoglobin levels, and VO_2max.

Results

This study was conducted on athletes who are members of the Taekwondo Performance Sports Club (KOP) at Universitas Negeri Jakarta. The total number of subjects in this research was 22 athletes (based on available data). The variables examined included Body Mass Index (BMI), hemoglobin levels, and VO_2max as an indicator of cardiovascular endurance.

The Kolmogorov–Smirnov normality test was conducted to examine whether the distribution of the research variables met the assumption of normality. The results (Table 1) indicated that hemoglobin ($p = 0.200$), VO_2max ($p = 0.116$), and BMI ($p = 0.200$) were normally distributed, as all p-values exceeded the significance threshold of 0.05. These findings confirm that the three variables showed no significant deviation from a normal distribution, allowing the use of parametric statistical procedures for subsequent correlation analyses.

The normal distribution of all physiological variables suggests consistent performance characteristics among the Taekwondo athletes, with no extreme outliers affecting the dataset. This supports the stability and representativeness of the measurements.

The linearity test was conducted to determine whether the relationships between the independent variables and VO_2max met the assumption of linearity. The results indicated that BMI did not meet the linearity assumption ($p = 0.002$), as illustrated in Figure 1. Meanwhile, hemoglobin demonstrated a linear relationship with VO_2max ($p = 0.069$), which is shown in Figure 2. These results indicate that parametric correlation analysis (Pearson) is appropriate for hemoglobin–VO_2max, whereas non-parametric analysis (Spearman) is more suitable for the BMI–VO_2max relationship due to its non-linear pattern.

The linearity test indicated that the relationship between BMI and VO_2max was non-linear ($p < 0.05$). Therefore, the relationship between these variables could not be analyzed using the Pearson correlation test. Instead, the analysis was conducted using the Spearman correlation test, which is more appropriate for data that are non-normally distributed or exhibit a non-linear relationship.

Because BMI and VO_2max did not meet the linearity assumption, the non-parametric Spearman correlation test was used. The results (Table 2) showed a correlation coefficient (r) of –0.029 with a significance value of 0.900 (> 0.05), indicating a very weak, negative, and statistically

Table 1
Tests of Normality

Variable	Kolmogorov–Smirnov Statistic	df	Sig.	Shapiro–Wilk Statistic	df	Sig.
Hemoglobin (HB)	.123	22	.200	.925	22	.098
VO_2max	.166	22	.116	.941	22	.206
Body Mass Index (BMI)	.117	22	.200	.944	22	.235

Note. Lilliefors significance correction applied.

Table 2
Spearman Correlation Between BMI and VO_2max

Variable	1	2
1. Body Mass Index (BMI)	—	−.029
2. VO_2max	−.029	—
Spearman's rho		
p (2-tailed) = .900		
N = 22		

Table 3
Pearson Correlation Between Hemoglobin Levels and VO_2max

Variable	1	2
1. VO_2max	—	.262
2. Hemoglobin (HB)	.262	—
Pearson correlation		
p (2-tailed) = .238		
N = 22		

insignificant relationship. Moreover, the negative sign of the coefficient indicates an opposite direction of the relationship; however, due to its minimal strength, this direction has no practical implication. The significance value far above 0.05 confirms that the observed relationship is not statistically significant. Therefore, it can be concluded that BMI has no meaningful influence on cardiovascular endurance among athletes of the Taekwondo Performance Sports Club (KOP) Universitas Negeri Jakarta.

The linearity test indicated that the relationship between hemoglobin levels and VO_2max was linear (p > 0.05). Therefore, the analysis of the relationship between these two variables was conducted using the Pearson correlation test, which is appropriate for normally distributed data and linear relationships.

Based on the interpretation guidelines above, the researcher concluded that the relationship between BMI and VO_2max (r = −0.029; p = 0.900) is very weak and not significant. As shown in Table 3, the correlation coefficient was r = 0.262 with p = 0.238 (> 0.05), indicating a weak and statistically insignificant relationship.

The results of the Pearson correlation analysis showed a correlation coefficient (r) of 0.262 with a significance value of 0.238. The r-value, which falls within the range of 0.20–0.39, indicates a positive but weak relationship, meaning that an increase in hemoglobin levels tends to be followed by an increase in VO_2max, although the relationship is not strong. However, since the significance value is greater than 0.05, this relationship is not statistically significant and cannot be generalized to a larger population. Therefore, it can be concluded that hemoglobin levels do not have a significant effect on cardiovascular endurance among KOP Taekwondo UNJ athletes.

Figure 1
Results of the Linearity Test Between BMI and VO_2max (SPSS Output)

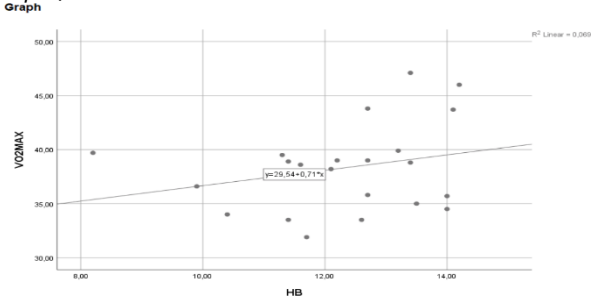
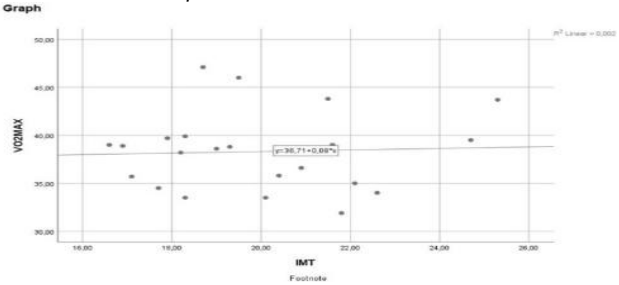


Figure 2
Results of the Linearity Test Between Hemoglobin Levels and VO_2max (SPSS Output)



Discussion

The findings of this study indicate that neither Body Mass Index (BMI) nor hemoglobin levels showed a significant relationship with cardiovascular endurance (VO_2max) among KOP Taekwondo athletes. These results contrast with several previous studies that reported a negative association between higher BMI and lower aerobic capacity, particularly in athletes whose sports require repeated high-intensity movements. For example, Bridge et al. (2014) and Salazar & Lankford (2020) highlight that excess body mass may increase metabolic cost during movement in combat sports, thereby reducing endurance efficiency. Similarly, Li et al. (2022) and Wang et al. (2021) found that higher BMI tends to correlate with lower physical fitness levels in university and youth athletes.

However, the non-significant findings in the current study are also consistent with research suggesting that BMI is often an imprecise predictor of endurance because it cannot differentiate between fat mass and lean mass. Combat sports athletes—including Taekwondo practitioners—typically possess higher lean mass due to strength and conditioning training. As shown in Nevill et al. (2021), BMI frequently misclassifies muscular athletes as overweight even when their physiological performance is optimal. This aligns with the characteristics of the sampled athletes, where BMI may not accurately reflect their functional body composition or endurance potential.

The absence of a significant correlation between hemoglobin and VO_2max also differs from studies demonstrating that higher hemoglobin enhances oxygen-carrying capacity and improves aerobic performance. Meta-analyses by Burtscher et al. (2019) and reviews by Faude et al. (2018) and Sharma & Marwaha (2021) provide strong evidence of a positive relationship between hemoglobin levels and endurance capacity. More specifically, research on Taekwondo athletes by Istiqomah et al. (2022) showed that higher hemoglobin concentrations were associated with better physical fitness performances in adolescents. In contrast, the current study found no such relationship, suggesting that other factors may be influencing VO_2max more strongly in this population.

A possible explanation is the relatively narrow range of hemoglobin values within the sample, which reduces the variability necessary to detect significant associations. Restricted-range effects are common in trained athletes who generally maintain healthy hematological profiles due to regular training (Joyner & Coyle, 2018). This homogeneity may have limited the ability of hemoglobin to statistically differentiate VO_2max performance among participants.

Several confounding factors may also explain why no significant relationships were observed. Training intensity, frequency, and periodization may not have been uniform across athletes, potentially influencing VO_2max independently of BMI or hemoglobin. Nutritional factors—including iron intake—may have affected hemoglobin concentration, as noted by Sharma & Marwaha (2021). Hydration status can also influence blood parameters and endurance test performance. These uncontrolled variables may have introduced noise into the dataset, masking relationships that have been documented in controlled laboratory studies (Zouhal et al., 2019).

Despite these non-significant findings, the study still fulfills its research objective by providing empirical evidence on the relationship between BMI, hemoglobin levels, and cardiovascular endurance in a university Taekwondo population. The absence of correlations contributes to the growing understanding that BMI and hemoglobin—although useful for general health monitoring—may not serve as primary determinants of endurance performance in competitive Taekwondo athletes. This aligns with the recommendations by Bridge et al. (2014) and Rocha et al. (2022), who emphasize that Taekwondo performance depends more heavily on sport-specific conditioning, explosive power, and recovery ability rather than basic anthropometric or hematological measures alone.

From a practical perspective, coaches should interpret these results as a reminder that athlete monitoring should extend beyond basic markers such as BMI and hemoglobin. Regular aerobic capacity assessments through field-based or laboratory-based VO_2max tests, combined with body composition analysis and training load monitoring, may offer more meaningful insights into performance progression (García-Hermoso et al., 2019). Maintaining healthy BMI and hemoglobin levels remains important for overall readiness, but they should be considered supportive rather than decisive indicators of endurance performance.

This study has several limitations, including a relatively small sample size, which may have reduced statistical power to detect subtle associations. The use of an indirect VO_2max estimation (Balke Test) may introduce measurement error compared with more precise laboratory methods. Additionally, the study did not control for dietary intake, hydration status, training load, or body composition—variables that have been shown to influence endurance performance in past research (Tuan et al., 2020). Future studies should involve larger samples, incorporate direct

VO_2max measurement techniques, include detailed body composition analysis, and control for key physiological and nutritional variables to provide a more comprehensive understanding of endurance determinants in Taekwondo athletes.

Conclusions

This study found no significant relationship between Body Mass Index (BMI) or hemoglobin levels and cardiovascular endurance (VO_2max) among KOP Taekwondo athletes at Universitas Negeri Jakarta. BMI showed a very weak and insignificant negative association with VO_2max ($r = -0.029$; $p = 0.900$), while hemoglobin demonstrated a weak but statistically insignificant positive association ($r = 0.262$; $p = 0.238$). These findings indicate that neither BMI nor hemoglobin meaningfully contributes to aerobic capacity variation in this athlete population.

Practically, the results suggest that Taekwondo coaches should not rely on BMI or hemoglobin as primary indicators of endurance performance but should instead prioritize more specific physiological and performance-based assessments. For applied practice and future research, it is recommended to conduct regular monitoring of athletes' nutritional and hematological status, increase sample size, include additional variables such as body fat percentage, lung function, or hematocrit, and employ direct VO_2max measurement methods to enhance accuracy and deepen understanding of endurance determinants in combat sport athletes.

Acknowledgment

Researcher would like to express sincere gratitude to senior mentors Surya Aji Prasetyo, Audi Arya Saputra, and Naufal Rifqi Fahreza for their continuous guidance, support, and trust, which have greatly contributed to the researcher's personal and academic development.

The researcher also extends appreciation to Gandi Sedana Putra, Fastabikulkhoirot, and Kus Puruhita Bekti Dwipayana for being valuable discussion partners and sources of insight throughout the research process.

Deepest gratitude is dedicated to Sabrina Nur Aisyah, Julia Febrianti Bukit, and Satria Pinandita Widyasena for their unwavering support, encouragement, and presence through both challenging and joyful moments. Their emotional support has been truly meaningful and essential to the completion of this study.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)
e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle JTIKOR 10(2): 137-143 (November 2025) | DOI: 10.17509/jtikor.v10i2.91424

Boosting Explosive Power: The Impact of Squat Jump Training on Futsal Athletes

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Article Info

Article History
Submitted: October 22, 2025
Accepted: November 25, 2025
Published: November 26, 2025

Article Access

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Abstract

There are problems such as weakness in kicking, lack of accuracy in passing, low heading when jumping, kicks that are still lacking in power, dribling still looks often shaky in futsal. This study aims to determine the effect of squat Jump training on the results of leg muscle explosive power in SN Anjels Palembang Futsal athletes. A quasi-experimental method with a one group pretest posttest design. The sample consisted of 30 people, namely all SN Anjels Palembang futsal athletes. This research uses the data analysis technique Paired Sample T-Test. The results show that there is a significant influence of Squat Jump training on the results of leg muscle explosive power in SN Anjels Palembang futsal athletes with a calculated t of 15.546 and a t table of 2.045, with a significance value of 0.00 < 0.05 with an increase percentage of 34.03 %. the table above it is known that the correlation coefficient value is 0.926 with a significance value (Sig.) of 0.000. A significance value of 0.000 < 0.05 means that there is a relationship between the scores before and after Squat Jump Training and the Results of Leg Muscle Explosive Power in SN Anjels Palembang Futsal Athletes.

Keywords: explosive power, futsal athletes, squat jump training.

Introduction

Futsal is one of the most popular indoor sports that demands a combination of technical skills, tactical understanding, and high levels of physical fitness. Among the various physical components required, leg muscle explosive power plays a crucial role in supporting key performance aspects such as shooting, dribbling, passing accuracy, and jumping (Hardiyono, 2020; Kristanto, 2021). Explosive power can contribute to players in the form of fast and strong movements in the shortest possible time, this is certainly very important when switching from defense to attack (Iksan et al., 2023). Thus, increasing muscle explosive power is a top priority in improving the abilities of futsal athletes. The popularity of futsal among students in Indonesia, the results of field observations found several problems in the performance of futsal athletes. Common problems seen on the field are weak kicks, inaccurate passing, dribbling movements that are often shaky and unstable. The explosive power of muscle fitness is still considered low and has been identified as one of the main factors causing these problems to appear on the field, so it is necessary to have a type of training that can increase the explosive power of muscle fitness of futsal athletes effectively and efficiently so that with the expected increase in muscle power there will be an improvement in the game of futsal athletes. Several research results have linked leg muscle strength to the ability to play futsal, of course this needs to be studied further, such as the results of research, for example, Frayoga and (Frayoga & Afrizal, 2019) The results of the study stated that leg muscle power was significantly related to the accuracy of futsal athletes' challenges, (Jatra & Sarwaki, 2022) the results of other studies show positive results, namely, there is a relationship between shooting ability in soccer athletes. (Ekawati et al., 2021) emphasized its contribution to balance and stability during shooting.

Other studies also produce the same results that support the research results, namely that plyometric-based training methods can significantly increase lower leg explosive power, sprint speed, and agility in futsal players. Of course, squat jump training is a type of plyometric training, so the results of this study are in line with the results of the research (Andri Irawan, Nur Fitranto et al., 2024; Fernández-Gavira et al., 2021; Hasan et al., 2021) However, most of these studies focus on professional or adult athletes, raising major questions about the impact on student or amateur futsal players, especially in Indonesia, particularly in the province of South Sumatra..

Squat jump training, one form of plyometric exercise, has been proven effective for increasing leg muscle power. This exercise stimulates the stretch-shortening cycle, improving muscle elasticity and power output (Pratama & Erawan, 2019; Swari, 2021) It also has practical advantages: it requires no special equipment, can be done in limited space, and supports both strength and agility development (Maulidin et al., 2023). Many previous research results have analyzed squat jump exercises, but a gap was found in research that examined the specific effects of squat jump exercises on leg muscle explosive power among student and amateur futsal athletes, especially at the SN Angel Futsal futsal club, Palembang.

Based on this gap, the present study aims to determine the effect of squat jump training on leg muscle explosive power in SN Angel futsal athletes in Palembang City. The novelty of this research lies in its focus on implementing a systematic squat jump training program with controlled duration and intensity, specifically tailored to student-level futsal players a context that has received little empirical attention in Indonesia. “Does squat jump training have a significant effect on leg muscle explosive power among SN Angel futsal athletes in Palembang City?” The hypothesis of this study states that: There is a significant effect of squat jump training on the leg muscle explosive power of SN Angel futsal athletes.

Methods

This study used a quasi-experiment research method with a one group pretest posttest design. experiment is judged based on the difference between the pretest and posttest (Dharma, 2013; Sugiyono, 2023)

Research Design

A one-group pretest-posttest design is a quasi-experimental research design involving a single group of participants who are measured before and after receiving a specific treatment. This design aims to assess the effectiveness of an intervention by comparing pretest and posttest results within the same group. The absence of a control group limits this study to whether this increase really occurred due to the effects of the treatment or the presence of external factors, even though the researcher’s conducted observations over time. This design is also based on practical considerations, especially the limited number of participants. The total sample consisted of 30 amateur athletes and students, and dividing the population into two groups (experimental and control) would result in a smaller number of participants in each group, with the division of the population it can reduce the statistical results and

reliability of the research results, so the population was included in one experimental group and made a sample that received squat jump training, with tests carried out before and after treatment to measure any changes that occurred. However, the main limitation of this design lies in the absence of a control group, which makes it difficult to determine whether the observed changes are entirely due to the intervention.

Participants

The sample in this study amounted to 30 female futsal athletes with an age range of 17-25 years. This study employed a total sampling technique, in which the entire population was used as the research sample. There were no specific inclusion criteria for the participants, as the SN Angel club itself accommodates female players who are adolescents and young adults aged over 20 years.

Instrument

This study was conducted by comparing the pretest before being given the Squat Jump Exercise with the posttest after being given the Squat Jump Exercise. The instrument used in this study was Jump Df T.K.K-5414 Vertical Jump Meter reliability (R > .97). and validity (R > .95) (Aragon, 2021; Hakim et al., 2023).

Procedure

This study was conducted through several stages to determine the effect of squat jump training on the explosive power of leg muscles in SN Angels Palembang futsal athletes. The procedure is outlined as follows:

1. Preparation Stage: Prior to the treatment, the researcher communicated with the coaches and athletes of the SN Angel club to explain the purpose of the study. Letters of consent were obtained from the participants, and training equipment and a test instrument for muscle power, the Jump DF leg test, were prepared by obtaining a request for use from the Sriwijaya University Physical Education and Health Laboratory.
2. Pre-test: This was conducted to determine leg muscle power before treatment. In this stage, all participants underwent a leg muscle explosive power test using the Jump DF instrument at the Sriwijaya University Physical Education and Health Laboratory. The test was conducted under standardized conditions to ensure consistency across all participants.
3. Intervention (Treatment Phase): Participants participated in a structured squat jump training program designed to improve leg muscle explosive power. Training was conducted over 6 weeks, with 3 sessions per week, under the supervision of the research team and trainers. Each session consisted of 3 sets of 12–15 repetitions of squat jumps, performed at moderate to high intensity (approximately 70–85% of maximal effort), with 60–90 seconds of rest between sets. The exercises were applied progressively, with intensity adjusted to the participants' abilities to maximize explosive power while minimizing injury risk, with 3 sessions per week.
4. Posttest: After the training period has been carried out for 6 weeks, a post-test is then carried out with the same instrument as when conducting the pre-test, namely using the Jump DF test, which is carried out under the same conditions on the sample. The purpose of this post-test is to measure changes in explosive leg power due to the treatment in the form of squat jump training, so that it can be measured whether there is an increase or not after the treatment.

Data Analysis

Normality Test: The normality of the data was examined using the Kolmogorov–Smirnov test. This test was performed to determine whether the pretest and posttest data were normally distributed. A significance level of $\alpha = 0.05$ was

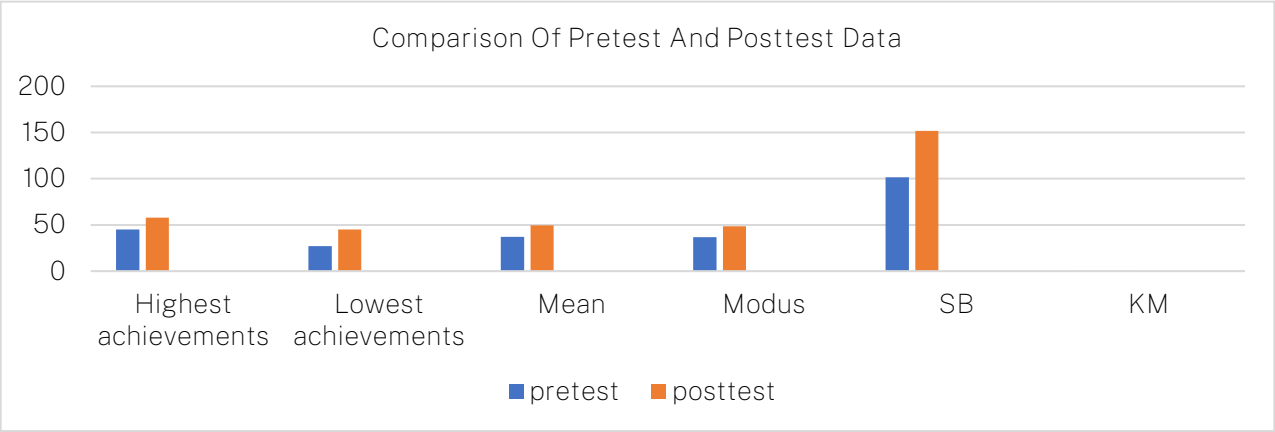
Table 1

Improvement of Pretest and Posttest Results of Squat Jump on Limb Muscle Explosiveness Results

Result	N	Highest achievements (cm)	Achievements Lowest (cm)	Mean	Comparison of mean *pretest* and *posttest*	Modus	SB	Km
Pretest	30	45	27	37.02	12.6	36.7	101.43	0.003
Posttest	30	58	45	49.62		48.58	151.88	0.006

Figure 1

Histogram of Pretest and Posttest Statistical Values of SN Angels Palembang Futsal Athletes



applied; if p > 0.05, the data were considered normally distributed, whereas p < 0.05 indicated a deviation from normality. Homogeneity Test: To verify that the sample groups originated from a homogeneous population, a homogeneity test was conducted using ANOVA on the pretest and posttest data. A significance level of $\alpha = 0.05$ was applied; if p > 0.05, the data were considered homogeneous, while p < 0.05 indicated heterogeneity. Ensuring homogeneity is important before conducting hypothesis testing. Hypothesis Test: After confirming that the data met the assumptions of normality and homogeneity, a paired-sample t-test was used to compare the mean pretest and posttest scores. This test was applied to examine the effect of the squat jump training on leg muscle explosive power. The significance level was set at $\alpha = 0.05$; results with p < 0.05 were considered statistically significant, indicating a significant difference between pretest and posttest performance, namely by comparing the mean between group 1 (pretest) and group 2 (posttest) (Budi, 2021; Sugiyono, 2023) the value of t count < than t table, then Ha is rejected, if t count > greater than t table, then Ha is accepted.

Results

The results in this study, the *pretest* data obtained the highest achievement in cm is 45 cm and the lowest is 27 cm, the average value is 37.02 which is included in the moderate category, mode 36.7, standard deviation 101. 43, and the slope of the curve is 0.003 while the results of the *posttest* data obtained the highest achievement in cm is 58 cm and the lowest is 45 cm, the average value is 49.62 cm in the good category, mode 48.58 cm, standard deviation 151. 88 and the slope of the curve is 0.006.

Table 1. shows the positive impact the training intervention has had on the athletes with regard to the squat jump. In the pretest, the participants had 27 cm and 45 cm as the lowest and highest scores, respectively, with a mean of 37.02 cm. After completing the squat jump training program, however, there was a remarkable improvement, with the highest score being 58 cm, the lowest 45 cm, and an average of 49.62 cm. The mean of 12.6 cm demonstrates a remarkable improvement in lower-limb explosive strength. The increase in the mean and mode values provides evidence of a reliable increase in performance for all participants. Furthermore, the increase in values of the standard deviation and the coefficient of variation provide evidence of a greater posttest score spread, which most likely reflects the individual training effect variances.

Data in Table 1 is complemented by Figure 1, depicting a unidirectional trend over the entire span of the squat jump score assessments. The majority of athletes improved the jump height during the training sessions, as evidenced by the histogram. This suggests that the squat jump exercises were effective in improving the lower limb muscle explosiveness of SN Angels Palembang futsal players.

In the Table 2 is known that the average pretest value is 37.02 < the average posttest value is 49.62 with 30 respondents. This means that descriptively there is a difference in the average score of leg muscle explosive power results for SN Angels Palembang Futsal Athletes.

In the Table 3 is known that the correlation coefficient value is 0.926 with a significance value (Sig.) of 0.000. A significance value of 0.000 < 0.05 means that there is a relationship between the scores before and after Squat Jump Training and the Results of Leg Muscle

Table 2

Staltistics

	Mean	N
Pretest	37.02	30
Posttest	49.62	30

Table 3

Correlation

	Correlation	Sig.
Pretest and Posttest	0.926	0.000*

Table 4

Paired Sample Test

	t	Sig.
Pretest and Posttest	-15.546	0.000*

Explosive Power in SN Anjels Palembang Futsal Athletes.

In the Table 4 is known that the Sig value. (2-tailed) is 0.000 < 0.05 so H0 is rejected and Ha is accepted so it can be concluded that there is a difference in the average score before and after squat jump training on the results of leg muscle explosive power in SN Angels Palembang Futsal athletes.

Discussion

The current study shows that six weeks of squat jump training significantly enhances the lower-limb explosive power in female futsal athletes. This result aligns with the study's objective, which aimed to determine if a structured plyometric intervention would improve the explosiveness of leg muscles in this specific population. From a biomechanical perspective, the efficacy of squat jump training can be attributed to changes involving the stretch–shortening cycle (SSC). The squat jump consists of an eccentric contraction followed by a rapid concentric contraction, which optimally achieves the storage and retrieval of elastic energy, enhances the neuromuscular coordination, and elevates the rate of force production. These changes are described in recent works (Behm et al., 2025; Stone et al., 2024; Wenchao et al., 2025) In contrast with recent studies, carried a 6-week plyometric training (Shuai et al., 2025) program with sprinters, showing a 28.5% improvement in squat jump power and the explosive gains retention after 2 weeks of detraining. (Xiao et al., 2023) analyzed the fast SSC plyometric training with female rhythmic gymnasts and reported important advancements in both fast and slow SSC strength qualities. (Cao et al., 2024) conducted a systematic review and meta-analysis of female basketball players, demonstrating that the plyometric training, and plyometric training to improve vertical jump, linear sprint and COD performance in female soccer players (Pardos-mainer et al., 2021), physical training enhanced the thickness, pennation angle, and fascicle length of the muscles assessed. Furthermore, plyometric exercises serve as a valuable method for boosting tendon stiffness and enhancing lower body strength and jump performance(Ramírez et al., 2022). The plyometric training program can increase muscle volume in the lower limbs and legs, increase the rate of force development, and shorten the jumping time, thereby enhancing explosive strength (Huang & Huang, 2023). Therefore, based on this study, squat jump training can improve explosive power in female futsal athletes.

Nonetheless, some limitations must be considered. First, it is difficult to isolate improvements as being due solely to squat jumps, as no control group is established (other changes such as regular training in futsal or maturation may also be a factor). Second, a single sample of 30 athletes from 1 club is bound to limit the generalizability of the findings. Third, though the 6-week time frame is long enough to produce short term changes, it is not enough to observe long term changes, a retention effect, or a plateau effect. In practical terms, these findings indicate that futsal coaches should incorporate squat jump–based plyometric training in their conditioning workouts, especially for the explosive training of actions that involve rapid accelerations, jumping, or powerful kicking. Since squat jumps require little to no equipment, they can be done in a variety of training situations. Recommendations for future investigations include: A comparison of squat jump

training to other plyometric strategies (such as depth jumps or bounding, or mixed plyometric protocols) for determining the best method to improve explosive power in futsal players. The performance of a larger sample randomized controlled trial that includes both males and females and different clubs, and the addition of biomechanical instruments (like force plates, EMG) to analyze neuromuscular adaptation.

Conclusions

The conclusion of this study is that there is an increase in explosive power of leg muscles due to the treatment of squat jump training carried out for 6 weeks on futsal athletes SN Anjels Palembang, with this finding it is hoped that squat jump training can be used as one type of training to increase leg muscle endurance so that it can improve the ability to play futsal. This study suggests that future research compares squat jump training with other plyometric training to determine which approach provides more significant results.

Acknowledgement

The researcher would like to express sincere gratitude to all parties who contributed to the completion of this study entitled "Boosting Explosive Power: The Impact of Squat Jump Training on Futsal Athletes."

First and foremost, deep appreciation is extended to the participants—30 female futsal athletes from the SN Angel club—who willingly devoted their time, energy, and commitment to take part in the pretest and posttest sessions. Without their cooperation, this research would not have been possible.

The researcher also conveys heartfelt thanks to the coaches and management of the SN Angel futsal club for granting permission, providing support, and facilitating the implementation of the squat jump training program throughout the study.

Special thanks are addressed to the academic advisors and lecturers who offered guidance, insightful feedback, and continuous encouragement during the research process. Their expertise greatly contributed to the refinement and completion of this work.

Lastly, the researcher is grateful to friends and family for their unwavering moral support, motivation, and understanding throughout the research journey.

With the contributions of all these parties, this study was able to be completed smoothly. The researcher hopes that this work can provide meaningful benefits for the development of training methods aimed at improving explosive power in futsal athletes.

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JTIKOR
(Jurnal Terapan Ilmu Keolahragaan)

e-ISSN: 2549-6360 | homepage: ejournal.upi.edu/index.php/JTIKOR/index
email: jtikor@upi.edu | DOI: 10.17509/jtikor.v10i2

Original Arcticle | JTIKOR 10(2): 144-150 (November 2025) | DOI: 10.17509/jtikor.v10i2.92854

Effects of Goal-Based Undulating Periodization on Muscular Endurance Development

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Article Info

Article History

Submitted: October 16, 2025
Accepted: November 24, 2025
Published: November 30, 2025

Article Access

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Abstract

Training programs that are designed and structured through periodization provide maximum improvement effects. Therefore, the periodization used must be appropriate to the expected goals for improving athletes' physical condition. One such method is undulating periodization, which provides many changes in stimulation and recovery periods that are more conducive to increasing strength. The purpose of this study was to determine the application of the undulating periodization training model based on training objectives for improving muscle endurance. The research method used was an experiment with a one-group pretest-posttest design, and the sample consisted of 10 PPLP athletes with disabilities. The undulating periodization model had a significant impact on improving the athletes' physical abilities, especially in terms of strength. Thus, the application of the undulating periodization training model based on training objectives had an effect on improving muscle endurance.

Keywords: periodization, undulating, muscle endurance.

Introduction

In the context of high-performance sports, the achievement of national elite athletes is profoundly influenced by the coach's capacity to optimize the physiological, technical, and psychological potential of their athletes. Nevertheless, performance limitations among elite athletes frequently originate from coaches' inability to fully develop these capacities, largely due to inadequate knowledge and competencies—particularly in the domain of physical conditioning (Sidik et al., 2019). A recurrent issue observed in the field is the lack of precision in determining appropriate training doses and selecting the specific components of training that correspond with the physiological demands of the sport and the individual needs of the athlete. This challenge becomes even more pronounced in circumstances characterized by uncertain or congested competition calendars. Such limitations in understanding comprehensive and sport-specific physical development at the elite level constitute a significant obstacle to achieving peak performance.

To attain superior athletic performance, the implementation of structured, systematic, and purposefully designed training is indispensable. A well-planned physical conditioning program, tailored to the specific bioenergetic and biomechanical demands of the sport, is essential for enhancing the functional capacities that serve as the foundation of competitive success (Sidik et al., 2019). Within this framework, training periodization plays a pivotal role. Periodization refers to a long-term planning strategy that systematically manipulates key training variables—including intensity, volume, frequency, and recovery duration—to optimize physiological adaptation and ensure the athlete reaches peak performance at predetermined times (Naclerio et al., 2013).

Among the various periodization models, linear and undulating periodization are two of the most widely implemented. Undulating periodization, in particular, is characterized by frequent fluctuations in training intensity and volume on a daily or weekly basis. This model provides a broader range of stimuli and allows more frequent neuromuscular recovery compared to traditional linear approaches (Buford et al., 2007). Such characteristics make it especially suitable for elite athletes who must cope with intensive, unpredictable, and often overlapping competitive schedules. Empirical studies have demonstrated that undulating periodization is highly effective in producing significant gains in muscular strength, which subsequently contributes to improvements in muscular endurance, movement efficiency, speed, agility, and injury resilience (Hartmann et al., 2015; Raiola & D'Isanto, 2016).

Given these considerations, a deeper investigation into the influence of undulating periodization on muscular endurance development among elite athletes is both relevant and necessary. Enhanced scientific understanding of this model will equip coaches with evidence-based strategies for designing adaptive and optimized training programs that align with athletes' physiological profiles, competitive demands, and recovery needs. Ultimately, such advancements are expected to contribute meaningfully to the elevation of athletic performance at the national and international stages.

Methods

This study employed an experimental research method. Experimental research is a methodological approach in which the researcher deliberately attempts to influence a particular variable, and when implemented appropriately, it is considered the most rigorous method for testing assumptions. The defining characteristic of experimental research is the researcher's ability to manipulate the independent variable. This includes determining what will occur to the participants, selecting who will be examined, and establishing the extent and conditions under which the manipulation takes place. In an experimental study, the researcher examines all aspects of one independent variable or multiple independent variables and observes their effects on the dependent variable(s) (Fraenkel, Wallen, & Hyun, 2012).

Research Design

The research design utilized in this study was the One-Group Pretest–Posttest Design. In this design, measurements or observations are conducted on a single group both before and after the treatment is administered. Such a design allows researchers to determine whether changes in the dependent variable occur following the implementation of the intervention (Fraenkel, Wallen, & Hyun, *How to Design and Evaluate Research in Education*, 2012).

The general structure of the One-Group Pretest–Posttest Design can be illustrated in the following table:

Table 1. Research Design: One-Group Pretest–Posttest Design

O_1	X	O_2
Pretest	Treatment	Postest

Description:

- O_1 represents the pretest measurement of muscular endurance.

- X represents the undulating periodization treatment.
- O_2 represents the posttest measurement of muscular endurance.

Participants

The study was conducted in the Sport Arcamanik complex in Bandung from March to June 2025. Training sessions were held three times per week, with frequency and training objectives determined based on established principles and norms of training load to ensure that the targeted outcomes were achieved. The participants involved in this study were athletes from the West Java PPLP Disability Program.

Population and Sample

To obtain the necessary data, the study required a clearly defined population. The population refers to the larger group to which the results of the study are intended to be generalized (Fraenkel, Wallen, & Hyun, *How to Design and Evaluate Research in Education*, 2012). It includes individuals who possess the characteristics of interest to the researcher and from whom the researcher seeks to draw conclusions. The population in this study consisted of 28 athletes from the 2025 West Java PPLP Disability Program.

A sample is a subset of the population that possesses the characteristics required for the study. Sampling refers to the process of selecting individuals, groups, or objects from which data will be collected (Fraenkel, Wallen, & Hyun, 2012). The sampling technique used in this study was purposive sampling, based on specific criteria: (1) male athletes and (2) individuals with complete and functional limbs. Based on these criteria, 10 athletes were selected from the population to form the study sample.

Instrument

Research instruments are measurement tools used to collect the necessary data. The instruments employed in this study were as follows:

- Upper-body muscular endurance was assessed using the Cadence Push-Up Test and the Wall Squat Test (Mackenzie, 2005).
- The treatment consisted of an undulating periodization training program, structured according to the intended training goals, including hypertrophy, muscular endurance, and power development.

Data Analysis

The data analysis technique used to evaluate the effects of undulating periodization on muscular endurance components was the Paired Sample t-test. This analysis aimed to determine whether the application of undulating periodization produced significant improvements in upper-body and lower-body muscular endurance. Data processing was conducted using SPSS Version 2.6. Hypothesis testing in this study served as the analytical stage to statistically examine whether the research questions could be answered based on the collected data and computed statistical values.

Results

To draw meaningful conclusions from the study, the data that had been collected were subsequently processed to provide interpretable scores. Data processing in research is essential for determining the answers to the research questions formulated earlier. In this study, data analysis was carried out using the Statistical Product and Service Solutions (SPSS) software, Version 26.

The following section presents the descriptive data obtained from the pretest and posttest measurements of muscular endurance for both the upper and lower body. Descriptive data for upper-body muscular endurance were derived from the push-up test, whereas lower-body muscular endurance data were obtained through the wall squat test, as shown in Table 1.

Based on the descriptive results, it is evident that both upper-body and lower-body muscular endurance improved after the implementation of the undulating periodization training program based on specific training goals. These findings suggest that the undulating training program contributed to measurable improvements in muscular endurance.

Results of the Paired Sample t-Test

The paired sample t-test was conducted to determine whether there was a significant effect or improvement in muscular endurance for both the upper and lower body following the intervention. Data processing was performed using SPSS, and the analysis compared the pretest and posttest scores for upper-body and lower-body muscular endurance. The SPSS output is summarized in Table 1.

Table 1

Descriptive Statistics of Upper and Lower Body Muscular Endurance Tests

Variable	**Pre-test *M***	**Pre-test *SD***	**Post-test *M***	**Post-test *SD***	***t*(9)**	***p***
Push Up (repetitions)	5.70	1.89	12.50	2.84	−15.84	< .001
Wall Squat (seconds)	47.70	9.15	78.50	12.05	−14.92	< .001

From Table 1, the significance value (Sig.) for lower-body muscular endurance was found to be 0.000. The decision-making criteria for hypothesis testing were as follows:

Hypotheses:

a) H_0: There is no significant improvement in lower-body muscular endurance resulting from the implementation of undulating periodization based on training goals.

b) H_1: There is a significant improvement in lower-body muscular endurance resulting from the implementation of undulating periodization based on training goals.

Decision Criteria:

a) If the significance value (Sig.) > 0.05, then H_0 is accepted.

b) If the significance value (Sig.) < 0.05, then H_0 is rejected.

Because the significance value for lower-body muscular endurance was 0.000 < 0.05, it can be concluded that the undulating training program produced a statistically significant improvement in lower-body muscular endurance.

Similarly, the significance value (Sig.) for upper-body muscular endurance was also 0.000. The hypotheses for this component were as follows:

Hypotheses:

a) H_0: There is no significant improvement in upper-body muscular endurance resulting from the implementation of undulating periodization based on training goals.

b) H_1: There is a significant improvement in upper-body muscular endurance resulting from the implementation of undulating periodization based on training goals.

Decision Criteria:

a) If the significance value (Sig.) > 0.05, then H_0 is accepted.

b) If the significance value (Sig.) < 0.05, then H_0 is rejected.

Given that the significance value for upper-body muscular endurance was 0.000 < 0.05, it can be concluded that the undulating periodization training program led to a statistically significant improvement in upper-body muscular endurance.

Discussion

This study was conducted to answer the research questions previously formulated: (1) Does the implementation of undulating periodization based on specific training goals result in a significant improvement in lower-body muscular endurance? (2) Does the implementation of undulating periodization based on specific training goals result in a significant improvement in upper-body muscular endurance?

Based on the results of data processing and statistical analysis, the findings indicate the following:

First, the implementation of undulating periodization based on training goals produced a significant improvement in lower-body muscular endurance. This was evidenced by the higher posttest scores compared to the pretest scores. Second, the implementation of undulating periodization also resulted in a significant improvement in upper-body muscular endurance, as demonstrated by the increased posttest scores relative to the pretest measurements.

These results lead to the conclusion that undulating periodization—structured around hypertrophy, muscular endurance, and power training—provides a positive and measurable impact on improving muscular endurance in both the lower and upper body.

Furthermore, the paired sample t-test results showed significance values lower than the critical t-value for both lower-body and upper-body muscular endurance. This statistical outcome confirms that the undulating training program based on specific training goals contributed significantly to improvements in muscular endurance among West Java PPLP Disability athletes.

These findings support the use of undulating periodization as a recommended training strategy for coaches, especially when preparing athletes for competitions with limited preparation time. This is consistent with the argument of Peixoto et al. (2022), who reported that daily undulating periodization results in greater strength improvements and is an attractive strategy for enhancing body composition, strength, and muscular endurance. Similarly, Franchini et al. (2015) found that a daily undulating periodization (DUP) model produced superior strength improvements compared to a non-periodized single-set program in collegiate female tennis players. Additionally, a study by Lian-Yee Kok et al. (2009) titled *Enhancing Muscular Qualities in Untrained Women: Linear versus Undulating Periodization*, involving 20 untrained women over a 3-week intervention, showed a significant improvement of 41.2%. Their findings reinforce the effectiveness of undulating periodization in enhancing muscular strength, particularly in trained female athletes.

Therefore, to achieve optimal training outcomes aligned with performance targets, coaches must design training programs that correspond to the athletes' needs, conditions, and competitive schedule. Given that elite athletes often face closely spaced competitions, the use of conventional or traditional periodization may not be feasible due to the extensive time required to

develop all fitness components progressively. Consequently, undulating periodization based on training goals serves as a more suitable, effective, and efficient model—especially when time constraints demand rapid yet targeted physical adaptation.

Conclusions

Based on the results of data processing and statistical analysis, the following conclusions can be drawn:

1. The implementation of undulating periodization based on specific training goals produced a significant improvement in upper-body muscular endurance.
2. The implementation of undulating periodization based on specific training goals also produced a significant improvement in lower-body muscular endurance.

Acknowledgement

The researcher would like to express sincere gratitude to all individuals and institutions that contributed to the successful completion of this study. First and foremost, deepest appreciation is extended to the academic advisors and lecturers whose guidance, constructive feedback, and unwavering support greatly assisted the researcher throughout the research process.

Special thanks are also conveyed to the participants who willingly devoted their time and effort to take part in the training interventions. Their commitment and cooperation made it possible to collect the data required for analyzing the effects of undulating training on upper- and lower-body muscular endurance.

The researcher further acknowledges the invaluable support from colleagues, friends, and all parties within the institution who provided encouragement, facilities, and assistance during the stages of data collection and analysis.

Finally, heartfelt appreciation is extended to the researcher's family for their continuous motivation, patience, and moral support. Without their understanding and encouragement, this research would not have been completed successfully.

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