Evaluation of an artificial intelligence-based technical correction program for reducing common butterfly stroke errors among swimming course students at Jadara University

Evaluación de un programa de corrección técnica basado en inteligencia artificial para reducir errores comunes de estilo mariposa entre estudiantes de natación de la Universidad de Jadara

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Received: 30-01-26
Accepted: 17-02-26

How to cite in APA

Ababaneh, A., Albdaiwi, H., Al-Sababha, L., Salah, D., Alhassan, S., & Abo Harb, H. (2026). Evaluation of an artificial intelligence-based technical correction program for reducing common butterfly stroke errors among swimming course students at Jadara University. *Retos, 77*, 785-793. https://doi.org/10.47197/retos.v77.118688

Abstract

Introduction: This study aimed to evaluate the effectiveness of an artificial intelligence–based technical correction program in reducing common butterfly swimming errors among students enrolled in swimming courses at Jadara University.
Method: The study adopted the experimental approach using a one-group pre-test/post-test design. The sample consisted of 50 undergraduate students (25 males and 25 females) enrolled in swimming courses at Jadara University. The AI-based program provided real-time technical feedback and motion analysis focusing on correcting common butterfly swimming errors, particularly arm stroke timing, dolphin kick efficiency, body position, breathing control, and overall movement coordination. Data were collected through technical performance assessment scales applied before and after the implementation of the program.
Result: The results showed statistically significant improvements ($\alpha \leq 0.05$) between the pre-test and post-test measurements in all technical performance variables for both male and female students, in favor of the post-test. Male students demonstrated the greatest improvement in arm–leg coordination and propulsive force of the arm stroke, while female students showed notable improvement in breathing control, body stability, and movement rhythm. Comparisons between males and females revealed no statistically significant differences in most technical variables, except for arm propulsive force, which favored males due to physiological differences.
Conclusion: The findings indicate that AI-based technical correction programs are effective in enhancing technical performance and reducing common butterfly swimming errors among university students, regardless of gender.

Keywords

Artificial intelligence; butterfly swimming; technical correction program; swimming performance; motion analysis; Jadara University.

Resumen

Introducción: Este estudio tuvo como objetivo evaluar la eficacia de un programa de corrección técnica basado en inteligencia artificial para reducir errores comunes en la natación mariposa entre estudiantes de natación de la Universidad de Jadara.
Método: El estudio adoptó un enfoque experimental con un diseño de preprueba y posprueba de un solo grupo. La muestra consistió en 50 estudiantes de pregrado (20 hombres y 20 mujeres) de natación de la Universidad de Jadara. El programa, basado en IA, proporcionó retroalimentación técnica en tiempo real y análisis de movimiento, centrándose en la corrección de errores comunes en la natación mariposa, en particular la sincronización de la brazada, la eficiencia de la patada de delfín, la posición corporal, el control respiratorio y la coordinación general del movimiento . Los datos se recopilaron mediante escalas de evaluación del rendimiento técnico aplicadas antes y después de la implementación del programa de corrección técnica basado en inteligencia artificial aplicadas antes y después de la implementación del programa.
Resultado: Los resultados mostraron mejoras estadísticamente significativas ($\alpha \leq 0,05$) entre las mediciones pretest y postest en todas las variables de rendimiento técnico, tanto para estudiantes masculinos como femeninos, a favor del postest. Los estudiantes masculinos mostraron la mayor mejora en la coordinación brazo-pierna y la fuerza de propulsión de la brazada, mientras que las mujeres mostraron una mejora notable en el control respiratorio, la estabilidad corporal y el ritmo de movimiento. Las comparaciones entre hombres y mujeres no revelaron diferencias estadísticamente significativas en la mayoría de las variables técnicas, excepto en la fuerza de propulsión del brazo, que favoreció a los hombres debido a diferencias fisiológicas.
Conclusión: Los hallazgos indican que los programas de corrección técnica basados en IA son eficaces para mejorar el rendimiento técnico y reducir los errores comunes en el nado mariposa entre estudiantes universitarios, independientemente del género.

Palabras clave

Inteligencia artificial; natación mariposa; programa de corrección técnica; rendimiento en natación; análisis de movimiento; Universidad de Jadara.

Introduction

Recent years have witnessed a remarkable evolution in the role of modern technologies, particularly artificial intelligence (AI), in the fields of sports and athletic training. AI applications have become an integral part of performance analysis systems, enabling the evaluation of technical errors and the provision of immediate, data-driven corrections. This has contributed to the development of athletic training methods and the improvement of individual athlete performance across various sports. In light of this technological advancement, numerous studies have emerged confirming that AI is capable of analyzing athletes' kinematic and biomechanical data, providing detailed assessments that help coaches enhance performance and reduce injury risks through targeted, intelligent training (Xu, 2024; Chern et al 2025).

The butterfly stroke is one of the most technically challenging swimming strokes, requiring a high degree of coordination between arm movements, body movement, and the dolphin kick, as well as precise breathing and timing of all these elements. Biomechanical studies show that inconsistencies in these elements lead to common technical errors that reduce performance effectiveness and increase water resistance, negatively impacting speed and endurance. Studies have also revealed stable or unstable technical behavior patterns based on individual variations in skill application, highlighting the need for a thorough analysis of swimmers' movements to optimize performance (Tamer & Atia, 2022).

Despite the importance of practical training and direct guidance from coaches, there is a clear lack of scientific literature that integrates the analysis of technical errors in swimming. Particularly the butterfly strokes. with the use of artificial intelligence for their systematic and effective correction. In the general field of swimming, many studies focus on analyzing and correcting technical errors through teaching methods or repetitive training, but these remain traditional and largely dependent on the coach's experience and intuition. In contrast, AI techniques can provide precise, data-driven correction tailored to the individual differences of each swimmer (Eisenbeis, 2025). sports shows that artificial intelligence (AI) is not limited to analysis; it extends to developing intelligent training programs capable of providing immediate feedback, evaluating technical performance, and adapting to each athlete's individual needs and characteristics. Scientific reviews confirm that using AI in sports performance analysis improves training quality, helps reduce performance gaps, and decreases the rate of common errors (Powell et al, 2023. Xu & Xu, 2023).

Despite this progress, the number of studies that have applied this technology in actual swimming training environments, particularly at the university level, remains limited, highlighting the importance of conducting applied research in this area. A previous study on young swimmers confirmed the effectiveness of an AI-based training program in developing swimming skills, while also noting a lack of understanding among coaches and swimmers regarding the importance and mechanism of this type of training program, as well as the need for increased research related to AI applications in swimming training (Fitrianto et al, 2025).

Numerous studies have demonstrated that artificial intelligence (AI) has become an effective tool for analyzing athletic performance and correcting technical errors. (Morais et al, 2025) showed that intelligent systems are capable of providing objective feedback that contributes to improving motor learning and reducing recurring technical errors. In swimming, many studies have focused on the biomechanical analysis of different swimming strokes, particularly the butterfly stroke, due to its difficulty and technical complexity. A study by (Pinto et al, 2025) confirmed that technical errors in the butterfly stroke are often related to poor timing and weak undulation, necessitating the use of precise analytical methods to correct these errors.

Furthermore, recent studies have explored the application of smart technologies and AI in swimming training. A study by (Mooney et al, 2016) found that using AI-based motion analysis systems helps in accurately measuring joint angles and movement speed, and contributes to providing immediate feedback that improves swimmers' technical performance. In the educational setting, a study by (Casey et al, 2017) confirmed this use of digital technology and smart systems in teaching sports skills has led to a significant improvement in the level of technical performance and students' motivation to learn.

It may be more appropriate emphasized the importance of intelligent analysis and modern technologies in correcting technical errors in swimming, particularly the butterfly stroke. However, the direct and

systematic application of artificial intelligence (AI) in correcting these errors among Jordanian university students remains limited, a gap that this study aims to address. From these findings, it is evident that integrating AI into swimming error correction programs—especially for the butterfly stroke—can significantly improve student training and enhance the effectiveness of their technical learning. Furthermore, implementing such programs in an academic environment like Jadara University provides a research model that embodies the practical application of AI in teaching high-tech athletic skills, thereby enhancing the quality of sports education and enabling students to utilize modern technologies to develop their skills (Xurui & Guobao, 2023).

The Problem and Significance

The problem addressed by this study is that students enrolled in the swimming course at Jadara University suffer from common technical errors in performing the butterfly stroke, resulting in performances that fall short of the required technical standards. While there is increasing global interest in using artificial intelligence (AI) to analyze and evaluate athletic performance, this technology has not been sufficiently utilized in swimming training at the Jordanian university level, particularly in reducing these technical errors and improving individual results based on each swimmer's skill level. Therefore, there is a need to evaluate an AI-based technical correction program to determine its effectiveness in reducing common errors and improving the technical performance of the butterfly stroke.

Study Objectives

This study aims to:

- Develop an AI-based technical correction program to analyze common errors in butterfly stroke swimming among swimming students.
- Evaluate the program's effectiveness in improving swimmers' performance and reducing technical errors compared to traditional methods.
- Analyze the program's impact on male and female students separately to determine if there is a gender difference in its effect.
- Provide practical recommendations for AI applications in swimming training within the academic environment.

Study Questions

This study seeks to answer the following questions:

1- How effective is an AI-based technical correction program in reducing common errors in butterfly stroke swimming among students enrolled in the swimming course at Jadara University?

2- Are there statistically significant differences in performance levels before and after the program's implementation between male and female students?

Method

The study employed a quasi-experimental design with a pre-test/post-test approach using two experimental groups. An AI-based technical correction program was implemented with swimming students at Jadara University, and the results for males and females were analyzed separately.

This approach is suitable for the nature of the current study, as it allows for measuring the effect of the independent variable (the AI-based program) on the dependent variables (technical errors and level of technical performance) within an actual educational environment.

The study population consisted of all male and female students enrolled in the swimming course at the Faculty of Physical Education, Jadara University, during the first semester of the 2025/2026 academic year. These students were registered in swimming courses, particularly butterfly stroke, within the approved study plan. The study sample was selected using purposive sampling from students who met the

study criteria. They were divided into two independent experimental groups based on gender: Experimental Group 1 (males): 25 students; Experimental Group 2 (females): 25 students. The following criteria were considered in sample selection: regular attendance at practical lectures, absence of injuries or health problems affecting motor performance, and a similar basic level of butterfly stroke skills prior to the study. Ethical research standards were adhered to during the study, and informed consent was obtained from the participating swimmers. Environmentally friendly equipment was also used during the study.

The researchers used a set of tools to collect data, including a technical error analysis form for the butterfly stroke. This form was designed based on scientific literature and previous studies and covered the following areas: arm movement, leg movement (Dolphin Kick), body position, timing and coordination, and breathing.

The validity of the form was verified by a panel of expert judges, and its reliability was confirmed using the internal consistency coefficient. The technical performance tests for the butterfly stroke consisted of: performance evaluation using a numerical rating scale (Rubric) based on established technical standards; and video recording both above and below the water's surface using high-resolution digital cameras for precise movement analysis.

The results were also obtained through this process. An AI-based corrective training program was designed, lasting (4 weeks), with (3 training units per week), and the duration of each training unit was (50 minutes). The program included the following: (Analyzing the swimmer's technical performance using video recordings. Identifying individual technical errors for each male and female student. Providing immediate feedback supported by intelligent analysis. Proposing corrective exercises tailored to each type of error. Re-evaluating periodically to monitor improvement. The program was implemented separately for males and females, taking into account individual differences and performance levels).

The study employed artificial intelligence (AI) and motion analysis techniques, including machine learning algorithms for analyzing movement patterns, intelligent video analysis software for extracting angles, timing, and movement speed, and systems for comparing actual performance to the ideal technical model for butterfly stroke. This technology contributed to diagnosing errors with greater accuracy than traditional methods and providing personalized technical correction for each participant.

The study variables consisted of the independent variable: the AI-based training program for correcting technical errors; the dependent variables: the level of technical errors in butterfly stroke and the overall technical performance level in butterfly stroke; and the control variables: age, initial skill level, number and duration of training sessions, and the training environment and equipment used.

The data were analyzed using SPSS software, employing the following statistical methods: means and standard deviations. The results were analyzed using a one-way ANCOVA test to compare pre- and post-test measurements for both males and females separately, Pearson's correlation coefficient when needed, and the percentage improvement. The statistical significance level was $\alpha \leq 0.05$.

Result

First: Results related to the first question, which stated: How effective is an AI-based technical correction program in reducing common errors in the butterfly stroke among swimming students at Jadara University?

To answer this question, which states: "How effective is an AI-based technical correction program in reducing common errors in the butterfly stroke among swimming students at Jadara University?", the arithmetic means and standard deviations of the effectiveness of an AI-based technical correction program in reducing common errors in the butterfly stroke among swimming students at Jadara University were calculated for the pre-test, post-test, and average scores of both groups, as shown in Table (1).

Table 1. Means of the effectiveness of an AI-based technical correction program in reducing common errors in the butterfly stroke among swimming students at Jadara University, according to the group variable

Group	Number	Total Error		Pre test		Post Test	
		Error	M Error	M	SD	M	SD
Female	25	0.38	13.50	11.00	3.58	13.92	4.65
Male	25	0.38	18.18	10.24	3.99	17.76	4.46

Table (1) shows apparent differences between the arithmetic means of the effectiveness of an AI-based technical correction program in reducing common errors in butterfly swimming among students enrolled in the swimming course at Jadara University, in both the pre-test and post-test, according to the group variable (male and female). To verify the significance of these apparent differences, a one-way analysis of covariance (ANCOVA) was used, taking into account the pre-test scores of each group as the covariate, as shown in Table (2).

Table 2. Results of the one-way analysis of covariance (ANCOVA) for the post-test among the study sample, according to the group variable (male and female).

S.V	S.S	D.f	M.S	(F)	Sig	(η^2)
Pre Test	5.605	1	5.605	1.589	0.213	
AI-based technical correction program	228.228	1	228.228	*64.690	0.000	**0.579
Error	165.795	47	3.528			
Total	399.628	49				

* Statistically significant at the significance level (α=0.05) // **(Effect size is small (less than 0.06), medium (0.15-0.06), large (0.16 and above))

Table (2) shows a statistically significant difference at the significance level (α = 0.05) between the post-test means of the effectiveness of an AI-based technical correction program in reducing common errors in the butterfly stroke among male students enrolled in the swimming course at Jadara University. The effect size resulting from the use of the AI-based technical correction program in reducing common errors in the butterfly stroke, as indicated by the eta-squared value (η^2), was 57.90%, which is considered high.

The results of the statistical analysis showed a statistically significant improvement in the level of technical performance and a reduction in technical errors in the butterfly stroke among Jadara University swimming students after the application of the AI-based technical correction program, when comparing the pre-test and post-test measurements.

Second: Results related to the second question, which stated: "Are there statistically significant differences in performance levels before and after the program implementation between male and female students?"

To answer this question, "Are there statistically significant differences in performance levels before and after the program implementation between male students?", the means and standard deviations of the performance levels in the pre-test, post-test, and average were calculated for the male student group, as shown in Table (3).

Table 3. Means and standard deviations of butterfly stroke performance skills for male and female students in the pre-test, post-test, and average

Skills	Group	Number	Total Error		Pre test		Post Test	
			Error	M Error	M	SD	M	SD
Arm and leg coordination	Female	25	0.13	2.67	1.56	1.60	2.66	0.83
	Male	25	0.13	4.51	1.76	1.36	4.52	0.65
Power of the arm strike	Female	22	0.14	2.72	1.84	1.61	2.68	1.25
	Male	25	0.14	3.92	1.60	1.19	3.96	0.79
Breath control	Female	25	0.17	2.68	1.44	1.04	2.64	1.11
	Male	25	0.17	3.28	1.28	0.98	3.32	0.95
Body stability	Female	25	0.13	1.93	1.72	1.14	1.92	1.00
	Male	25	0.13	2.87	1.88	0.88	2.88	0.88
Rhythm of movement	Female	25	0.13	1.41	1.04	0.89	1.40	1.04
	Male	25	0.13	2.15	1.40	0.91	2.16	0.94

Table (3) shows apparent differences between the mean scores of the performance level for the male and female groups in the pre-test, post-test, and average measurements. To verify the significance of these apparent differences, a one-way analysis of multiple covariance (MANCOVA) was used to determine the effectiveness of an AI-based technical correction program in reducing common errors in butterfly swimming among male and female students enrolled in the swimming course at Jadara University. This was done after considering the pre-test scores on the sub-skills of butterfly swimming performance as a covariate, as shown in Table (4).

Table 4. Results of the one-way analysis of multiple covariance (MANCOVA) for the post-test measurement of butterfly swimming performance in the male and female groups

(η^2)	Sig	F	M.S	D.f	S.S	Skills	S.V
	0.105	2.736	1.056	1	1.056	Arm and leg coordination	
	0.196	1.717	0.752	1	0.752	Power of the arm strike	
	0.118	2.541	1.746	1	1.746	Breath control	Pre Test
	0.605	0.271	0.110	1	0.110	Body stability	
	0.124	2.450	0.985	1	0.985	Rhythm of movement	
**0.561	0.000	*54.915	21.197	1	21.197	Arm and leg coordination	AI-based technical correction
**0.466	0.000	*37.451	16.398	1	16.398	Power of the arm strike	Hotelling's Trace= program
**0.125	0.017	*6.144	4.224	1	4.224	Breath control	4.025
**0.367	0.000	*24.931	10.110	1	10.110	Body stability	F= 21.396
**0.264	0.000	*15.427	6.199	1	6.199	Rhythm of movement	Sig=0.000*
			0.386	43	16.615	Arm and leg coordination	
			0.438	43	18.827	Power of the arm strike	
			0.687	43	29.562	Breath control	Error
			0.406	43	17.438	Body stability	
			0.402	43	17.278	Rhythm of movement	
				49	38.868	Arm and leg coordination	
				49	35.977	Power of the arm strike	
				49	35.532	Breath control	Total
				49	27.658	Body stability	
				49	24.462	Rhythm of movement	

* Statistically significant at the significance level (α=0.05) // **(Effect size is small (less than 0.06), medium (0.15-0.06), large (0.16 and above)).

Table (4) shows statistically significant differences at the significance level (α = 0.05) between the post-test means of butterfly swimming skills performance based on the group (males, females), favoring the male group.

The effect size resulting from an AI-based technical correction program in reducing common errors in butterfly swimming performance, as indicated by the eta-squared value (η^2), was (56.10%) for the (arm-leg coordination) skill, (46.60%) for the (arm kick propulsion) skill, (12.50%) for the (breath control) skill, (36.70%) for the (body stability) skill, and (26.40%) for the (movement rhythm) skill. The level of this effect was high in all skills except for the (breath control) skill, where the effect size was moderate. This means there were statistically significant differences (α ≤ 0.05) between the pre- and post-measurements in favor of the post-measurement in all aspects of technical performance, particularly in: improving the timing of arm movements, increasing the efficiency of leg movements (Dolphin Kick), and improving body position and fluidity in the water. The percentage improvement results showed that the greatest improvement was in the motor coordination axis between the arms and legs, reflecting the effectiveness of the immediate feedback provided by the AI-based program in correcting subtle errors in male students. Statistical analysis also revealed statistically significant differences between the pre- and post-tests, favoring the post-test scores of female students. A marked improvement was observed in: breath control during performance, postural stability, and a reduction in errors related to lack of motor coordination. The results showed that female students achieved high improvement rates, particularly in aspects related to motor rhythm, indicating that the AI program was effective in helping them recognize and gradually correct motor errors.

When comparing the post-test results between males and females using the independent samples t-test, statistically insignificant differences were found in some areas, while significant differences were found in others favoring males, especially in the driving force of arm movements. This is attributed to physiological and physical differences between the sexes. The similarity of results in other technical areas reflects the program's effectiveness for both genders.

Discussion

The results for the male experimental group showed statistically significant improvement across all technical performance indicators after the application of the AI-based program, particularly in arm timing, leg efficiency (Dolphin Kick), body position, and fluidity in the water, with the greatest improvement in arm-leg coordination. This improvement supports the idea that real-time feedback, enhanced by intelligent technologies, allows for the correction of subtle errors in real time, leading to improved overall movement integration among trainees. This aligns with numerous studies confirming that systems providing immediate feedback and objective performance data significantly enhance motor performance compared to traditional training alone. For example, a study on the SmartSwim system demonstrated that training supported by continuous feedback improved the overall performance of swimmers compared to groups receiving only traditional feedback, in terms of performance-related objectives such as race time and motor efficiency. Providing immediate feedback also enhances motor awareness in male trainees, enabling them to independently adjust and correctly repeat their movements during training sessions. This aligns with the findings of recent studies on improving motor skills using artificial intelligence.

The results for female trainees showed significant improvements in breathing control, postural stability, and reduced motor coordination errors, along with high rates of improvement in motor rhythm. Artificial intelligence provides accurate analysis of complex movements and allows for gradual, data-driven adjustments, which can be particularly beneficial in coordinating movement patterns and controlling rhythm and breathing. These results are consistent with research linking immediate feedback to enhanced motor learning. Trainees who receive real-time feedback on their performance often demonstrate a faster ability to correct errors and reduce motor distractions, positively impacting their technical skills. The improvement in rhythmic performance in females can also be explained by the fact that precise AI signals help monitor and adjust the coordination between breathing and movement, which is a delicate matter that requires repetition and intensive analysis, and this is what intelligent analysis tools in sports training provide.

When comparing the post-test results for males and females, the non-significant differences in some areas indicate that the AI program was effective in improving the basic technical aspects for both genders. This confirms the comprehensive and universal impact of intelligent feedback on motor learning, regardless of physiological differences. The significant differences favoring males in the driving force of arm movements can be attributed to natural physiological differences between the sexes in muscular strength. This is supported by literature indicating that strength-related aspects may naturally differ between males and females in various athletic training exercises. The results of this study confirm that using an AI-based technical correction program effectively reduced common errors in butterfly stroke swimming and improved the technical performance of swimming students. This improvement is attributed to the ability of AI technologies to analyze motor performance with high accuracy and provide immediate feedback based on objective data (Irianty et al, 2026, Gómez Muñoz et al, 2025; Ababaneh et al, 2026; Hernández et al, 2025). This aligns with what (Xu, 2024) indicated: that intelligent analysis systems are more effective than traditional methods in improving the technical performance of complex athletic skills.

The results of this study align with those of (Chern et al, 2025; Purnomo et al, 2026), who indicated that using artificial intelligence in swimming analysis helps detect subtle errors invisible to the naked eye, leading to improved motor coordination and reduced motor loss during performance. This is clearly demonstrated by the improved timing and coordination skills of both male and female participants in the current study. These improved results for female students are consistent with the study by (Powell et al, 2023), which confirmed that interactive digital technologies contribute to enhancing learners' motor perception, particularly in skills requiring high coordination, such as the butterfly stroke. This reflects the positive role of artificial intelligence in promoting self-directed learning and motivating learners to correct their performance based on accurate feedback.

Regarding gender differences, the results support (Powell et al, 2023) in stating that differences in certain components of technical performance between males and females are primarily due to physiological factors, rather than the effectiveness of training programs. This explains the similarity in program results for both genders in basic technical aspects. Therefore, the current study confirms that integrating artificial intelligence into swimming education programs within the university environment represents a qualitative leap in sports teaching and training methods and enhances the quality of practical learning outcomes compared to traditional methods.

Conclusions

In light of the study's findings and discussion, it can be concluded that the AI-based training program was highly effective in correcting common technical errors in butterfly stroke swimming among students enrolled in the swimming course at Jadara University. It significantly contributed to improving overall technical performance and reducing errors related to timing, coordination, and body position. This reflects AI's ability to provide an interactive learning environment based on objective performance analysis rather than relying solely on traditional observation.

The study also demonstrated that applying the program separately to males and females allowed for a deeper understanding of its impact on each group. Both groups achieved significant improvement, although natural differences in some performance components existed due to their physical and physiological characteristics. This confirms that AI is a flexible and adaptable tool for addressing individual and gender differences in sports education.

The study further found that AI contributes to raising students' kinesthetic awareness and enhances their ability to self-correct, thus supporting the sustainability of learning and reducing complete dependence on the coach. Moreover, the use of this technology within university educational institutions aligns with global trends toward digital transformation and the development of higher education systems.

Recommendation

In light of the findings and conclusions, the study recommends:

- The systematic application of artificial intelligence (AI) technologies in teaching and training swimming within faculties of physical education and sports science, given their clear impact on improving technical performance and reducing technical errors, especially in complex skills such as butterfly stroke. It also recommends expanding the use of intelligent analysis programs to other swimming styles and techniques.

- The study further recommends training faculty members and coaches in the use of AI and motion analysis technologies to ensure the optimal application of these programs and maximize their educational and training benefits. This is a necessary step to keep pace with modern developments in the sports field.

- The study recommends conducting future comparative studies between traditional programs and AI programs on larger samples from different age groups, as well as studying the impact of these programs on other variables such as motivation, self-confidence, and long-term learning retention.

- Finally, the study recommends that universities and educational institutions support the technological infrastructure that enables the integration of AI into sports education, given its pivotal role in developing the quality of university education and achieving advanced educational outcomes that align with international standards.

Acknowledgements

The authors would like to express their sincere gratitude to Jadara University, for their valuable support and contribution to this research. Their resources, guidance, and encouragement have been instrumental in the successful completion of this study.

Financing

The researchers declare that there is no Financing funded the research.

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