



Training methods and motor educability predict lay-up performance in basketball competitive players

Los métodos de entrenamiento y la educabilidad motora predicen el rendimiento en bandejas en jugadores de baloncesto competitivos

Authors

Rury Rizhardi ¹
Bambang Priyono ¹
Nasuka ¹
Hadi ¹
Harry Pramono ¹
Heny Setyawati ¹

¹ Universitas Negeri Semarang (Indonesia)

Corresponding author:
Rury Rizhardi
ruryrizhardi@students.unnes.ac.id

Received: 04-02-26
Accepted: 27-04-26

How to cite in APA

Rizhardi, R., Priyono, B., Nasuka, N., Hadi, H., Pramono, H., & Setyawati, H. (2026). Training methods and motor educability predict lay-up performance in basketball competitive players. *Retos*, 80, 807-820. <https://doi.org/10.47197/retos.v80.118723>

Abstract

Introduction: Lay-up shooting is a fundamental offensive skill that significantly influences scoring effectiveness in basketball; however, empirical evidence on its multifactorial determinants in Southeast Asian competitive contexts remains limited.

Objective: This study aimed to examine the effects of training method (part vs. whole), motor educability, and practice density on lay-up shooting performance, as well as to compare the relative contribution of each predictor among competitive players.

Methodology: A 2 × 2 factorial experimental design was employed involving 80 competitive basketball players (60 males, 20 females; M age = 18.5 ± 2.3 years) recruited from clubs and university teams. Motor educability was measured using the Iowa Brace Motor Educability Test, practice density was monitored through systematic time-sampling, and lay-up performance was assessed using an AAHPERD-adapted shooting test. Data were analyzed using hierarchical multiple regression and two-way ANOVA.

Results: The results indicated that motor educability accounted for 42.5% of the variance in lay-up performance ($R^2 = 0.425$; $p < 0.001$). The inclusion of practice density increased the explained variance by 17.8% ($\Delta R^2 = 0.178$; $p < 0.001$), while training method contributed an additional 7.5% ($\Delta R^2 = 0.075$; $p = 0.003$), resulting in a total R^2 of 0.678. A significant interaction effect between training method and motor educability was observed ($F(1,76) = 8.34$, $p = 0.005$, $\eta^2 = 0.099$), indicating that whole figure training is more effective for athletes with higher motor educability.

Conclusions: These findings highlight the importance of individualized training approaches, emphasizing motor educability assessment and optimal practice density to enhance lay-up performance.

Keywords

Basketball training; lay-up shooting; motor educability; practice density; skill acquisition.

Resumen

Introducción: El tiro en bandeja es una habilidad ofensiva fundamental que influye significativamente en la eficacia de anotación en el baloncesto; sin embargo, la evidencia empírica sobre sus determinantes multifactoriales en contextos competitivos del Sudeste Asiático sigue siendo limitada.

Objetivo: Este estudio tuvo como objetivo examinar los efectos del método de entrenamiento (parte vs. global), la educabilidad motriz y la densidad de práctica sobre el rendimiento del tiro en bandeja, así como comparar la contribución relativa de cada predictor en jugadores competitivos.

Metodología: Se empleó un diseño experimental factorial 2 × 2 con 80 jugadores de baloncesto (60 hombres, 20 mujeres; edad media = 18.5 ± 2.3 años) provenientes de clubes y equipos universitarios. La educabilidad motriz se evaluó mediante el Iowa Brace Motor Educability Test, la densidad de práctica se registró mediante muestreo sistemático del tiempo y el rendimiento del tiro en bandeja se midió con una prueba adaptada de la AAHPERD. Los datos se analizaron mediante regresión múltiple jerárquica y ANOVA de dos vías.

Resultados: Los resultados mostraron que la educabilidad motriz explicó el 42.5% de la varianza ($R^2 = 0.425$; $p < 0.001$). La densidad de práctica incrementó la varianza explicada en un 17.8% ($\Delta R^2 = 0.178$; $p < 0.001$), mientras que el método de entrenamiento aportó un 7.5% adicional ($\Delta R^2 = 0.075$; $p = 0.003$), alcanzando un R^2 total de 0.678. Se observó una interacción significativa entre método de entrenamiento y educabilidad motriz ($F(1,76) = 8.34$, $p = 0.005$), indicando que el entrenamiento global es más eficaz en atletas con alta educabilidad motriz.

Conclusiones: Estos hallazgos destacan la importancia de enfoques de entrenamiento individualizados para optimizar el rendimiento del tiro en bandeja.

Palabras clave

Entrenamiento de baloncesto; tiro en bandeja; educabilidad motora; densidad de práctica; adquisición de habilidades.

Introduction

Basketball has evolved into one of the most widely participated and spectated sports globally, with an estimated 450 million active players across 213 national federations worldwide (Amaro et al., 2022; Begu et al., 2023). The sport demands a sophisticated integration of physical attributes, technical proficiency, tactical awareness, and psychological resilience. Among the fundamental skills that comprise basketball competency, the lay-up shot holds particular significance because it represents one of the most frequently attempted close-range scoring techniques and serves as a foundation for more complex offensive maneuvers (Burkaitė et al., 2025; Huston & Grau, 2003).

The lay-up shot is biomechanically complex, requiring the coordinated execution of approach footwork, ball handling, vertical propulsion, body control, and precise ball release, often under defensive pressure (Boonsom & Bungmark, 2024; Okazaki et al., 2015). Because the lay-up integrates locomotor coordination, object control, spatial judgment, and timing, its successful execution depends not only on repeated technical practice but also on the interaction between the athlete's motor learning capacity and the structure of the training environment (Li et al., 2026; Maarseveen & Oudejans, 2018). In competitive basketball, lay-up proficiency contributes substantially to offensive efficiency, making it a meaningful indicator of individual skill development and team performance.

In the Indonesian context, basketball has experienced substantial growth in participation and competitive development, particularly in urban centers such as Palembang City, South Sumatra. Despite this growing prominence, there remains a notable deficit in empirically grounded training methodologies specifically validated for Indonesian athlete populations. This evidence gap is important because training models developed in other contexts may not automatically transfer to local athlete populations with different developmental experiences, coaching structures, and competitive exposure. Therefore, research is needed to identify which training-related and learner-related variables most strongly explain basketball skill performance in Indonesian competitive settings.

The scientific literature on basketball skill acquisition has been predominantly informed by motor learning theories emphasizing the interaction between task complexity, learner characteristics, and practice conditions (Svoboda et al., 2024; Tani et al., 2014). Two principal training approaches are frequently discussed: part training, which decomposes complex skills into constituent components practiced separately before integration (Hillman, 2019), and whole training, which emphasizes practice of the complete skill sequence from the outset (Healy et al., 2014; Kimoto et al., 2024). The effectiveness of these approaches is not necessarily universal. Rather, prior research suggests that training method efficacy may depend on the complexity of the task and the learner's capacity to process and organize movement information (Hansen et al., 2005; Sattelmayer et al., 2016).

Motor educability, defined as an individual's capacity to acquire new motor skills with speed and precision, represents a theoretically important learner-related factor in sport performance contexts (Bompa & Buzzichelli, 2019; Davids et al., 2021; Hands et al., 2018). Athletes with higher motor educability may be better equipped to detect relevant movement information, adapt to task constraints, and integrate multiple components of a complex motor skill. The Iowa Brace Motor Educability Test has been used as a standardized assessment to identify individual differences in general motor learning potential and has demonstrated acceptable psychometric properties across athletic populations (Abeles et al., 2023; Anderson et al., 2021).

Practice density, conceptualized as the ratio of active engagement time to total practice session duration, has emerged as a critical determinant of skill acquisition efficiency (Ericsson & Lehmann, 1996; Gabbett et al., 2017). In basketball training, practice density reflects the amount of meaningful, task-relevant repetition available to the athlete during a session. Higher practice density may accelerate skill acquisition by increasing active exposure to movement problems, feedback opportunities, and corrective repetitions. Contemporary load-monitoring research also suggests that well-managed practice density can enhance learning outcomes while controlling physiological stress and reducing unnecessary non-productive training time (Afonso et al., 2021; Sandbakk et al., 2025).

From an integrative theoretical perspective, lay-up shooting performance can be understood as the outcome of a dynamic interaction between learner characteristics, task structure, and practice conditions.



Within an ecological dynamics and constraints-led framework, motor educability represents an organismic constraint that reflects the athlete's capacity to perceive, adapt, and coordinate movement solutions during skill acquisition (Liu, 2023; Pugliese et al., 2023). Training method represents a task-related constraint because part and whole approaches structure the complexity, sequencing, and information available to the learner in different ways (Dehghansai et al., 2020). Practice density, in turn, functions as a practice-environment constraint that determines the amount of active, skill-relevant engagement available for stabilizing and refining movement patterns. Therefore, these variables should not be viewed as isolated predictors, but as interdependent components of an explanatory model of basketball skill performance. Athletes with higher motor educability may be better able to benefit from whole training because they can process the complete movement sequence more efficiently, whereas athletes with lower motor educability may require part training to reduce cognitive and coordinative demands (Maudrich et al., 2021). Similarly, higher practice density may amplify the effects of both training method and motor learning capacity by increasing meaningful repetitions and reducing non-productive practice time (Christiansen et al., 2020).

Despite the substantial body of research addressing basketball skill development, several critical gaps persist. First, the majority of studies have been conducted in Western contexts, with limited attention to Southeast Asian athlete populations. Second, investigations examining the interactive effects of training methods, individual differences in motor learning capacity, and practice characteristics on basketball-specific skill outcomes remain scarce. Third, rigorous factorial experimental designs that combine experimental manipulation with predictive modeling remain limited, particularly in competitive athlete samples. Consequently, the theoretical and practical mechanisms through which training method, motor educability, and practice density jointly explain lay-up performance remain insufficiently understood.

The present investigation was designed to address these gaps by examining the predictive relationships between training method, motor educability, and practice density on lay-up shooting performance in competitive basketball players from Palembang City, Indonesia. Specifically, this study aimed to: (1) examine the relationship between training method, namely part versus whole training, and lay-up shooting performance; (2) analyze the relationship between motor educability and lay-up shooting performance; (3) assess the association between practice density and lay-up shooting performance; and (4) determine the combined predictive contribution and interaction effects of these variables within an explanatory model of lay-up performance.

Method

Participants

A total of 80 competitive basketball players were recruited from basketball clubs, high school teams, and university basketball programs in Palembang City, South Sumatra, Indonesia. The sample comprised 60 male athletes (75.0%) and 20 female athletes (25.0%), with ages ranging from 16 to 23 years ($M = 18.5$, $SD = 2.3$ years). All participants had a minimum of two years of competitive basketball experience ($M = 4.8$, $SD = 1.9$ years), were actively participating in organized training at least three times per week, and reported no current musculoskeletal injuries precluding full participation. Athletes with prior formal exposure to the specific training protocols or who could not commit to the full 12-week intervention were excluded. Demographic characteristics are summarized in Table 1.

Table 1. Demographic Characteristics of Study Participants (N = 80)

Variable	n (%)	M	SD
Age (years)	80 (100)	18.5	2.3
Sex			
Male	60 (75.0)	-	-
Female	20 (25.0)	-	-
Basketball Experience (years)	80 (100)	4.8	1.9
Height (cm)	80 (100)	175.3	8.7
Body Mass (kg)	80 (100)	68.4	9.2

Note. M = Mean; SD = Standard Deviation



Sample size determination was conducted a priori using G*Power 3.1 software (Faul et al., 2009). Based on a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, power = 0.80, and three predictor variables, a minimum of 77 participants was required. To account for potential attrition, 80 participants were enrolled, and all completed the study protocol.

Study Organization: 2 × 2 Factorial Experimental Design

This study employed a 2 × 2 factorial experimental design with two independent variables: (1) training method (part training vs. whole training) and (2) motor educability level (high vs. low), assessed via median split. Practice density was included as a continuous predictor variable. The dependent variable was post-intervention lay-up shooting performance. The research was conducted over 12 weeks (February to April 2024), comprising a one-week baseline assessment, a ten-week training intervention, and a one-week post-intervention evaluation. Participants were stratified into high and low motor educability groups using a median split ($Mdn = 14$), and then randomly assigned within each stratum to part training ($n = 40$) or whole training ($n = 40$) using computer-generated randomization sequences. The experimental design is detailed in Table 2.

The implementation of both training methods followed distinct but systematically structured protocols. Table 2 provides a comprehensive summary of the training method application, session parameters, and standardized testing conditions employed in this study.

Table 2. Implementation of Training Methods, Session Parameters, and Testing Conditions

Aspect	Part Training (n = 40)	Whole Training (n = 40)
Training Approach	Lay-up components practiced in isolation before progressive integration	Complete lay-up sequence practiced from outset with increasing contextual variability
Weekly Progression	Wks 2-3: Approach footwork; Wks 4-5: Ball handling & approach run; Wks 6-7: Vertical take-off; Wks 8-9: Release & finishing; Wks 10-11: Full integration	Wks 2-4: Basic lay-ups (no opposition); Wks 5-7: Lay-ups vs. passive defense; Wks 8-11: Lay-ups under game-realistic conditions
Session Duration	90 minutes per session	90 minutes per session
Frequency	3 sessions per week	3 sessions per week
Total Sessions	30 sessions (10 weeks × 3 sessions/week)	30 sessions (10 weeks × 3 sessions/week)
Supervision & Fidelity	Certified basketball coaches; 2-day pre-intervention protocol workshop; independent fidelity checks on 25% of all sessions	
Testing Conditions (Both Groups)		
Test Timing	Week 1 (baseline) and Week 12 (post-intervention); consistent time of day per participant	
Venue & Equipment	Regulation indoor court; basket height 3.05 m; official ball specifications; standardized court surface and controlled lighting	
Test Procedure	20 lay-up attempts (10 right-side, 10 left-side); standardized 3-step approach from initiation zone ≈4 m from basket	
Scoring	Successful shot = 2 pts; correct technique without score = +1 pt; maximum total = 40 pts	
Evaluators & Reliability	Two certified evaluators scoring independently; Test-retest reliability $r = 0.89$; minimum 24-hour rest prior to each test session	

Note. Both training conditions shared identical session duration, frequency, total sessions, venue, and testing protocols. Differences pertained exclusively to the method of skill presentation (segmented vs. holistic). Wks = Weeks.

Table 3. Research Design and Experimental Procedures

Design Aspect	Description
Research Design	2 × 2 factorial experimental
Independent Variable 1	Training Method (Part vs. Whole Training)
Independent Variable 2	Motor Educability Level (High vs. Low, median split)
Continuous Predictor	Practice Density (% active engagement time)
Dependent Variable	Lay-up Shooting Performance (0-40 points)
Research Duration	12 weeks (February-April 2024)
Study Phases	Baseline (Week 1); Intervention (Weeks 2-11); Post-test (Week 12)
Randomization Method	Computer-generated stratified randomization
Training Setting	Standardized indoor basketball facilities, Palembang City
Training Supervision	Certified basketball coaches trained with standardized protocols

Instrument and Measurement Procedures

Three primary instruments were employed to assess the independent and dependent variables. Their descriptions, scoring systems, reliability, validity, and classification criteria are presented in Table 4.



Table 4. Description of Research Instruments and Measurement Procedures

Variable / Instrument	Measurement Description	Scoring	Reliability / Validity	Classification / Output
Motor Educability (Iowa Brace Test)	21 stunt items assessed capacity to learn new motor skills under standardized conditions	Dichotomous: pass = 1, fail = 0; Total: 0-21	$\alpha = 0.78$; Test-retest $r = 0.85$	\geq Median (14): High ME; $<$ Median: Low ME
Practice Density	% of active skill-related engagement relative to total session duration via 30-second time-sampling	PD (%) = (Active Time / Total Time) \times 100	ICC = 0.91 (on 20% of sessions)	Continuous percentage score
Lay-Up Shooting Performance (AAHPERD-adapted)	20 attempts (10 right-side, 10 left-side) under standardized conditions	Success = 2 pts; Correct technique = +1 pt; Max = 40 pts	Test-retest $r = 0.89$; Two certified evaluators	Total performance score (accuracy + technique)

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics Version 26 (IBM Corp., Armonk, NY, USA). Prior to inferential testing, descriptive statistics (means, standard deviations, ranges) were computed for all study variables. Data normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots and histograms. Homogeneity of variance was evaluated using Levene's test.

A two-way Analysis of Variance (ANOVA) was performed to examine the main effects of training method and motor educability level on lay-up performance, as well as their interaction effect. Hierarchical multiple regression analysis was employed to evaluate the sequential contribution of predictor variables: Step 1 entered motor educability; Step 2 added practice density; Step 3 included training method (dummy-coded: whole training = 1, part training = 0).

The order of entry in the hierarchical regression model was specified a priori according to motor learning theory. Motor educability was entered in Step 1 because it represents a learner-related characteristic and a relatively stable organismic constraint influencing the capacity to acquire new motor skills. Practice density was entered in Step 2 because it reflects the amount and quality of active engagement during the intervention and therefore represents a practice-process variable beyond individual learning capacity. Training method was entered in Step 3 because it was the experimentally manipulated instructional condition; entering it last allowed the analysis to determine whether whole versus part training explained additional variance after controlling for both motor educability and practice density. Accordingly, the hierarchical model progressed from learner capacity, to practice exposure, and finally to instructional method.

Multicollinearity was assessed through Variance Inflation Factors (VIF) and Tolerance values. Effect sizes were reported as partial eta-squared (η^2) for ANOVA and R^2 change (ΔR^2) for regression. The significance threshold was set at $\alpha = 0.05$ for all tests.

Ethical Considerations

This study was reviewed and approved by the Research Ethics Committee of the Faculty of Sports Science, Universitas Negeri Semarang, Indonesia (Approval Number: B/8778/UN37.1.6/KM.07/2024, dated August 06, 2024). All procedures were conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013). Written informed consent was obtained from all participants prior to enrollment. For participants under 18 years of age, additional parental or guardian consent was secured. Participants were informed of their right to withdraw from the study at any time without penalty, and confidentiality of all personal data was maintained through de-identification procedures.

Results

Descriptive Statistics

Descriptive statistics for all study variables are presented in Table 5. Motor educability scores ranged from 8 to 19 points ($M = 13.65$, $SD = 2.84$), indicating substantial individual variation in motor learning capacity. Practice density across the intervention period averaged 76.3% ($SD = 8.7\%$), ranging from 58.2% to 92.4%. Post-intervention lay-up shooting performance scores ranged from 18 to 38 points ($M = 28.45$, $SD = 5.23$), representing 45–95% of the maximum possible score.



Table 5. Descriptive Statistics for Study Variables (N = 80)

Variable	M	SD	Min	Max	Range
Motor Educability (Iowa Brace Score)	13.65	2.84	8	19	11
Practice Density (%)	76.30	8.70	58.2	92.4	34.2
Lay-Up Performance (0-40)	28.45	5.23	18	38	20
Part Training Group (n = 40)	26.18	5.09	18	36	18
Whole Training Group (n = 40)	30.73	4.67	20	38	18
High Motor Educability (n = 40)	31.22	4.18	22	38	16
Low Motor Educability (n = 40)	25.68	5.08	18	34	16

Note. M = Mean; SD = Standard Deviation; Min = Minimum; Max = Maximum.

Assumption Testing

All statistical assumptions were evaluated prior to inferential analyses. The Shapiro-Wilk test confirmed normality of residuals ($W = 0.978$, $p = 0.186$). Levene's test indicated no violation of homogeneity of variance ($F(3,76) = 1.42$, $p = 0.244$).

Table 6. Summary of Statistical Assumption Testing

Assumption	Test / Method	Result / Statistic	Conclusion
Normality of Residuals	Shapiro-Wilk test; visual inspection of Q-Q plots and histograms	$W = 0.978$, $p = 0.186$	Normality confirmed; assumption met
Homogeneity of Variance	Levene's test	$F(3,76) = 1.42$, $p = 0.244$	No violation; assumption met
Absence of Outliers	Inspection of standardized residuals	No cases $ z > 3.0$	No influential outliers detected
Multicollinearity	Variance Inflation Factor (VIF) and Tolerance values	Tolerance > 0.60 ; VIF < 2.0 (all predictors)	Predictors are independent; no multicollinearity

Note. Assumption satisfied. All tests confirmed that the data met required statistical assumptions for proceeding with two-way ANOVA and hierarchical multiple regression analyses.

Examination of standardized residuals revealed no cases exceeding $|3.0|$, indicating absence of influential outliers. Multicollinearity diagnostics showed acceptable tolerance values (all > 0.60) and VIF values (all < 2.0), confirming independence among predictor variables.

Two-Way ANOVA: Main Effects and Interaction

A two-way ANOVA examined the main and interactive effects of training method and motor educability on lay-up performance. Results are presented in Table 6. A significant main effect was found for training method ($F(1,76) = 14.87$, $p < 0.001$, $\eta^2 = 0.164$), with whole training ($M = 30.73$, $SD = 4.67$) yielding significantly higher performance than part training ($M = 26.18$, $SD = 5.09$). A significant main effect was also found for motor educability ($F(1,76) = 38.54$, $p < 0.001$, $\eta^2 = 0.336$), with high motor educability athletes ($M = 31.22$, $SD = 4.18$) outperforming their low motor educability counterparts ($M = 25.68$, $SD = 5.08$).

Critically, a statistically significant interaction between training method and motor educability was observed ($F(1,76) = 8.34$, $p = 0.005$, $\eta^2 = 0.099$). Post-hoc simple effects analyses revealed that the advantage of whole training over part training was significantly larger for high motor educability athletes (Mean difference = 6.45 points, $p < 0.001$) than for low motor educability athletes (Mean difference = 2.62 points, $p = 0.041$). The interaction pattern presented in Figure 1 indicates that the difference in lay-up performance between whole training and part training was more pronounced among participants with high motor educability. Therefore, the observed performance pattern should be interpreted as a conditional association between training method and motor educability level, rather than as evidence of a direct causal mechanism.

Table 7. Two-Way ANOVA: Effects of Training Method and Motor Educability on Lay-Up Performance

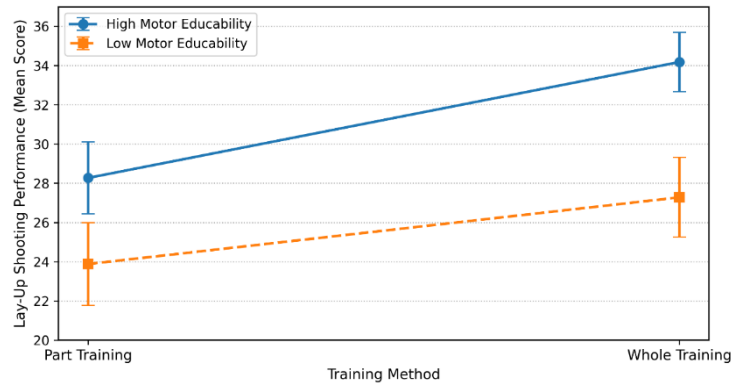
Source of Variation	SS	df	MS	F	p	η^2
Training Method (TM)	318.46	1	318.46	14.87	< 0.001	0.164
Motor Educability (ME)	824.31	1	824.31	38.54	< 0.001	0.336
TM \times ME Interaction	178.52	1	178.52	8.34	0.005	0.099
Error (Within groups)	1626.71	76	21.40	—	—	—
Total	2948.00	79	—	—	—	—

Note. SS = Sum of Squares; df = degrees of freedom; MS = Mean Square; η^2 = partial eta-squared.



The two-way ANOVA showed a significant interaction between training method and motor educability on lay-up shooting performance. Participants with high motor educability benefited more from whole training than from part training. This interaction pattern is presented in Figure 1.

Figure 1. Interaction Between Training Method and Motor Educability on Lay-Up Shooting Performance.



The interaction pattern is presented in Figure 1, showing that the advantage of whole training over part training was more pronounced among participants with high motor educability than among those with low motor educability.

Hierarchical Multiple Regression Analysis

Hierarchical multiple regression was conducted to evaluate the sequential contribution of motor educability, practice density, and training method to lay-up shooting performance. This sequence was consistent with the theoretical rationale described in the statistical analysis section, in which learner-related capacity was controlled first, followed by practice-process exposure and then instructional method. Results are presented in Table 8.

In Step 1, motor educability explained 42.5% of the variance in lay-up performance ($R^2 = 0.425$, $F(1,78) = 57.63$, $p < 0.001$). In Step 2, the inclusion of practice density significantly increased the proportion of explained variance ($\Delta R^2 = 0.178$, $\Delta F(1,77) = 26.49$, $p < 0.001$), resulting in a cumulative R^2 of 0.603. In Step 3, the addition of training method further increased explained variance ($\Delta R^2 = 0.075$, $\Delta F(1,76) = 17.22$, $p = 0.003$), producing a final model R^2 of 0.678. The final regression model was statistically significant ($F(3,76) = 53.41$, $p < 0.001$), indicating that the three predictors collectively accounted for 67.8% of the variance in lay-up performance.

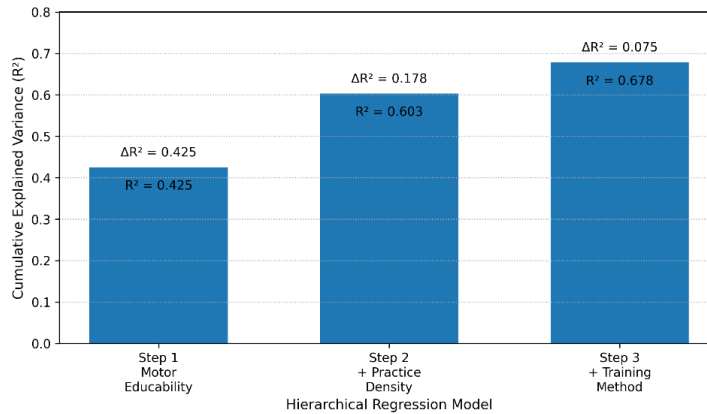
Within the final model, motor educability remained the strongest standardized predictor ($\beta = 0.548$, $p < 0.001$), followed by practice density ($\beta = 0.388$, $p < 0.001$) and training method ($\beta = 0.304$, $p = 0.003$). These results indicate that higher motor educability, greater practice density, and participation in whole-training conditions were each associated with higher lay-up performance scores, after accounting for the other predictors in the model.

Table 8. Hierarchical Multiple Regression Analysis Predicting Lay-Up Shooting Performance

Step / Predictor	B	β	t	p	ΔR^2	Cumulative R^2
Step 1	—	—	—	—	0.425***	0.425
Motor Educability	1.32	0.652	7.59	< 0.001	—	—
Step 2	—	—	—	—	0.178***	0.603
Motor Educability	1.18	0.582	7.14	< 0.001	—	—
Practice Density (%)	0.19	0.433	5.15	< 0.001	—	—
Step 3	—	—	—	—	0.075**	0.678
Motor Educability	1.11	0.548	6.89	< 0.001	—	—
Practice Density (%)	0.17	0.388	4.72	< 0.001	—	—
Training Method	3.14	0.304	4.15	0.003	—	—

Note. B = unstandardized regression coefficient; β = standardized coefficient; Training Method coded: 1 = Whole, 0 = Part. ** $p < 0.01$; *** $p < 0.001$

Figure 2. Hierarchical Regression Model Explaining Lay-Up Shooting Performance.



Note. Step 1 included motor educability, Step 2 added practice density, and Step 3 added training method. The final model explained 67.8% of the variance.

As shown in Figure 2, motor educability accounted for the largest proportion of explained variance in lay-up shooting performance at Step 1. The addition of practice density and training method further improved the model's explanatory capacity. These findings should be interpreted as evidence of predictive associations among the study variables, rather than as confirmation that any single predictor independently caused changes in lay-up performance.

Group Performance Comparisons

Table 9 presents mean lay-up performance scores across the four experimental groups formed by the 2 × 2 factorial design. High motor educability athletes in the whole training condition achieved the highest performance ($M = 34.18$, $SD = 3.22$), while low motor educability athletes in the part training condition recorded the lowest scores ($M = 23.88$, $SD = 4.51$). The pattern of results is consistent with the significant interaction effect identified in the two-way ANOVA.

Table 9. Mean Lay-Up Shooting Performance Scores Across Experimental Groups

Group	n	M	SD	95% CI
High ME + Whole Training	20	34.18	3.22	[32.67, 35.69]
High ME + Part Training	20	28.27	3.91	[26.44, 30.10]
Low ME + Whole Training	20	27.28	4.33	[25.25, 29.31]
Low ME + Part Training	20	23.88	4.51	[21.77, 25.99]

Note. ME = Motor Educability; M = Mean; SD = Standard Deviation; CI = Confidence Interval for the Mean.

Discussion

Interpretation of Research Outcomes

The present study showed that motor educability, practice density, and training method collectively accounted for 67.8% of the variance in lay-up shooting performance among competitive basketball players in Palembang City, Indonesia. These findings support a predictive model of basketball skill performance in which individual motor learning capacity, the density of active practice engagement, and the structure of training are meaningfully associated with lay-up shooting outcomes. Rather than implying direct causality, the results should be interpreted as evidence that these variables function as significant predictors of performance within the conditions of the present study.

Motor educability emerged as the strongest predictor of lay-up performance, explaining 42.5% of the variance. This finding is consistent with theoretical perspectives suggesting that general motor learning capacity is closely linked to the rate and quality of sport-specific skill acquisition (Anderson et al., 2021; Dewi et al., 2026). Athletes with higher motor educability scores tended to demonstrate higher lay-up performance, suggesting that the capacity to learn and coordinate new movement patterns may be an

important individual characteristic in basketball skill development. Accordingly, motor educability assessment may provide useful information for athlete profiling and training differentiation (Burkaitė et al., 2025).

Practice density also made a meaningful additional contribution to the prediction of lay-up performance. The increase in explained variance after the inclusion of practice density indicates that athletes who spent a greater proportion of training time in active, skill-related engagement tended to obtain higher lay-up scores. This finding is aligned with deliberate practice and training-monitoring perspectives, which emphasize that the quality and organization of practice time are important components of sport skill development (Abady et al., 2025; Guimarães et al., 2021). However, the present results should be interpreted as showing an association between practice density and performance, not as evidence that practice density alone directly caused improvements in lay-up shooting.

The significant interaction between training method and motor educability represents an important finding. Whole training was associated with higher lay-up performance, particularly among athletes classified as having high motor educability (Gaggioli et al., 2013; Moradi et al., 2023). In contrast, the difference between whole and part training was smaller among athletes with lower motor educability. This pattern suggests that athletes with greater motor learning capacity may be better positioned to manage the complexity of holistic skill practice, whereas athletes with lower motor educability may benefit from more structured and segmented learning progressions. This interpretation is consistent with cognitive-load and motor-learning perspectives, which suggest that the effectiveness of a training method may depend partly on the learner's ability to process and integrate complex movement information (Christiansen et al., 2020).

Comparison with Previous Research

The finding that motor educability was the dominant predictor of lay-up performance extends previous research showing that individual differences in motor skill learning capacity are associated with sport-specific performance. The magnitude of the association observed in the present study suggests that motor educability may be a relevant variable for understanding why athletes respond differently to similar training conditions (Abeles et al., 2023; Mizuguchi et al., 2021; Ranganathan et al., 2022).

The observed advantage of whole training among athletes with higher motor educability is also consistent with previous evidence indicating that whole-practice approaches may be particularly appropriate for skills characterized by strong interdependence among movement components (Fontana et al., 2009; Park et al., 2004). Because the lay-up requires coordinated footwork, ball control, take-off, body orientation, and finishing mechanics, practicing the complete movement sequence may provide a more integrated learning context for athletes who already possess sufficient motor learning capacity (Gaggioli et al., 2013). Nevertheless, the present findings should not be interpreted as showing that whole training is universally superior. Rather, the interaction effect indicates that its predictive association with performance depends on the athlete's motor educability level.

The role of practice density observed in this study also supports earlier work emphasizing the importance of active engagement during training. Players exposed to higher active practice proportions tended to demonstrate better lay-up outcomes, suggesting that efficient session organization may be relevant to basketball skill development (Larkin et al., 2022; Moradi et al., 2023). This finding is particularly important for applied coaching contexts, where training time is often limited and the organization of drills may influence the amount of meaningful skill repetition available to athletes.

In the Indonesian basketball context, the present study contributes novel evidence by integrating training method, motor educability, and practice density into a single predictive model. Previous studies have examined part and whole learning methods, but fewer have considered how individual motor learning capacity may moderate the relationship between training structure and basketball-specific performance (Burkaitė et al., 2025; Moradi et al., 2023). Therefore, the current findings provide a more differentiated understanding of how training approaches may be adapted to individual athlete characteristics.

Theoretical and Practical Implications

From a theoretical perspective, the findings contribute to motor learning and ecological dynamics frameworks by demonstrating that athlete-related constraints and task-related training structures are



jointly associated with skill performance. Motor educability may be understood as an organismic constraint that influences how athletes respond to different training formats (Woods et al., 2020). The significant interaction between motor educability and training method supports the view that skill acquisition is shaped by the dynamic relationship between the learner, the task, and the practice environment (Christiansen et al., 2020; Maarseveen & Oudejans, 2018).

From a practical standpoint, the findings suggest several implications for coaches and sport practitioners. First, motor educability assessment may be useful as part of pre-season athlete profiling, particularly when coaches need to design differentiated training programs. Second, whole training may be considered especially appropriate for athletes who demonstrate higher motor educability, as these athletes may be more capable of integrating complex movement sequences during holistic practice. Third, athletes with lower motor educability may require a more progressive part-training approach before being exposed to more complex whole-skill practice. Fourth, coaches may benefit from monitoring practice density to ensure that athletes spend an adequate proportion of training sessions in active, skill-relevant engagement.

Importantly, these recommendations should be viewed as practice-informed implications rather than definitive causal prescriptions. The findings indicate predictive and interactive patterns that may help guide coaching decisions, but further longitudinal and multi-site studies are needed to confirm whether these relationships remain stable across different athlete populations, competitive levels, and basketball skill domains.

Limitations and Future Research Directions

Several limitations should be acknowledged. First, the sample was drawn exclusively from basketball organizations in Palembang City, which may limit the generalizability of the findings to other Indonesian regions or international contexts. Future studies should include multi-site samples involving athletes from diverse competitive and cultural settings.

Second, the classification of motor educability into high and low groups was based on a median split. Although this approach was suitable for the factorial design, it may reduce the precision of individual differences. Future research should consider continuous moderation analyses to provide a more nuanced understanding of how motor educability interacts with training method.

Third, the 12-week intervention period does not permit conclusions regarding the long-term stability or retention of lay-up performance. Follow-up assessments conducted several months after the intervention would help determine whether the observed predictive patterns are maintained over time.

Fourth, the sample was predominantly male, which limits interpretation of possible sex-related differences in responses to training method and motor educability. Future research should aim for more balanced sex representation and examine whether sex moderates the relationship between training variables and lay-up performance.

Finally, the present study focused only on lay-up shooting performance. Future investigations should examine whether the predictive model identified here applies to other basketball skills, such as jump shooting, passing accuracy, dribbling under pressure, and defensive movement.

Conclusions

This study demonstrated that motor educability, practice density, and training method were significant predictors of lay-up shooting performance among competitive basketball players. The hierarchical regression model accounted for 67.8% of the variance in lay-up performance, with motor educability emerging as the strongest predictor, followed by practice density and training method. These findings suggest that individual motor learning capacity and the organization of practice are important factors associated with basketball skill performance.

The significant interaction between training method and motor educability indicates that the relationship between training structure and lay-up performance may depend on the athlete's motor learning capacity. Whole training was more strongly associated with higher lay-up scores among athletes with



high motor educability, whereas athletes with lower motor educability appeared to show a smaller performance difference between whole and part training. This pattern suggests that training methods should be selected with attention to individual learner characteristics rather than applied uniformly across all athletes.

From an applied perspective, coaches may consider incorporating motor educability assessment into athlete profiling, monitoring practice density during training sessions, and adjusting training methods according to athletes' learning characteristics. However, these implications should be interpreted as guidance based on predictive associations rather than as definitive causal recommendations. Further research using longitudinal designs, balanced sex representation, multi-site samples, and additional basketball skill outcomes is needed to strengthen the generalizability and practical application of these findings.

The present study contributes to basketball training research by providing empirical evidence from an Indonesian competitive context and by identifying motor educability as an important moderator in the relationship between training method and lay-up shooting performance. These findings may inform the development of more individualized and evidence-guided basketball training programs in Indonesia and similar sport development contexts.

Acknowledgements

This research was supported by the Beasiswa Pendidikan Indonesia (BPI)-Funded and managed by the Centre for Higher Education Funding and Assessment (Pusat Pembiayaan dan Asesmen Pendidikan Tinggi – PPAPT and the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia – (Lembaga Pengelola Dana Pendidikan - LPDP). The authors express sincere gratitude to the basketball players, coaches, and club administrators from Palembang City who generously contributed their time and expertise to this research endeavor. Special appreciation is extended to the State University of Semarang (Universitas Negeri Semarang) for providing institutional support and research facilities. The authors also acknowledge the valuable assistance of research assistants who contributed to data collection and analysis procedures.

Funding

This research was financially supported by the Indonesian Education Scholarship (Beasiswa Pendidikan Indonesia, BPI), administered by the Centre for Higher Education Funding and Assessment (Pusat Pembiayaan dan Asesmen Pendidikan Tinggi, PPAPT), Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, in collaboration with the Indonesia Endowment Fund for Education (Lembaga Pengelola Dana Pendidikan, LPDP). The funders had no role in the study design, data collection, analysis, interpretation, manuscript preparation, or decision to submit the article for publication.

Conflicts of Interest

The authors declare no conflicts of interest. The funding agency had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.



References

- Abady, A. N., Butar, P. W. M. B. B. P. W. M. B., Longakit, J., & Gordichev, V. G. V. (2025). Technological Innovations and Pedagogical Advancements in Basketball Skill Learning: A Systematic Review of High School Physical Education. *INSPIREE Indonesian Sport Innovation Review*, 6(2), 117. <https://doi.org/10.53905/inspiree.v6i02.149>
- Abeles, D., Herszage, J., Shahar, M., & Censor, N. (2023). Initial motor skill performance predicts future performance, but not learning. *Scientific Reports*, 13(1), 11359. <https://doi.org/10.1038/s41598-023-38231-5>
- Afonso, J., Nakamura, F. Y., Canário-Lemos, R., Peixoto, R., Fernandes, C., Mota, T., Ferreira, M., Silva, R., Teixeira, A., & Clemente, F. M. (2021). A Novel Approach to Training Monotony and Acute-Chronic Workload Index: A Comparative Study in Soccer. *Frontiers in Sports and Active Living*, 3, 661200. <https://doi.org/10.3389/fspor.2021.661200>
- Amaro, C. M., Gomes, B. B., Mendes, R., & Castro, M. A. (2022). *Journal of Physical Education and Sport*, 22(5). <https://doi.org/10.7752/jpes.2022.05159>
- Anderson, D. I., Lohse, K. R., Lopes, T. C. V., & Williams, A. M. (2021). Individual differences in motor skill learning: Past, present and future. *Human Movement Science*, 78, 102818. <https://doi.org/10.1016/j.humov.2021.102818>
- Begu, B., Miftari, F., Dalip, M., & Haxhnikaj, L. (2023). Comparing Situational and Motor Abilities Among Kosovo Junior Basketball Players in Super and Unique Leagues. *Physical Education Theory and Methodology*, 23(4), 552. <https://doi.org/10.17309/tmfv.2023.4.09>
- Bompa, T. O., & Buzzichelli, C. A. (2019). Periodization. In *Human Kinetics eBooks. Human Kinetics*. <https://doi.org/10.5040/9781718225435>
- Boonsom, N., & Bungmark, W. (2024). Effects of balance shooting training program on jump shot performance and dynamic balance in male basketball university players. *Journal of Physical Education and Sport*, 24(1). <https://doi.org/10.7752/jpes.2024.01023>
- Burkaitė, G., Figueira, B., Schöllhorn, W. I., Coutinho, D., & Paulauskas, R. (2025). Differential shooting training in youth basketball players: an analysis of performance effects. *Frontiers in Psychology*, 16, 1709103. <https://doi.org/10.3389/fpsyg.2025.1709103>
- Christiansen, L., Larsen, M. N., Madsen, M. A. J., Grey, M. J., Nielsen, J. B., & Lundbye-Jensen, J. (2020). Long-term motor skill training with individually adjusted progressive difficulty enhances learning and promotes corticospinal plasticity. *Scientific Reports*, 10(1), 15588. <https://doi.org/10.1038/s41598-020-72139-8>
- Davids, K., Fabian, & Rothwell, M. (2021). Adopting an ecological perspective on skill performance and learning in sport. *European Journal of Human Movement*, 46. <https://doi.org/10.21134/eurjhm.2021.46.667>
- Dehghansai, N., Lemez, S., Wattie, N., Pinder, R. A., & Baker, J. (2020). Understanding the Development of Elite Parasport Athletes Using a Constraint-Led Approach: Considerations for Coaches and Practitioners [Review of Understanding the Development of Elite Parasport Athletes Using a Constraint-Led Approach: Considerations for Coaches and Practitioners]. *Frontiers in Psychology*, 11. *Frontiers Media*. <https://doi.org/10.3389/fpsyg.2020.502981>
- Dewi, N., Sudijandoko, A., Nurhasan, N., Kartiko, D. C., & Pranoto, A. (2026). A systematic review and bibliometric analysis of motor performance factors influencing basketball shooting skills. *Retos*, 77, 628. <https://doi.org/10.47197/retos.v77.118311>
- Ericsson, K. A., & Lehmann, A. (1996). EXPERT AND EXCEPTIONAL PERFORMANCE: Evidence of Maximal Adaptation to Task Constraints. *Annual Review of Psychology*, 47(1), 273. <https://doi.org/10.1146/annurev.psych.47.1.273>
- Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, 41(4), 1149. <https://doi.org/10.3758/brm.41.4.1149>
- Fontana, F., Furtado, O., Mazzardo, O., & Gallagher, J. D. (2009). Whole and Part Practice: A Meta-Analysis. *Perceptual and Motor Skills*, 109(2), 517. <https://doi.org/10.2466/pms.109.2.517-530>
- Gabbett, T. J., Nassis, G. P., Oetter, E., Pretorius, J., Johnston, N., Medina, D., Rodas, G., Myslinski, T., Howells, D., Beard, A., & Ryan, A. (2017). The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. *British Journal of Sports Medicine*, 51(20), 1451. <https://doi.org/10.1136/bjsports-2016-097298>



- Gaggioli, A., Morganti, L., Mondoni, M., & Antonietti, A. (2013). Benefits of Combined Mental and Physical Training in Learning a Complex Motor Skill in Basketball. *Psychology*, 4(9), 1. <https://doi.org/10.4236/psych.2013.49a2001>
- Guimarães, E., Baxter-Jones, A., Williams, A., Tavares, F. H., Janeira, M. A., & Maia, J. (2021). Modelling the dynamics of change in the technical skills of young basketball players: The INEX study. *PLoS ONE*, 16(9). <https://doi.org/10.1371/journal.pone.0257767>
- Hands, B., McIntyre, F., & Parker, H. (2018). The General Motor Ability Hypothesis: An Old Idea Revisited. *Perceptual and Motor Skills*, 125(2), 213. <https://doi.org/10.1177/0031512517751750>
- Hansen, S., Tremblay, L., & Elliott, D. (2005). Part and Whole Practice: Chunking and Online Control in the Acquisition of a Serial Motor Task. *Research Quarterly for Exercise and Sport*, 76(1), 60. <https://doi.org/10.5641/027013605x13076330976786>
- Healy, A. F., Kole, J. A., & Bourne, L. E. (2014). Training principles to advance expertise. *Frontiers in Psychology*, 5, 131. <https://doi.org/10.3389/fpsyg.2014.00131>
- Hillman, K. M. (2019). Part-Task Training versus Whole-Task Training for Simple versus Complex Tasks. UTC Scholar (University of Tennessee at Chattanooga). <https://scholar.utc.edu/rcio/2019/sessions/40>
- Huston, R. L., & Grau, C. A. (2003). Basketball shooting strategies — the free throw, direct shot and layup. *Sports Engineering*, 6(1), 49. <https://doi.org/10.1007/bf02844160>
- Kimoto, Y., Hirano, M., & Furuya, S. (2024). Decomposition of a complex motor skill in learning improves experts' expertise. *Research Square* (Research Square). <https://doi.org/10.21203/rs.3.rs-4148558/v1>
- Larkin, P., Barkell, J., & O'Connor, D. (2022). The Practice Environment—How Coaches May Promote Athlete Learning [Review of The Practice Environment—How Coaches May Promote Athlete Learning]. *Frontiers in Sports and Active Living*, 4. *Frontiers Media*. <https://doi.org/10.3389/fspor.2022.957086>
- Li, Q., Quan, F., Li, L., & Wang, J. (2026). Cognitive-coordination training: impact on sport-specific physical fitness and technical skill of adolescent basketball athletes. *Frontiers in Psychology*, 16, 1669608. <https://doi.org/10.3389/fpsyg.2025.1669608>
- Liu, C. (2023). A Constraint-Led Approach: Enhancing Skill Acquisition and Performance in Sport and Physical Education Pedagogy. *Studies in Sports Science and Physical Education*, 1(1), 1. <https://doi.org/10.56397/ssspe.2023.06.01>
- Maarseveen, M. J. J. van, & Oudejans, R. R. D. (2018). Motor and Gaze Behaviors of Youth Basketball Players Taking Contested and Uncontested Jump Shots. *Frontiers in Psychology*, 9. <https://doi.org/10.3389/fpsyg.2018.00706>
- Maudrich, T., Kenville, R., Schempp, C., Noack, E., & Ragert, P. (2021). Comparison of whole-body sensorimotor skill learning between strength athletes, endurance athletes and healthy sedentary adults. *Heliyon*, 7(8). <https://doi.org/10.1016/j.heliyon.2021.e07723>
- Mizuguchi, N., Tsuchimoto, S., Fujii, H., Kato, K., Nagami, T., & Kanosue, K. (2021). Recognition capability of one's own skilled movement is dissociated from acquisition of motor skill memory. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-021-96381-w>
- Moradi, J., Maleki, M., & Moradi, H. (2023). The Effect of Part and Whole Practice on Learning Lay-Up Shot Skill in Young and Adolescent Male Students. *Journal of Motor Learning and Development*, 11(1), 143. <https://doi.org/10.1123/jmld.2022-0033>
- Okazaki, V. H. A., Rodacki, A. L. F., & Satern, M. N. (2015). A review on the basketball jump shot. *Sports Biomechanics*, 14(2), 190. <https://doi.org/10.1080/14763141.2015.1052541>
- Park, J.-H., Wilde, H., & Shea, C. H. (2004). Part-Whole Practice of Movement Sequences. *Journal of Motor Behavior*, 36(1), 51. <https://doi.org/10.3200/jmbr.36.1.51-61>
- Pugliese, E., Forte, & D'Anna, C. (2023). *Journal of Physical Education and Sport*, 23(9). <https://doi.org/10.7752/jpes.2023.09285>
- Ranganathan, R., Cone, S., & Fox, B. G. (2022). Predicting individual differences in motor learning: A critical review. *Neuroscience & Biobehavioral Reviews*, 141, 104852. <https://doi.org/10.1016/j.neubiorev.2022.104852>
- Sandbakk, Ø., Tønnessen, E., Sandbakk, S. B., Losnegard, T., Seiler, S., & Haugen, T. (2025). Best-Practice Training Characteristics Within Olympic Endurance Sports as Described by Norwegian World-Class Coaches. *Sports Medicine - Open*, 11(1), 45. <https://doi.org/10.1186/s40798-025-00848-3>



- Sattelmayer, M., Elsig, S., Hilfiker, R., & Baer, G. (2016). A systematic review and meta-analysis of selected motor learning principles in physiotherapy and medical education. *BMC Medical Education*, 16(1), 15. <https://doi.org/10.1186/s12909-016-0538-z>
- Svoboda, I., Bon, I., Rupčić, T., Cigrovski, V., & Đurković, T. (2024). Defining the Quantitative Criteria for Two Basketball Shooting Techniques. *Applied Sciences*, 14(11), 4460. <https://doi.org/10.3390/app14114460>
- Tani, G., Corrêa, U. C., Basso, L., Benda, R. N., Ugrinowitsch, H., & Choshi, K. (2014). An adaptive process model of motor learning: insights for the teaching of motor skills. *PubMed*, 18(1), 47. <https://pubmed.ncbi.nlm.nih.gov/24314130>
- Woods, C. T., McKeown, I., O'Sullivan, M., Robertson, S., & Davids, K. (2020). Theory to Practice: Performance Preparation Models in Contemporary High-Level Sport Guided by an Ecological Dynamics Framework. *Sports Medicine - Open*, 6(1). <https://doi.org/10.1186/s40798-020-00268-5>
- World Medical Association Declaration of Helsinki. (2013). *JAMA*, 310(20), 2191. <https://doi.org/10.1001/jama.2013.281053>

Authors' and translators' details:

Rury Rizhardi	ruryrizhardi@students.unnes.ac.id	Author
Bambang Priyono	bambangpriyono@mail.unnes.ac.id	Author
Nasuka	nasuka@mail.unnes.ac.id	Author
Hadi	hadi_pabbsi@mail.unnes.ac.id	Author
Harry Pramono	hpr4mono@mail.unnes.ac.id	Author
Henry Setyawati	henysetyawati@mail.unnes.ac.id	Author