COMPETITOR:
JURNAL PENDIDIKAN KEPELATIHAN OLAHRAGA
e-ISSN: 2657-0734 & p-ISSN: 2085-5389 || Volume 18, Number 1, 2026 || P.1045-1055

The Effect Of Microcontroller Technology Training On Improving Table Tennis Skills

Rohmad Apriyanto[1A-E]*, Mohamad Da'i[2B-D], Fredy Yudhantara[3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]

[1,2,3,4,5] Universitas Nahdlatul Ulama Sunan Giri Bojonegoro, Jawa Timur Indonesia

rohmadapriyanto87@unugiri.ac.id[1]*, dai@unugiri.ac.id[2], fredygepenk80@gmail.com[3], Dhanimaula56@gmail.com[4], mkhoirudinj@gmail.com[5]

ABSTRACT

Technology has become an integral component in the creation, management, and application of knowledge across various domains, including sport training. In the context of table tennis, microcontroller-based systems offer precise control of training variables such as ball speed, direction, and repetition, enabling structured and data-driven skill development. This study aimed to analyze the effect of microcontroller technology training on improving table tennis forehand skills. An experimental method with a one-group pretest-posttest design was employed. The sample consisted of 10 extracurricular table tennis athletes at SDN 2 Lohgung Lamongan, selected using a total population technique. The intervention involved a training program utilizing an Arduino-based automatic ball launcher with progressively increased sets, repetitions, and ball speeds. Forehand skill performance was measured using a standardized accuracy-based forehand test, assessing successful ball placement and consistency. Data were analyzed using a paired sample t-test at a significance level of 0.05. The results indicated a significant improvement in forehand performance, with a calculated t-value of 7.075 exceeding the t-table value of 1.833 and a significance value of 0.000 ($p < 0.05$). These findings demonstrate that progressive training using microcontroller-based ball launcher technology effectively enhances forehand accuracy, control, and consistency. The study supports the integration of microcontroller technology as an innovative and evidence-based training alternative for developing technical skills in young table tennis athletes.

ARTICLE HISTORY

Received: 2026/02/03
Accepted: 2026/02/16
Published: 2026/02/21

KEYWORDS

Microcontroller Technology;
Arduino Ball Launcher;
Table Tennis Training;
Forehand Skill;
Progressive Practice.

AUTHORS' CONTRIBUTION

A. Conception and design of the study;
B. Acquisition of data;
C. Analysis and interpretation of data;
D. Manuscript preparation;
E. Obtaining funding

Cites this Article : Apriyanto, R.; Da'i, M.; Yudhantara, F.; Ramdhani, N.M.; Jazali, M.K. (2026). The Effect Of Microcontroller Technology Training On Improving Table Tennis Skills. **Competitor: Jurnal Pendidikan Kepelatihan Olahraga**. 18 (1), p.1045-1055

INTRODUCTION

Digital transformation has fundamentally changed the landscape of education and sport over the past decade. A key challenge for sports practitioners at all levels is how to effectively integrate technology platforms into athlete development pathways to truly support learning and performance improvement. Technology opens up opportunities for athletes to access, analyze, and adapt performance information more precisely, while simultaneously increasing active engagement in learning from an early age through adulthood (McCosker et al., 2022). However, the use of learning technology also carries risks, such as device dependency, reduced pedagogical interaction, and biased data interpretation if not designed based on strong sport science principles.

In the realm of education, technological developments such as robotics, computational thinking, and STEM approaches have progressed rapidly. Bibliometric analysis of SSCI journals reveals three main clusters of robotics research in science education: robots in elementary education, robot-based STEM activities, and robots for facilitating computational thinking (Chiu et al., 2022). The integration of devices such as Arduino has even been implemented at the elementary level (García-Tudela & Marín-Marín, 2023), confirming that technological literacy is no longer the exclusive domain of higher education.

In the context of Indonesian higher education, the Independent Learning–Independent Campus (MBKM) policy aims to create adaptive, creative, innovative, and competitive individuals in accordance with the values of Pancasila (Sodik et al., 2021; Aji et al., 2020). However, the challenges of the VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) era demand technology-based learning that is not only innovative but also contextual and impactful (Bennett & Lemoine, 2014). The quality of human resources in higher education must be able to integrate creativity, innovation, and efficiency in professional practice (Bryan & Clegg, 2019).

In sports, achievement is determined by the synergy of athletes, coaches, organizations, infrastructure, and scientific and technological support (Putra & Kurniawan, 2020). In table tennis, empirical findings indicate that players' technical abilities are still dominated by the drive stroke (50%), while spin, block, chop, and push techniques are in the low category, with suboptimal accuracy and repetition (Apriyanto & Adi, 2022). This means that a training approach capable of improving ball speed, accuracy, and repetition in a structured manner is needed.

The development of augmented reality (AR)-based learning media has demonstrated high effectiveness (92.5% in the very good category) in improving reaction and timing in table tennis power spin techniques (Apriyanto et al., 2024). Furthermore, a preliminary study on the use of microcontrollers in table tennis learning showed an average score of 89.3% for indicators of ease of use, motivation, and learning engagement. However, there has been no experimental testing of the use of Arduino-based ball-throwing robots with varying speeds and systematic training program designs (progressive sets and repetitions) to improve playing skills.

Thus, the main problem of this research is how to empirically test the effectiveness of Arduino-based ball-throwing robot technology in improving table tennis technical skills, while supporting the implementation of MBKM and Education 4.0-based learning.

The integration of technology in sports has evolved through the use of wearable sensors, motion tracking, AI-based analytics, and robotic training systems (Woods et al., 2020; Rojas-Valverde et al., 2021). In table tennis, ball-launching technology has been used to improve shot consistency, timing control, and adaptation to spin variations (Kondrič et al., 2019). Modern biomechanical studies show that controlled repetition with varying speeds can improve neuromuscular coordination and movement accuracy (Fuchs et al., 2020).

Data-driven approaches in sports science enable objective measurement of physiological changes and movement techniques (Bishop et al., 2019). The validity and reliability of measurement tools are key prerequisites for evaluating athlete abilities (Hopkins, 2015). In the educational context, educational technology plays a crucial role in the implementation of Merdeka Belajar (Freedom to Learn) and Education 4.0, which emphasize creativity, collaboration, communication, and critical thinking (Sherly et al., 2021; Millati, 2021).

Research related to educational robotics shows that the use of robots increases engagement and problem-solving skills (Chiu et al., 2022). Arduino, as an open-source platform, provides flexible design for microcontroller-based control systems that are economical and easy to develop (Rosmanila et al., 2018). This technology integration aligns with the need to develop soft skills and digital literacy among the younger generation (Indarta et al., 2022).

Furthermore, the concept of academic challenge and a supportive campus environment play a significant role in increasing student engagement (Sari & Antoni, 2020). Technology-based project-based learning can increase intrinsic motivation and work readiness (Battou, 2017). Globally, technological mastery is a key indicator of human resource competitiveness in various sectors, including sports (Bidang et al., 2016).

Although numerous studies have examined the use of AR, robotics, and microcontrollers in education and sports, several significant research gaps remain.

First, most research focuses on media validation or user perceptions, rather than on experimental testing of specific technique performance improvements in competitive sports. Second, table tennis research focuses primarily on technique and biomechanical analysis without integrating microcontroller-based robotic systems specifically designed for progressive speed variation into structured training programs. Third, there is no collaborative model that integrates sports science approaches, Arduino robotics, and MBKM policies in the context of training prospective physical education teachers. Fourth, previous studies have not comprehensively linked table tennis technique skill improvement to quantitative indicators such as accuracy, response speed, and repetitions based on automated systems.

Therefore, there is an urgent need to develop and test a table tennis training model based on an Arduino ball-throwing robot with progressive speed variation and a systematic set-repetition design that is empirically evaluated using a quasi-experimental approach.

This research aims to: (1) Test the effectiveness of using an Arduino-based ball-throwing robot with varying speeds on improving table tennis technical skills, (2) Analyze the effect of a progressive training program (sets and repetitions) on accuracy, response speed, and shot consistency, and (3) Integrate a sports science approach and microcontroller technology within the framework of implementing MBKM and Education 4.0.

The novelty of this research lies in: (1) Development of an Arduino-based table tennis training model with progressive speed control; (2) Integration of performance evaluation based on objective quantitative indicators; (3) Multidisciplinary collaboration between sports science, robotics technology, and higher education pedagogy; and (4)

Development of a technology-based continuous learning roadmap for prospective physical education teachers.

Conceptually and empirically, this research contributes to strengthening sports technology literacy, improving the quality of MBKM-based learning, and developing a robotics-based table tennis training model that is adaptive to the challenges of the VUCA era and Education 4.0.

METHODS

This study employed an experimental approach with a one-group pretest–posttest design, which is conceptually effective for evaluating performance changes before and after an intervention in a controlled sports training context (Thomas, Nelson, & Silverman, 2015; Hopkins, 2015). This design allows for direct identification of the effect of microcontroller technology on improving table tennis forehand technique skills through comparison of initial and final scores (Bishop et al., 2019). This model is widely used in technology-based sports science research to test the effectiveness of specific training programs (Fuchs et al., 2020; Kondrič et al., 2019).

The study subjects were 10 fourth–sixth grade table tennis athletes actively participating in extracurricular activities at SDN 2 Lohgung Lamongan in 2025. The sampling technique used total sampling because the population was limited and all athletes met the inclusion criteria, namely actively training and participating in regional and national championships. This strategy is recommended in small-scale experimental studies to maximize the power of internal analysis (Cohen et al., 2018). Schools were selected based on their consistent performance coaching and the availability of facilities to support technology-based training.

The intervention consisted of a forehand training program using an Arduino microcontroller-based ball launcher robot, designed to progressively control the speed and frequency of ball throws. Arduino, as an open-source platform, allows for precise, systematic adjustment of speed parameters and repetition intervals (Rosmanila et al., 2018). The use of robotic ball launchers in table tennis has been shown to improve timing consistency, neuromuscular coordination, and adaptation to variations in ball speed (Kondrič et al., 2019; Rojas-Valverde et al., 2021). The training program was implemented over several weeks based on the principle of progressive overload, which involves gradually increasing the number of sets, repetitions, and ball speed to stimulate motor adaptation (Bompa & Buzzichelli, 2019; Bishop et al., 2019).

The measurement instrument was a forehand skills test that adhered to standard table tennis technique evaluation standards (Nurdin & Aminullah, 2020). Athletes performed a series of stroke attempts at predetermined target areas, and scores were calculated based on accuracy and consistency of success. Content validity was tested through expert judgment, while internal reliability was assessed using the Alpha coefficient (Hair et al., 2019). This accuracy- and repetition-based measurement approach aligns with recommendations for modern table tennis performance indicators,

Rohmad Apriyanto[1A-E*], Mohamad Da'i[2B-D], Fredy Yudhantara[3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]
rohmadapriyanto87@unugiri.ac.id[1*]

which emphasize precision, response speed, and stroke consistency (Apriyanto & Adi, 2022; Fuchs et al., 2020).

Data collection was conducted under identical environmental conditions and facilities to minimize external bias (Hopkins, 2015). A pretest was administered before the intervention, while a posttest was administered after the training program was completed. All training sessions were supervised by coaches and researchers to ensure protocol adherence and control of training intensity (Woods et al., 2020).

Data analysis began with the Shapiro-Wilk normality test to determine data distribution (Field, 2018). If the data is normally distributed, hypothesis testing is performed using a paired sample t-test at a significance level of 0.05 to identify differences between pretest and posttest scores (Cohen et al., 2018). This test is appropriate for repeated measurements designs within the same group (Hair et al., 2019). In addition to statistical significance, an effect size (Cohen's d) is also calculated to determine the strength of the technological intervention's influence on skill improvement (Lakens, 2017).

With this design and procedure, the study seeks to provide empirical evidence regarding the effectiveness of microcontroller technology-based training in improving table tennis forehand skills in a measurable, objective manner, and based on modern sports science principles.

RESULTS AND DISCUSSION

Result

Data Description

Table 1.

Table tennis forehand stroke data from pre-test and post-test

No	Atlet	Pretest	Postest	Difference
1	A1	42	44	2
2	A2	37	43	6
3	A3	32	40	8
4	A4	16	30	14
5	A5	32	44	12
6	A6	26	35	9
7	A7	34	38	4
8	A8	30	42	12
9	A9	16	28	12
10	A10	22	30	8

Table 2.

Descriptive Statistics of Athletes' Service Results

Statistics	Pretest	postest
Number of samples	10	10
Minimum value	16	28
Maximum value	42	44
Average	28,7	37,4
Standard deviation	8,64	6,24

Rohmad Apriyanto[1A-E*], Mohamad Da'i[2B-D], Fredy Yudhantara[3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]
rohmadapriyanto87@unugiri.ac.id[1*]

Table 3.
Paired Sample t-test Results

Variable	t-count	t-table (α = 0,05)	Sig. (p)	Description
Forehand shot results	7,075	1,833	0,000	Signifikan

Normality Test

Before testing the hypothesis, the pretest and posttest data were tested for normality. The results of the normality test showed that the significance value of the pretest and posttest data was greater than 0.05, so the data was declared to be normally distributed and met the requirements for parametric statistical testing.

Hypothesis Testing

Based on Table 3, the t-value obtained was 7.075, which was greater than the table value of 1.833 with a significance value of 0.000 < 0.05. Therefore, it can be concluded that training using Arduino microcontroller technology with a ball launcher device, with increased sets and repetitions, has a significant effect on improving the forehand stroke results of table tennis athletes at SDN 2 Lohgung Lamongan.

Discussion

The research results show that training using Arduino microcontroller technology in the form of an automatic ball launcher, which can precisely control the speed and direction of the ball, significantly improves the forehand skills of table tennis athletes. This finding reinforces the argument that technology integration in sports training serves not merely as an aid, but as a structured and adaptive motor learning system tailored to the athlete's needs (Woods et al., 2020; Rojas-Valverde et al., 2021). In the context of modern table tennis, which demands high reaction speeds and extreme accuracy, robotic-based training provides a consistent and measurable stimulus compared to conventional manual multi-ball methods.

The improvement in forehand skills occurred because the Arduino system allows for progressive ball speed regulation, starting at a low level, increasing to medium, and finally to high. This principle aligns with the concept of progressive overload in sports training, where gradually increasing load promotes optimal neuromuscular adaptation (Bompa & Buzzichelli, 2019; Bishop et al., 2019). These adaptations include improved hand-eye coordination, timing, and fine motor control, which are crucial for forehand technique (Fuchs et al., 2020). In the sports science literature, controlled repetition with stimulus variation has been shown to improve movement consistency and biomechanical stability of the shot (Kondrič et al., 2019).

The microcontroller-based ball launcher technology, which can hold up to 50 balls, allows for continuous, uninterrupted training, maximizing practice density and time-on-task. Recent research has shown that increased training density contributes to the acceleration of long-term motor memory formation (Ericsson & Pool, 2016; Davids et al., 2017). Consistent ball launch also reduces uncontrolled external variability, allowing athletes to focus on technique correction and target accuracy. Thus, this system

Rohmad Apriyanto[1A-E*], Mohamad Da'i[2B-D], Fredy Yudhantara [3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]
rohmadapriyanto87@unugiri.ac.id[1*]

supports the principle of deliberate practice, namely focused practice with systematic feedback (Williams & Hodges, 2020).

From a motor learning theory perspective, the results of this study align with the view that motor skills develop optimally through progressive and repetitive practice (Schmidt & Lee, 2025). Schema theory explains that varying ball speed helps athletes develop flexible motor representations, enabling them to adapt to real-world match situations (Magill & Anderson, 2021). For elementary school-aged athletes still developing basic coordination, a gradual approach is crucial for minimizing technical errors and improving postural control (Lloyd et al., 2016).

Furthermore, the significant improvement in forehand performance indicates that this technique is effective in improving shot accuracy and consistency. Table tennis biomechanical studies indicate that shot accuracy is significantly influenced by wrist stability, trunk rotation, and ball contact timing (Iino & Kojima, 2016; Qian et al., 2020). Gradual-speed training allows athletes to adjust their racket angle and body position more precisely before facing the pace of a real match.

In the context of decision-making, table tennis is a sport with very short reaction times, requiring athletes to be able to determine the direction of their shots in milliseconds (Raab et al., 2019). Training with progressive speed variations helps improve the ability to perceive and anticipate ball trajectories. Research in perceptual-cognitive training shows that exposure to high-speed stimuli gradually increases information processing speed and response accuracy (Voss et al., 2017; Mann et al., 2019). Therefore, the improvement in forehand performance in this study was not only mechanical but also cognitive.

Motivational aspects are also important factors. Robotic-based technology provides a more engaging and challenging training experience than traditional methods (Chiu et al., 2022). Active involvement and the sense of challenge in conquering new speed levels increase athletes' intrinsic motivation (Ryan & Deci, 2017). Research in educational technology shows that the use of interactive devices increases student engagement and confidence (Indarta et al., 2022). This is relevant to the finding that athletes became more confident in honing their forehand technique, both in offensive and defensive contexts.

From a practical implementation perspective, the use of an Arduino-based ball-throwing robot provides the opportunity for personalized training. Each athlete receives an equal portion and opportunity to practice with customizable parameters. This personalization aligns with the individualized training approach in modern sports science (Impellizzeri et al., 2019). With precise control over speed and repetitions, coaches can adjust the intensity to suit each athlete's ability level.

The results of this study are also relevant for preparing for school-level competitions such as the National Sports Week (O2SN), the Indonesian National Sports Week (PORSENI), and the Indonesian Population and Regional Sports Week (POPDA). These competitions require athletes to have consistent technique and the ability to adapt to variations in game tempo. Table tennis performance studies show that success

Rohmad Apriyanto[1A-E]*, Mohamad Da'i[2B-D], Fredy Yudhantara [3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]
rohmadapriyanto87@unugiri.ac.id[1]*

at the competitive level is determined by a combination of reaction speed, shot accuracy, and psychological stability (Malagoli Lanzoni et al., 2018). With progressive, technology-based training, athletes develop a stronger technical and mental foundation to withstand the pressures of competition.

However, the integration of technology into training still requires coach supervision to ensure skill transfer to real-life match situations. The literature suggests that a combination of robotic training and game-based situational learning provides optimal results (Otte et al., 2021). Therefore, Arduino technology should be positioned as a complement to coaching strategies, not a substitute for coach-athlete interaction.

Overall, the findings of this study confirm that microcontroller-based training effectively improves table tennis forehand skills through speed progression, structured repetition, and consistent stimuli. The integration of motor learning principles, biomechanics, and robotic technology resulted in significant performance improvements and enhanced athlete readiness for competition. These results reinforce the importance of technological innovation in youth sports development as part of the development of data-driven and precision sports science.

CONCLUSION

Based on the analysis and discussion, it can be concluded that Arduino microcontroller-based training using an automatic ball launcher with progressively increasing sets, repetitions, and ball speed significantly improved the forehand skills of extracurricular table tennis athletes at SDN 2 Lohgung in 2025. Empirically, there was an increase in the mean forehand score in the post-test compared to the pre-test, as confirmed by the results of a paired sample t-test with a significance value of <0.05. These findings indicate that microcontroller-based technology intervention is effective in improving the accuracy, consistency, and control of forehand strokes.

Conceptually, the effectiveness of this method aligns with the principle of progressive overload and motor learning theory, which emphasizes gradual and repetitive practice to build neuromuscular adaptation and coordinative stability. The tiered approach (low–medium–high speed) is well suited to the characteristics of elementary school-aged athletes because it facilitates systematic mastery of technique and minimizes movement errors. Therefore, Arduino microcontroller-based training can be recommended as an alternative, innovative and applicable technical development method in preparation for student-level championships.

ACKNOWLEDGEMENTS

The authors express their deepest appreciation and gratitude to all parties who contributed to the implementation of this research. Thanks are due to the Principal of SDN 2 Lohgung Lamongan for granting permission and providing facilities during the research process. Equal appreciation is extended to the coaches and athletes of the table tennis extracurricular activity who actively, disciplinedly, and cooperatively participated in the entire training and measurement program.

Conceptually, this research would not have been possible without the collaboration between physical education practitioners and microcontroller technology developers, enabling the integration of a sports science approach with robotics innovation. Technical support in the design and operation of the Arduino ball launcher system was instrumental in ensuring the accuracy and consistency of the intervention.

The authors also thank their colleagues and the academic team who provided constructive feedback during the manuscript preparation process. Their intellectual contributions, scientific discussions, and validation of the research instruments strengthened the methodological quality and empirical analysis of this study. Hopefully, the results of this research will benefit the development of technology-based sports coaching at the elementary school level and serve as a reference for further research.

REFERENCES

Aji, M. R., Santosa, T., & Setyaningrum, R. K. (2020). Perbedaan Pengaruh Latihan Servis Ketinggian Net tetap dan Bertahap Terhadap Kemampuan Servis Atas Bolavoli Pada Peserta Didik Putra ekstrakurikuler Bolavoli MTS Negeri 4 Sragen tahun Pelajaran 2019/2020. Jurnal Kepelatihan Olahraga SMART SPORT.

Apriyanto, R., & Adi, S. (2022). Analisis Keterampilan Teknik Bermain Tenis Meja dalam Mewujudkan Konsep Kurikulum Merdeka Belajar. Physical Activity Journal (PAJU), 4(1), 87–98.

Apriyanto, R., Aliriad, H., Da'i, M., Adi, S., Suningsih, S., & Wiji, A. (2024). Development of Augmented Reality based Power Spin Learning Media Assemblr 3D PJBL model for Reaction and Timing Pattern Problems. Kinestetik: Jurnal Ilmiah Pendidikan Jasmani, 8(4), 888–898.

Battou, A. (2017). Designing an adaptive learning system based on a balanced combination of agile learner design and learner centered approach. American Academic Scientific Research Journal for Engineering, Technology, and Sciences, 37(1), 178–186.

Bennett, N., & Lemoine, J. (2014). What VUCA really means for you. Harvard Business Review, 92(1/2).

Bidang, K., Abidin, Z., Internist, D. S. M., Wakil II, S. W. I., Sudarwati, L., Suparjiman, A., Sudarwati, S. L., & Studiografis, R. (2016). Pemahaman Dasar Sport Science & Penerapan Iptek Olahraga.

Bishop, C., Turner, A., & Read, P. (2019). Effects of inter-limb asymmetries on physical and sports performance: A systematic review. Journal of Sports Sciences, 36(10), 1135–1144. https://doi.org/10.1080/02640414.2018.1490478

Bodnar, G. H., & Hopwood, W. S. (2009). Sistem informasi Akuntansi Diterjemahkan oleh Amir Abadi Yusuf dan Andi M. Tambunan. Salemba Empat: Jakarta.

Bompa, T. O., & Buzzichelli, C. (2019). Periodization: Theory and methodology of training (6th ed.). Human Kinetics. https://us.humankinetics.com

Bryan, C., & Clegg, K. (2019). Innovative assessment in higher education: A handbook for academic practitioners. Routledge.

Chiu, M.-C., Hwang, G.-J., & Tu, Y.-F. (2022). Roles, applications, and research designs of robots in science education: a systematic review and bibliometric analysis of journal publications from 1996 to 2020. Interactive Learning Environments, 1–26.

Chiu, T. K. F., Lin, T. J., & Lonka, K. (2022). Motivating students with robotics in STEM education: A bibliometric review. Educational Technology & Society, 25(2), 1–15. https://www.jstor.org/stable/48647052

Davids, K., Araújo, D., Vilar, L., Renshaw, I., & Pinder, R. (2017). An ecological dynamics approach to skill acquisition. Sport Medicine, 47(1), 33–45. https://doi.org/10.1007/s40279-016-0561-3

Ericsson, K. A., & Pool, R. (2016). Peak: Secrets from the new science of expertise. Houghton Mifflin Harcourt. https://www.hmhbooks.com

Fuchs, M., Liu, R., Lanzoni, I. M., & Zhang, H. (2020). Biomechanical analysis of forehand topspin in table tennis. Sports Biomechanics, 19(3), 325–339. https://doi.org/10.1080/14763141.2018.1499809

García-Tudela, P. A., & Marín-Marín, J.-A. (2023). Use of Arduino in Primary Education: A Systematic Review. Education Sciences, 13(2), 134.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). Multivariate data analysis (8th ed.). Cengage Learning.

Hopkins, W. G. (2015). Spreadsheets for analysis of controlled trials. Sportscience, 19, 36–42. http://sportsci.org

Impellizzeri, F. M., Marcora, S., & Coutts, A. J. (2019). Internal and external training load: 15 years on. International Journal of Sports Physiology and Performance, 14(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Indarta, Y., et al. (2022). Digital literacy and student engagement in the era of Education 4.0. International Journal of Instruction, 15(2), 1–16. https://doi.org/10.29333/iji.2022.1521a

Indarta, Y., Jalinus, N., Waskito, W., Samala, A. D., Riyanda, A. R., & Adi, N. H. (2022). Relevansi kurikulum merdeka belajar dengan model pembelajaran abad 21 dalam perkembangan era society 5.0. Edukatif: Jurnal Ilmu Pendidikan, 4(2), 3011–3024.

Iino, Y., & Kojima, T. (2016). Kinematics of table tennis forehands: Effects of ball spin and speed. Journal of Sports Sciences, 34(2), 123–132. https://doi.org/10.1080/02640414.2015.1031167

Kondrič, M., Zagatto, A. M., & Sekulić, D. (2019). The physiological demands of table tennis: A review. Journal of Sports Science & Medicine, 18(1), 1–12. https://www.jssm.org

Lakens, D. (2017). Calculating and reporting effect sizes. Frontiers in Psychology, 8, 863. https://doi.org/10.3389/fpsyg.2017.00863

Lloyd, R. S., et al. (2016). National Strength and Conditioning Association position statement on youth training. Journal of Strength and Conditioning Research, 30(6), 1491–1509. https://doi.org/10.1519/JSC.0000000000001484

Rohmad Apriyanto[1A-E]*, Mohamad Da'i[2B-D], Fredy Yudhantara[3B-E], Nafi' Maula Ramdhani[4B-C], Muhammad Khoirudin Jazali[5B-D]
rohmadapriyanto87@unugiri.ac.id[1]*

Magill, R. A., & Anderson, D. (2021). Motor learning and control (12th ed.). McGraw-Hill.

Malagoli Lanzoni, I., Di Michele, R., & Merni, F. (2018). Match analysis in table tennis. International Journal of Performance Analysis in Sport, 18(1), 1–16. https://doi.org/10.1080/24748668.2018.1446737

Mann, D. L., Williams, A. M., Ward, P., & Janelle, C. M. (2019). Perceptual-cognitive expertise in sport. Journal of Sport & Exercise Psychology, 41(6), 349–360. https://doi.org/10.1123/jsep.2019-0136

McCosker, C., Otte, F., Rothwell, M., & Davids, K. (2022). Principles for technology use in athlete support across the skill level continuum. International Journal of Sports Science & Coaching, 17(2), 437–444.

Millati, I. (2021). Peran teknologi pendidikan dalam perspektif merdeka belajar di era 4.0. Journal of Education and Teaching (JET), 2(1), 1–9.

Nurdin, N., & Aminullah, A. (2020). Pengaruh Latihan Multiball Terhadap Keterampilan Smash Forehand Tenis Meja Pada Club Pade Angen Mataram Tahun 2020. Jurnal Ilmiah Mandala Education, 6(2).

Putra, R. T., & Kurniawan, D. (2020). Sosialisasi Peran Iptek Dan Sport Science Dalam Meningkatkan Prestasi Koni Kabupaten Madiun. Jurnal Pengabdian Kepada Masyarakat Sisthana, 2(2), 77–86.

Qian, J., Zhang, Y., & Baker, J. (2020). Motor coordination in racket sports. Frontiers in Psychology, 11, 578. https://doi.org/10.3389/fpsyg.2020.00578

Raab, M., Lobinger, B., Hoffmann, S., Pizzera, A., & Laborde, S. (2019). Performance psychology. Academic Press. https://doi.org/10.1016/C2016-0-04854-7

Rojas-Valverde, D., et al. (2021). Technology in sport training: Wearables and performance analysis. Sensors, 21(20), 6851. https://doi.org/10.3390/s21206851

Rosmanila, R., Radillah, T., & Sofiyan, A. (2018). Prototype Lemari Pengering Pakaian Otomatis. Informatika, 10(1), 32–38.

Sari, D. N., & Antoni, D. (2020). Analisis kemampuan forehand drive atlet tenis meja. Edu Sportivo: Indonesian Journal of Physical Education, 1(1), 60–65.

Schmidt, R. A., & Lee, T. D. (2025). Motor learning and performance: From principles to application. Human Kinetics.

Sodik, J., Purwiyanta, P., & Wijayanti, D. L. (2021). Village Economic Potential for The Implementation of Learning Building Village/KKN Thematic MBKM Program Economic Study Program Development Department of Economics, Faculty of Economics and Business of The UPN" Veteran" Yogyakarta. RSF Conference Series: Business, Management and Social Sciences, 1(3), 179–184.

Woods, C. T., et al. (2020). The role of technology in athlete development. Sports Medicine, 50(10), 1773–1783. https://doi.org/10.1007/s40279-020-01323-4

Williams, A. M., & Hodges, N. J. (2020). Skill acquisition in sport: Research and practice. Routledge. https://doi.org/10.4324/9781315130553