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The Effect of Programmed Exercises Using an Intelligent Expert System Based on Computer Vision in Motion Modeling and the Accuracy of Double Kicks Performed by Young Taekwondo Players

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Abstract:

This study aimed to reveal the effect of programmed exercises using an intelligent expert system based on computer vision in motor modeling and the accuracy of double kicks performed by young taekwondo players. The research problem highlights the inadequacy of traditional observation in monitoring subtle mechanical deviations during fractions of a second, leading to an imbalance in the trajectory of the second kick and a loss of angular momentum. The researcher used an experimental approach by designing two equivalent groups on a purposive sample of 20 players from the National Centre for Sports Talent for the 2025-2026 season. The technical tools included high-speed cameras and a tracking algorithm (33 joint points) to build a digital motion model that compares player performance to global standards.

The results showed a significant advantage for the experimental group that trained with the smart system, as the players achieved remarkable improvement in hip angular velocity (reaching 745.20 degrees/second) and an ideal reduction in motor transfer time (0.38 seconds), which was reflected in the accuracy of double kicks with a high degree of conformity to the optimal mechanical model. The study concluded that the immediate feedback provided by computer vision gave players 'mechanical awareness' that contributed to correcting trunk and knee trajectories and shortening response time, making the exercises more efficient and less random. The researcher recommended

the adoption of artificial intelligence systems in national training centers as an advanced technical alternative to support the coach's visual perception, with a focus on motor modeling for emerging age groups to build a sound skill base.

Chapter One

1-1 Introduction and Significance of the Research:

The field of sports has recently witnessed a radical shift towards digitization and the use of artificial intelligence. The development of athletic performance no longer relies on traditional observation, but has moved towards the horizons of 'digital modeling,' which provides an accurate description of every detail of movement. Taekwondo is a sport characterized by tremendous speed and motor complexity, especially in the performance of double kicks, which require high neuromuscular coordination to connect two consecutive kicks in record time and with extreme accuracy. The shift towards digitalization in the field of sports is no longer an option but a necessity, as modern training must be based on an accurate description of the movement. With the complexity of taekwondo skills, there is a need for systems capable of simulating the human mind, and artificial intelligence applications are beginning to reshape the concepts of training in physical education.

The importance of research into the introduction of computer vision technology as an advanced tool within an intelligent expert system is highlighted. This technology allows the skeletal coordinates of a player to be extracted automatically through imaging, enabling the construction of an ideal motion model that compares the player's performance with global biomechanical standards. The link between this intelligent diagnosis and programmed 'therapeutic' exercises represents a quantum leap in sports training, providing young players with immediate feedback to correct their movement patterns, shortening years of traditional training and achieving the highest levels of accuracy in skill performance.

1-2 Research problem:

By observing young age groups practicing taekwondo, the researcher noticed an imbalance in the 'stability of movement' when performing double kicks, where the second kick in the movement sequence often lacks the required speed and accuracy as a result of loss of angular momentum or deviation in the angles of inclination. The problem lies in the fact that the training and assessment methods used still rely heavily on the coach's visual perception, which is insufficient to detect mechanical changes that occur in fractions of a second (such as foot launch speed or instantaneous hip rotation angle).

The failure to use intelligent systems based on 'computer vision' capable of detecting these deviations and building accurate motion models leads to the consolidation of technical errors that are difficult to correct in the future. Therefore, the problem lies in the need to build an intelligent expert system that programmers exercises based on computer vision data to develop mechanical variables and the accuracy of double kicks in this category.

1-3 Research objectives:

1. Build an intelligent expert system that uses computer vision technology to determine the mechanical trajectories of double kicks.
2. Design programmed exercises based on the kinematic modeling outputs extracted from the intelligent system.
3. Identify the effect of these exercises on the development of certain kinematic variables (angular velocity, flight time, joint angles) and the accuracy of double kicks performed by young taekwondo players.

1-4 Research hypotheses:

1. There are statistically significant differences between the pre- and post-tests of the experimental group in kinematic variables and performance accuracy in favor of the post-test.

2. There are statistically significant differences in the post-tests between the experimental and control groups in terms of kinetic modeling and performance accuracy, in favor of the experimental group that used the smart system.

1-5 Research areas:

1-5-1 Human domain: Players of the National Centre for Sports Talent at the Ministry of Youth and Sports for the 2025-2026 sports season.

1-5-2 Temporal domain: The period from 3/11/2024 to 27/1/2025.

1-5-3 Spatial domain: The sports hall of the National Centre for Sports Talent at the Ministry of Youth and Sports.

1-6 Definition of terms:

- Computer vision: A field of artificial intelligence that aims to enable computers to understand and analyze digital images and videos and automatically extract structural data from them.
- Kinetic modeling: The process of creating a mathematical and digital representation of human body movement that determines the ideal trajectories, speeds and angles required to achieve maximum mechanical efficiency.
- Double kicks: A skill consisting of two or more consecutive kicks without placing the foot on the ground, relying on speed of movement and maintaining balance.

Chapter Two

2- Research methodology and field procedures:

1-2 Research methodology:

The researcher used an experimental methodology with two equivalent groups (experimental and control) and two tests, pre-test and post-test, to suit the nature and objectives of the research. To achieve kinematic modeling, the study relied on computer vision, which allows for the automatic extraction of skeletal data, in line with Labib's (2020) proposal on the importance of digital analysis in monitoring kinematic variables.

2.2 Research population and sample:

The research sample was selected deliberately from among young taekwondo players at the National Centre for Sports Talent (Ministry of Youth and Sports), numbering 20 players for the 2025-2026 sports season, divided into two groups (experimental and control) with 10 players in each group.

1-3-2 Homogeneity of the research sample:

The researcher conducted a homogeneity test on the sample in the basic variables to ensure its normal distribution.

Table (1) shows the homogeneity of the research sample in the basic variables (n = 20).

Twist coefficient	The Mediator	Standard deviation	Arithmetic mean	Unit of measurement	Variables	t
0.45	16.00	0.85	16.50	year	Chronological age	1
- 0.12	172.00	4.12	172.40	cm	Total height	2
0.62	61.50	3.55	62.10	kg	Body weight	3
0.25	4.00	1.10	4.20	year	Training age	4

Equivalence of the two research groups:

To ensure the equivalence of the two groups before starting the experiment, the researcher conducted preliminary tests on the variables under study.

Table (2) shows the equivalence of the two research groups (experimental and control) in the preliminary tests.

Statistical significance	Significance level	Calculated t-value	Control group	Experimental group	Unit of measurement	Variables studied	t
Not applicable	0.650	0.45	612.30	610.45	Degree/Second	Angular velocity of the pelvis	1
Not applicable	0.740	0.32	0.59	0.58	Second	Kinetic transfer time	2
Not applicable	0.810	0.21	6.15	6.20	Degree	Accuracy of kicking performance	3

2-3 Technical equipment and methods used:

The researcher used a smart system based on computer vision, consisting of:

- High-speed cameras (120-240 frames/second).
- A workstation equipped with a high-performance graphics processor.
- An algorithm for tracking the digital skeleton (33 joint points).

2-4 Scientific basis of the smart system and tests:

In order to ensure the accuracy of the data extracted from the computer vision system and its ability to measure variables (angular velocity, transfer time, accuracy), the researcher performed the following scientific tests:

First: Test validity:

The researcher used logical content validity by presenting the components of the intelligent system and the programmed exercises to a group of experts in the fields of biomechanics, sports training, and artificial intelligence (Appendix 1). Ninety per cent of the experts agreed on the validity of the system for measuring the variables under study. The validity associated with the test was also confirmed by comparing the system's results in ‘joint angles’ with manual analysis using the Kenova programmed, and the results showed a high degree of consistency.

Secondly: Test stability:

The researcher used the test and retest method, where the test was applied to the stability sample (the same sample as the exploratory experiment) with an interval of seven days between the first and second applications. The correlation coefficient (Pearson) was calculated as shown in the table below:

Table (3) Shows the reliability and stability coefficients for the variables under study.

Value (z) or significance level	Correlation coefficient (stability)	Variables studied	t
Not applicable	0.89	Angular velocity of the pelvis	1
Not applicable	0.87	Kinetic transfer time	2
Not applicable	0.91	Accuracy of kicking performance	3

Fourth: Objectivity of the test:

Since the smart system relies on automated digital processing without human intervention in extracting coordinates, the test is highly objective, as the results are not affected by the subjectivity of the analyst or trainer.

2-5 Field research procedures:

2-5-1 Preliminary tests:

The researcher conducted preliminary tests for the two research groups (experimental and control) at 3 p.m. on Monday, 3 November 2024, in the sports hall of the National Centre for Sports Talent. The researcher took care to stabilize the spatial and temporal conditions and standardize the tools used, measuring the following variables:

- Kinematics variables (angular velocity, transfer time) using the smart system.
- Accuracy of double kicks on the electronic shield.

2-5-2 Exploratory experiment:

The researcher conducted an exploratory experiment on 15/11/2024 on a sample of three players from the research community and outside his primary sample to achieve the following objectives:

1. To verify the efficiency of the tracking algorithm in monitoring key points under the lighting of the sports hall.
2. To determine the optimal height and angle of the cameras to cover the full range of motion of double kicks.
3. To verify the clarity of feedback (audio and visual) and the players' response to it.
4. Calculate the time taken by each player in the tests to organize the training unit.

(As we wrote earlier, this is included here to ensure the safety of the tools before starting the curriculum).

2-6 Training programmed (main experiment):

The exercises programmed into the smart system were implemented on the experimental group, while the control group continued with its usual (traditional) programmed, from 17/11/2024 until 25/1/2025, at a rate of three training units per week (Sunday, Tuesday, Thursday) for a period of eight weeks.

Note: Immediate feedback was provided to the experimental group via a display screen linked to the smart system to correct movement patterns in real time.

2-6-1 Post-tests:

After completing the training curriculum, the researcher conducted post-tests for both groups (experimental and control) on (27/1/2025), in full compliance with the same conditions and circumstances of the pre-tests in terms of (place, time, technical tools, and method of implementation) to ensure the accuracy of the comparison between the results.

Table (4). shows the structure of the training curriculum and the distribution of loads according to the expert system.

Volume (repetitions)	Intensity	Type of feedback	Training objectives	Stage
High (educational)	% 70-60	Visual (digital structure display)	Motion control and modeling	Week 1-2
Medium	% 80	Digital (speed	Angular	Week 3-5

		and time values display)	velocity and force development	
Low (qualitative)	% 100- 90	Audible (instantaneous error alerts)	Dynamic stability and precision	Week 6-8

2-7 Statistical methods:

The data were processed using SPSS to represent the results through: (arithmetic mean, standard deviation, median, coefficient of skewers, T-test for independent and paired samples, and percentage of improvement (%).

Chapter Three

3- Presentation, analysis and discussion of results

3-1 Presentation and analysis of test results (pre- and post-test) for the experimental group:

The table below shows the results of the group trained using the smart system, to demonstrate the extent of progress achieved by the experiment:

Table (5) Pre- and post-test results for the experimental group in the variables studied and accuracy (n=10)

Statistical significance	Significance level	Calculated t-value	Post-test	Pre-test	Unit of measurement
applicable	0.000	8.12	745.20	610.45	Degree/second
applicable	0.001	6.45	0.38	0.58	Second
applicable	0.000	9.33	9.10	6.20	Degree

Table (4) shows statistically significant differences between the pre-test and post-test in favour of the post-test, with players achieving an increase in angular velocity and a decrease in transfer time, demonstrating the effectiveness of intelligent programming.

3-2 Presentation and analysis of the post-test results for the two groups (experimental and control):

To demonstrate the superiority of the intelligent system over traditional training, the table below presents a comparison of the final results:

Table (6) Post-test results for the experimental and control groups (n1+n2=20)

Statistical significance	Significance level	Calculated t-value	Post-test	Pre-test	Measurement unit	Variables studied
For experimental purposes	0.002	5.12	650.30	745.20	Degree/Second	Angular velocity of the pelvis
For experimental purposes	0.003	4.88	0.49	0.38	Second	Kinetic transfer time
For experimental purposes	0.000	6.15	7.40	9.10	Degree	Accuracy of double kicks

The clear superiority of the experimental group is evident in Table (5), showing a significant superiority of the experimental group that used the intelligent system over the control group, as the experimental group achieved a mean performance accuracy of (9.10) compared to (7.40) for the control group, with a calculated (t) value of (6.15). This proves that the use of 'computer vision' in motor correction outperforms the traditional visual method used by trainers.

3-3 Discussion of results:

The researcher attributes this qualitative development (shown in the tables above) to the fact that the intelligent expert system acted as a 'precise mechanical observer.' The immediate feedback that the player received when monitoring the 33 pivotal points helped to 'program' the muscular response according to correct mechanical pathways. The reduction in 'motor transfer time' to (0.38 seconds) was a direct result of the system's instant alerts, which led to energy savings and increased accuracy in hitting the electronic protector, which is consistent with the study **(Lee &Kim, 2023)** on the importance of computer vision for the development of martial arts.

The results presented in Tables 4 and 5 clearly show the superiority of the experimental group that used the exercises programmed by the intelligent system. The researcher attributes this development to the following factors:

First: Digital modeling effectiveness and angular velocity: The use of computer vision technology allowed for the monitoring of 33 joint points, enabling the player to perceive the correct movement path. The increase in the angular velocity of the pelvis is due to the system's ability to correct the 'radius of rotation' instantaneously. This is confirmed by **(Al-Fadli, 2010)** that 'the efficiency of circular kicks is related to the ability to transfer angular velocity from the trunk to the limbs at the maximum possible speed.' This is also supported by Zhang (2024), who states that 'point tracking algorithms provide accurate data on kinetic explosion that exceeds human observation capabilities.'

Second: Kinetic transfer time and feedback: The results showed a reduction in kinetic transfer time to 0.38 seconds, which is ideal for double kicks. The researcher believes that the instant alerts provided by the expert system contributed to reducing response time. This is consistent with a study **(Hermann, 2023)** which indicated that 'intelligent intervention in correcting motor trajectories reduces the transfer time between compound movements in combat sports.'

Third: Performance accuracy and dynamic stability:

The superiority in performance accuracy is due to the 'expert system' that addressed trunk tilt and body centre of gravity deviation. The programmed exercises helped the player maintain angular momentum, which **Bridge (2021)** pointed out as 'the stability of the body's longitudinal axis is the key to achieving accuracy in consecutive kicks.' **Lee & Kim (2023)** also confirmed that 'the integration of computer vision gives the player "mechanical awareness" that translates into high accuracy on electronic targets.'

The researcher believes that the smart system was not merely a measurement tool, but rather a 'digital coach,' transforming the exercises from random repetition to 'mechanically programmed performance,' which led to the qualitative leap in the statistical results shown in the tables above.

3-4 Presentation of the results of 'kinematic modeling' and comparison with the global standard:

This table shows the extent to which the system succeeded in bringing the players to the ideal performance model:

Table (7) Percentage of conformity of the experimental group's performance with the optimal mechanical model for the experimental group

Numerical evaluation	Deviation ratio	Achieved mean (two-dimensional)	Ideal model	Biomechanical criteria
Identical	% 21	14.2 درجة	15-12درجة	Trunk angle
Identical	% 1.4	170.5 درجة	175 – 165 درجة	Knee angle at kick moment
Identical	% 3.5	0.37 ث	0.40 – 0.35 ث	Flight time

5-3 Discussion of results:

The remarkable development of the experimental group to the effectiveness of the intelligent expert system that provided accurate ‘immediate feedback’. The use of computer vision technology allowed for the detection of hip and knee joint deviations that are not visible to the naked eye, enabling the player to correct his movement path instantly. The programmed exercises also addressed ‘movement hesitation’ in the transition time between kicks, resulting in increased angular velocity and stability of the body's centre of gravity, which was directly reflected in the accuracy of the electronic shield. These figures reflect the qualitative shift from a random movement path to a mechanically controlled path, which the young player lacked due to the coach's visual impairment in perceiving fractions of a second.

The researcher attributes the clear superiority of the experimental group (as shown in Tables 4, 5, and 6) to the nature of the immediate feedback provided by computer vision.

1. Angular velocity: The system's monitoring of 33 joint points allowed the player to perceive ‘kinetic lag’ in the hip joint and immediately address it through programmed exercises, which reduced the radius of rotation and increased angular velocity.
2. Movement transfer time: The system's audio alert (less than 0.40 seconds) helped create a rapid neuromuscular response, resulting in the two kicks being linked with high mechanical harmony.
3. Accuracy: Maintaining the stability of the centre of gravity according to the expert system's instructions reduced the dispersion of force and achieved the highest accuracy of impact on the electronic target.

Chapter Four

4. Conclusions and Recommendations:

4-1 Conclusions:

The researcher reached the following conclusions:

1. Effectiveness of the technique: The intelligent expert system based on computer vision proved to be highly accurate in monitoring and analyzing the kinematic variables of double kicks, thus outperforming traditional observation methods.

2. Importance of modeling: The process of ‘kinematic modeling’ provided young players with an ideal visual and digital standard, which helped them to quickly understand and correct mechanical errors.

3. Variable development: The computer-programmed exercises led to a significant improvement in angular velocity and kinetic transfer time, which had a positive effect on the power and speed of the second kick in the double series.

4. Enhanced accuracy: Stabilizing the body's centre of gravity and adjusting the angles of the torso's inclination, as directed by the expert system, contributed to increasing the accuracy of hits in the legal areas of the electronic shield.

5. Economy of effort: Data-driven training reduced random errors, resulting in improved skill performance efficiency with minimal physical effort.

5-2 Recommendations:

Based on the above conclusions, the researcher recommends the following:

1. Technical adoption: The need to adopt computer vision and artificial intelligence systems as essential tools in national taekwondo training centers, rather than relying solely on traditional methods.

2. Staff development: Organize training courses for coaches to teach them how to read biomechanical reports generated by expert systems and convert them into practical training solutions.

3. Scientific foundation: Focus on 'kinematic modeling' in emerging age groups and youth to ensure the development of a skill base with a sound mechanical foundation that prevents the consolidation of errors.

4. Expansion of research: Conduct similar studies on aerial kicks or defensive and blocking skills using 3D computer vision techniques.

5. Software integration: Invite sports science and software engineering specialists to develop simple mobile applications based on the same algorithms to be made available to coaches in small clubs.

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- **Proposed training programmed (programmed exercise curriculum)**

1. Programmed objective:

To develop kinematic variables (angular velocity, kinetic transfer time) and the accuracy of double kicks using feedback from the smart system.

2. Load distribution (training sessions):

- Number of weeks: 8 weeks.
- Number of weekly sessions: 3 sessions (Sunday, Tuesday, Thursday).
- Session duration: 90 minutes.
- Training method: high-intensity interval training and targeted qualitative training.

3. Training unit content (main section - 60 minutes):

The exercises are divided into three basic groups based on the expert system outputs:

Group 1: Modeling and motor path exercises (weeks 1-2)

- Exercise: Slowly perform a double kick in front of the camera (computer vision).
- Role of the system: The system shows the player the 'digital skeleton' and compares it to the ideal model.
- Objective: Sensory perception of the correct angles of the pelvis and knee before moving on to high speeds.

Group 2: Angular velocity and explosive power exercises (weeks 3-5)

- Exercise: Hop over small barriers (20 cm) and then perform a quick double kick at an electronic target.
- Role of the system: Immediately measure the 'angular velocity' of the pelvis. If it is below the standard, the system requests that the exercise be repeated with greater focus on the 'rotation of the supporting foot'.
- Volume: 3 sets × 6 repetitions. Rest for 2 minutes.

Third set: Dynamic stability and accuracy exercises (weeks 6-8)

- Exercise: Perform a double kick after a turn (360 degrees) or after a feint.
- Role of the system: Measure the deviation of the centre of gravity and alert the player audibly in case of trunk tilt, which causes a loss of accuracy.
- Objective: Maintain the efficiency of the 'motor pattern' under conditions similar to those of a match.

Programmed exercise model (therapeutic/developmental)

Exercise name: Development of 'angular momentum' and double kick accuracy (Double DollyoChagi).

1. Exercise objective:

- Mechanical objective: Increase the angular velocity of the hip joint and reduce the kinetic transfer time between kicks.

- Skill objective: Hit two electronic targets at different levels (chest and then head) without losing balance.

2. Kinetic description (procedures):

1. The player stands in a ready position in front of the camera system.
2. The player performs a quick double kick on the makiwara or electronic targets.
3. Computer vision draws an imaginary line for the centre of gravity and determines the angle of the ‘support foot’.

3. Software criteria (expert system programming):

The system analyses performance in real time and issues the following instructions based on the result:

- Situation (A): If the transfer time between kicks is >0.40 seconds ← the system issues a visual alert (red color) and asks the player to perform additional ‘response speed’ exercises.
- Case (b): If the torso leans back more than 15 degrees ← the system issues an audio instruction (‘Keep your back straight’) and suggests exercises to strengthen the core muscles.

4. Training dose (intensity and volume):

- Intensity: Maximum (90-100%) of performance speed.
- Repetitions: 5 repetitions per set.
- Number of sets: 4 sets.
- Rest: Rest between repetitions (15 seconds) and between sets (2 minutes) to restore the phosphate system.