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Kinetic Analysis Using Computer Vision Technology in the Execution of the Badminton Smash Skill by an Iraqi National Team Player

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ABSTRACT: The importance of the current study lies in the employment of one of AI advance technology (Computer Vision) in kinematic analysis in sports. These techniques allow to follow the player's movement, and extract accurate quantitative metrics from video such as joint positions, motion paths, velocities, and time-series variations in performance. This is considered as a new tendency in sport measurement. This approach minimizes dependence on subjective observation and visual estimation, offering coaches and athletes objective, quantifiable data amenable to both statistical and mechanical analysis. Such data can subsequently be leveraged to enhance achievement (performance). Moreover, it emphasizes kinetic variables as fundamental parameters that explain force, power, torque, momentum, and energy generation during execution, moving beyond a mere qualitative description of the movement's external appearance. This is because the skillful performance in badminton does not only depend on joint position and angles of movement, but also it affected by how power is produced, distributed, and transferred through the kinetic chain, and how the player's changes the muscular strength (biomechanics) to high speed for racket and shuttlecock.

The aim of the research is to find out new means in analyzing the performance, particularly for those games with high speed sport likes badminton. This is because smash skill is one of the most important attack skills which determines match points and demands a high degree of coordination among kinematic sequencing, reactive speed, and projection angle, in order to guarantee maximal post-impact shuttlecock velocity. Mostly, the local and traditional studies depend on visual observations or traditional programs in dynamic analysis of body movement during the performance. The Computer Vision technology having proven its capability in athletic movement analysis via body landmark detection and kinematic parameter estimation from video.

The research problem delimited the population to all recorded attempts of the Iraqi national number one (Rami Wissam Salah), as he is the player who settles outcomes and earns medal-winning results across both singles and doubles champions. concerning the samples of the study, the researcher takes (50) try only and extracts its data. These observations are considered as samples because the samples are the taken observation wither from one person or group of people. The researcher used appropriate equipment and devices for his research. The most significant of them is AI technology (Computer Vision) which is a framework of algorithms and mathematical models that processes digital visual data (images/video) for the purposes of object detection, recognition, classification, and temporal tracking, in addition to motion analysis and 3D scene reconstruction. The study's results showed that the kinetic energy variable had the highest contribution rate to the proficiency test score, and the Computer Vision analysis was highly accurate in detecting subtle motion details.

1. INTRODUCTION

1.1. Definition

In recent decades, the world has witnessed unprecedented technological revolution which changes all the aspects of the life. The technology becomes a crucial part of our everyday life, starting with social media and education reaching to industry, medicine and transport which contributes to progress accelerating and life –quality improving. During this transformation, the sport is not a way from this revolution. It was one of the most beneficial area of developing technology. Technology played a pivotal role in developing the sport performance, analyzing the data, improving training, reducing injuries, and reinforcing the audience experience. By using AI technology, virtual reality technologies, and sensor devices, the sport becomes more accurate, professional, and communicative which open new horizons for all; athletes, coaches and audience.

Badminton is one of the most racket games which spreads among its participants the spirit of challenge and enjoyment because it is practiced everywhere by everyone. It is played by children, young, and old ages. This is because of its lightweight racket comparing with other rackets, and its low cost where everyone can buy it. In addition, the shuttlecock (the tool) does not get away during the playing. All these things, make Badminton the favorite game for many people, it is played in garden and halls. It gives vitality and energy for both sexes. Studies indicate that badminton is one of the quickest game in the world because it characterized by fast-paced gameplay. Moreover, this game is played for short period with high intensity. Also it characterized by continuous communication and quick response. It requires thinking and quick reaction which characterized by precise performance (Ahmed, Mahmood: 2016, 25-26). This means it leaves little time for the player as reaction for these attacks. So, the player should be fast and precise in making decision in the game.

The importance of this research located in focusing on kinematic variables as explanatory variables for force, power, torque, momentum, and energy produced during performance, rather than merely describing the external form of the movement. The professional performance in smash skill does not only depend on positions or the angles of movement, but also it affected by how produced the power, distributed and transferred it via kinetic chain and the player's ability to convert muscular force into high velocity for the racket and the shuttlecock. In addition to employment of AI technology and computer vision in athletic biomechanical analysis. These technologies allowed to follow the movement of the player and extract accurate quantitative indicators from the video like joint positions, movement trajectories, velocities, and temporal changes during performance. This represents a modern trend in sports measurement because it minimizes the depending on auto observation or visual measuring, and provides for coaches and players objective data that might be analyzed statistically and mechanically, and get benefit from them later on to improve the level of achievement (performance).

The problem of the study determines that the performing effectiveness of the badminton smash skill does not explain by technical notes or external indicator for the motion only, because this skill depends on precise kinematic variables related to the rotational motion of the striking arm, and particularly the moment of inertia, angular momentum, and kinetic energy. Despite of the importance of these variants in explain the power production and shift it to racket and the shuttlecock but its use in analyzing the performance of Iraqi national team player, especially AI technology and computer vision was still limited. Being such techniques have not been systematically used in kinematic performance studies on badminton players in Iraq. This prompted the researcher to venture into such an investigation, aiming to contribute to providing a precise and objective mechanical interpretation of the performance.

1.2 **The Goal of the Study**

1. Identifying the impact of the relation of the three kinematic variables among each other on one hand, and the performance level of the forehand smash stroke among Iraqi national badminton team players, utilizing AI algorithms implemented in Python.
2. Applying computer Vision technology to extract the kinematic data to perform forehand smash stroke skill for Iraqi national badminton team player.

1.3 **The Study Dimensions**

1. Human dimension: Iraqi national badminton team player for 2024-2025.
2. Spatial dimension: the close sport hall for specialized collage in badminton (Al-Mahaweel) which belong to directorate of youth and sport in Babylon.
3. Temporal dimension: from 2-6-2025 to 26-6-2025.

1.4. **Determining the Terms**

- Computer Vision: it is one of AI branches and computer science, it helps the computer systems to acquire the ability of understanding the digital images and videos, then analyze them and extract a meaningful data in a similar way to human visual understanding (some time it extends this understanding). Computer vision depends mainly on 'Deep Learning', especially convolutional neural networks (CNNs) and the attention models (transformers) which makes development in accuracy and speed of the analysis (Mendes: 2023, 1-3).

3- THE PROCEDURES OF THE STUDY:

3.1 Designing the study

The researcher depends on descriptive analytic approach in studying the case of quantum biomechanical case of multiple trials. Because it is suitable to the aim of the research which is analyzing some extracted kinematic variables by using AI technology in performing of the badminton smash stroke skill in Iraqi national team player. And the player was chosen deliberately because he represents elite performance level. While the sample of the analysis is the successful documented trails of smash stroke skill which is (50) which met the technical and analytic acceptance criteria. The filming of the performance is in controlled training environment by using 4 cameras with filming rate (60 fps), with fixing the scope of cameras, vision, and spatial inspection. Then, the videos are treated by using the computer vision algorithms to extract the key anatomical landmarks of the striking arm (shoulder, elbow, and wrist), and converting the extracted coordinates into numerical analyzable data. After applying data smoothing and discarding low-confidence frames, the impact frame was detected, and its preceding frame was utilized to derive the kinetic indices—namely, the moment of inertia, angular momentum, and kinetic energy of the striking arm.

The followed frames are not treated as independent unites for statistical analysis, but they are used to extract the values of each trail while each trail is considered as basic analytic unite. Measurement quality was ensured through face and content validity, while reliability was assessed using a test-retest approach. This involved computing the Interclass Correlation Coefficient (ICC), the Standard Error of Measurement (SEM), and the Coefficient of Variation (CV%) to determine the degree of agreement between the algorithmically derived measurements and the manually obtained reference measurements across a selected subset of frames. Also, suitable statistic treatments are used such as descriptive statistics, correlation tests, and regression analysis, this is to make sure of kinematic variables contributions in performing of the smash stroke mission.

3.2 **The Society and the Study Sample**

The problem determines the society of the research where a player was chosen from Iraqi national badminton team, he is classified as number one in Iraq, and he is described as elite sporting case because he is the one who decides the results and achieves the colorful medals in champions whether in single or double champions. While the sample of the research, the researcher analyzes large number of trails and time frames which was (50) trail. He analyzes them by adapting computer vision. Each successful trail is considered as independent analytical unite to extract the determined kinematic variables, with check the filming conditions and calibration, and determines the moment of stroke and the standards of accepting the trails. These observations are considered as samples, because the samples are the taken observations wither from one person or from group of people. The sample is considered (as part of society represented honestly and imposes us particular size fits with the society the sample is taken from (Hisham: 2021, 78).

This kind of study is called a study of single case or case study. It is a detailed study about one case (one person) in order to understand the behavior or the case deeply. This kind is mostly used in social studies (Yin: 2009, 127), therefore, knowing the quantitative data values of the influential variables on achievement level (performance). The next table shows some specifications of this player, where some of body measurements are taken.

3.3. **The Used Devices, Tools, and Means**

(The observation, Arabic and English sources, supporting team, personal interview, internet, 1 data registration form, 3 rackets of (yonex) type, 7 boxes of shuttlecock, laptop of (Dell Core-i7, 10TH GEN) type, cameras of 60 fps of (Nikon D7100|0 type, accuracy test skill, colorful tape (adhesive tape), scale drawing, measuring tapes to measure the accuracy areas, 1 electrical connector, 2 iron stands to fix the cameras, AI algorithm to extract anatomical points like (Media Pipe Holistic، Open Pose، YOLO-Pose, Python program for analysis، Open CV for video processing ، NumPy / Pandas for accounts ، SPSS for statistical analysis)

3.4 **The Used Tests in the Research**

- Badminton forehand smash skill test (Wissam: 2013, 61-62).
- The goal of the test: to measure the accuracy of the forehand smash skill.
- The required tools: badminton rackets, natural or synthetic shuttlecocks, additional support poles (213 cm high), an elastic cord, a data recording form, and a badminton court lined according to the test design.

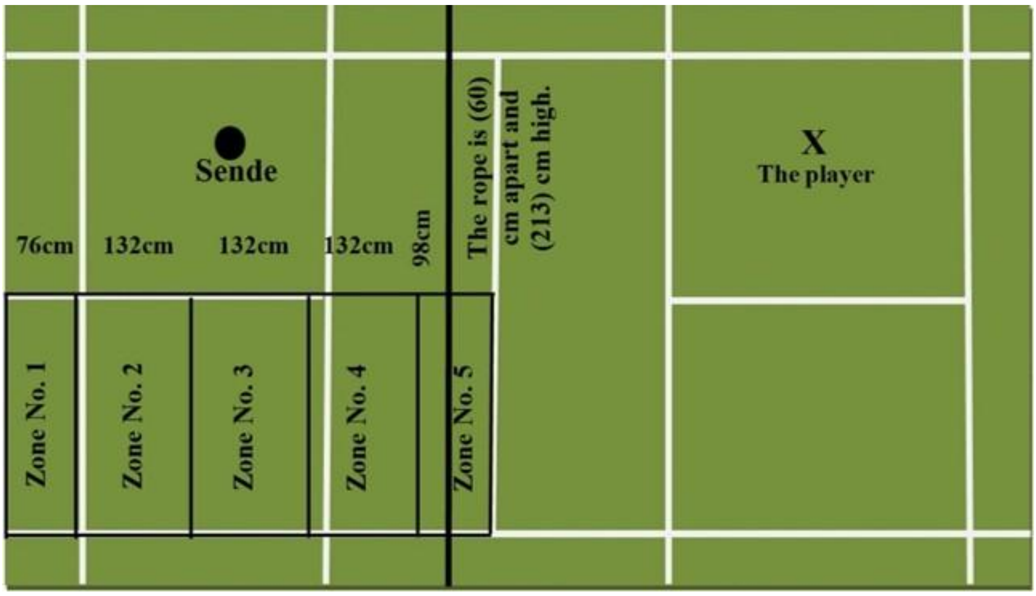

Figure number (1) Procedure for performing the forehand smash accuracy test

The description of the performance:

The player stands in his position (x) and holds his racket with a front grip, and returns the shuttlecock sent to him by the couch on the left side of the right- handed player. And it is the opposite if the player is left- handed from the opposite area by using strong smash stroke trying to fall it down in a high degree area if shuttlecock passes above the net and under elastic cord which is fixed behind the net, 60 cm distance, and 213 cm high. The player makes 70 trial, with observing the strength of smash stroke.

Method of Calculating the Grades:

- The shuttlecock that touches the net and falls in front of it or does not pass under the elastic cord does not regarded a trail and is repeated again.
- The shuttlecock that passes the determined accuracy area is not regarded a trail and is repeated again.
- For each correct trail, the value grade is calculated of the area where the shuttlecock falls, as it clarified in figure (6).
- The total value of the performance is calculated by sum of performance evaluation for each trail with its accuracy with speed rate of the shuttlecock with time of effect after unifying the units of measurement. This means:

The followed variable= evaluation of the performance + accuracy of the performance+ the speed rate of the shuttlecock+ time of effect.

So, the grade of the player is the total score for skill performance evaluation out of (5) with the result of accuracy of the performance out of (5) with the shuttlecock speed rate with time of effect. So, the total result appears out of (100) for each trail. After that, the scientific treatments are extracted for this complex test.

3.4.1 **Drop Shot Skillful Performance**

Two indicators are adapted to know how to extract the level of skillful performance progress (the followed variable), they are (player's performance accuracy) inner evaluation and (performance evaluation by the experts) external evaluation. This is because it could not depend on one indicator, and they may be considered as the most important indicators because the sum of their results shows the completed followed variable of achievement level (skillful performance). Below are the details of each:

3.4.1.1 **Performance Evaluation:**

By making videos, the data is determined about the player's performance level. Then the video is divided into trails by using Microsoft Clipchamp program. After that, they are sent to two specialized experts in badminton to analyze and evaluate the performance by observing and monitor what the player is doing, then giving (5) grades for each trail where the best and highest value of performance is (5) while the lest and lowest is (1). The indirect analysis by repetitive observation is used because the movements in this game are characterized by speed. Recording is more accurate than direct analysis since it depends on reshow the skill in different way for more than once. This makes the experts focusing on the performance details in more accurate way. And this is what Yasir Najah focuses on (2015) "With direct qualitative analysis, it is impossible for the observer to discern performance intricacies as the speed of sports movements increases, particularly when such movements are governed by specific skill demands. As the execution speed of motor skills accelerates, the visibility of performance details diminishes, consequently reducing the accuracy of movement or skill analysis"(Yasir, Ahmed: 2015, 38). After taking the results from the two experts, the kappa statistic coefficient was computed to be sure about the agreement of the experts (Hisham Hindawi: 2021, 176). The calculated Kappa coefficient was (0.84), which is statistically significant ($p < 0.001$), indicating strong agreement among experts and confirming the reliability of adopting their results.

3.5 **The variables of the Study**

It has extracted all the variables by using computer vision technology.

3.5.1 **Right Arm Striking Moment of Inertia**

"The moment of inertia is one of the factors affecting rotational motion, just as mass affects translational motion." (Adel: 1998, 82) because it is directly proportional to its mass. While the other factor that affects the moment of the body is the distance of the body from the axis of rotation where the **moment** increases with distance increasing between the mass and the axis of rotation (Talha: 1998, 258-259). That is why the player in early stage of the movement, tends to reduce the moment of inertia by flexing the elbow and bringing the body segments closer to the axis of rotation, the angular velocity of the arm increases. Subsequently, the radius is gradually increased by extending the elbow just before the moment of impact, which converts the angular velocity into high linear velocity at the distal end, thereby enhancing both the racket and shuttlecock speeds. The data were extracted from the rear-view camera using Computer Vision technology, according to the formula ($I = m \times r^2$), where the moment of inertia is measured in units of ($kg \cdot m^2$), as shown in Figure (2).

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Figure (2) Right Arm Striking Moment of Inertia

3.5.2 **Angular Momentum of the Right Striking Arm**

Angular momentum is considered one of essential dynamic variables in analyzing badminton smash stroke, where it reflects the rotational momentum of the arm around particular axis during the performance. Depending on third law of Newton (action and reaction) " If a body exerts a torque (or angular impulse) on another body, the second body will experience a change in its angular momentum. However, in a closed system with no external net torque, the total angular momentum of the system remains constant. This is known as the law of conservation of angular momentum" (Sameer: 1999, 216). It is considered essential in power transforming in kinesthetic system Where it is subject to the principle of conservation of angular momentum in relative closed systems. In smash stroke, angular momentum is generated through the rotation of the trunk and its transfer to the shoulder, then the elbow, then the wrist where a gradual amplification happens in the speed for distant parts. This leads to accumulation of angular momentum of the right striking arm to reach its climax at moment of contact which leads to produce high speed for racket. This variable is extracted from the back camera by using computer vision technology and according to the law (Angular momentum = Moment of inertia × Angular velocity), "since the momentum of the striking arm in rotational movements is the product of its moment of inertia and its angular velocity." (Adel: 2007, 137). As in figure (3).

Figure (3) shows the Angular momentum of the right striking arm

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3.5.3 **Kinetic Energy of the Striking Arm**

Kinetic energy variable of striking arm is considered one of essential dynamic variable, it reflects the amount of the stored mechanical energy in the movement of the arm during its moving to the racket, then to the shuttlecock. The kinetic energy of the racket varies according to the different radii (distances from the axis of rotation) as the racket is brought closer to or farther from the axis by extending or flexing the elbow joint. "However, this energy differs for two bodies of equal mass when each is moved at the same angular velocity, if the two bodies are not identical." (Adel: 1998, 85). This energy is the product of interaction of mass of the arm parts with its speed with the angular. This makes it a perfect indicator of the efficiency of movement production and its translation into effective offensive performance, "furthermore, since the racket is held in the hand—which is the most distal segment of the upper limb-the radius of rotation is maximized when the arm is fully extended, thereby increasing the kinetic energy as a result of the increased radius" (Sameer, 1999: 218). Where it is extracted from the back camera by using computer vision technology. According to the law $K=1/2\ mv^2$ (Sameer: 1999, 218), they are measured by $(kg)\times(m/s)^2$ ، as in figure (4).

Figure (4) Shows Kinetic energy of the striking arm

3.8. **The Main Experience:**

The researcher with his supported staff make the main experience on Monday 2-6-2025 at 4 PM, in close sport hall in Al-Mahaweel. The body measurements of top-ranked Iraqi player are taken. After that, the player makes the warm-up and starts the test after settling 4 cameras in already determine locations in exploratory experiment. Then, the results have been put in table form to make it easy to extract scientific evidence.

3.9 **Instructional Aids**

The researcher uses the statistical box (SPSS).

Arithmetic mean

Standard deviation

Coefficient of variation

Regression

4. **THE RESULTS PRESENTATION, ANALYSIS, AND DISCUSSION**

This chapter deals with the results presentation, analysis, and discussion of the research according to the taken data from the sample of the study. These results are organized in statistical tables to provide precise and accuracy in data presentation. In addition to its role in facilitating the extraction of scientific implications, it serves as a methodological tool appropriate to the nature of the research and its data. "It reduces the likelihood of error in subsequent stages of research and strengthens and reinforces scientific evidence." (Rowdy: 1973, 35). It is worth to mention here is "Information analysis means extracting the first quantitative and qualitative scientific indicators that prove the answer to questions and confirm the acceptance or rejection of the hypothesis." (Saleh: 1995, 11). This is in order to achieve to the research's objectives and verifying its hypotheses.

4.1 **presentation of Descriptive Values Results for the Bio kinematic variables and Sending Accuracy of high rotation in Tennis; analyzing and discussing them.**

According to the results of the biokinematic variables analysis, there is a precise quantity for variables of the study. This depends on scientific base that is the employment of inferential statistic coefficients does not make any sense if is not preceded by comprehensive statistic description of data. This description gives more accurate understanding for the biokinematic variables values. This involves verifying the normality of their distribution and evaluating how well they represent the research sample's traits, as well as helping to interpret the hidden meanings underlying these numerical estimations. So, the researcher adapts statistical descriptive approach to analyze the biokinematic variables values that the player has achieved them during all his trails which are (50). This is by employing measures of central tendency, measures of dispersion, as well as tests for normal distribution.

Table (1) Descriptive Variables

Variables	lower value	Higher value	Arithmetic mean	Standard error	Standard deviation	Range	variance	Skewness value	Kurtosis value
Moment of inertia	7.07	9.86	8.19	0.71	0.10	2.79	0.51	0.727	-0.03
Angular momentum	83.99	96.46	91.34	2.89	0.41	12.47	8.40	-0.54	-0.19
Kinetic energy	315.33	1605.28	1068.71	307.76	43.52	1289.95	94719.08	-0.33	-0.41
The score	5	9	7.1	1.37	0.19	4	1.89	-0.09	-1.20

Table (1) shows arithmetic mean values for each variable which means the center point of data which initially shows for the reader the level of performance where the arithmetic mean is the most truthful measure of central tendency in demonstrating the data's orientation toward their central value. This scale (arithmetic mean) partially explains the form of data, as it lacks the departure of values from that central point. That is why the description required suitable measure of dispersion to give a clear image for the reader about the nature results sample (the trails). It is observed whenever the standard deviation decreases (as measure of dispersion to arithmetic mean) the values are approaching in the middle. while the standard deviation increases to a quarter of arithmetic mean value, gives indictor of high dispersion (editors: 2007: 16-17). This is very clear in (Angular momentum, Moment of inertia, skill test result, Kinetic energy) respectively concerning the increasing in dispersion value.

The standard error is considered as one of measures of dispersion similar to standard deviation but it differs in that it takes the size of the sample in its consideration. So, if the standard error is low, it means the validity of handing data scientifically. So, the increasing of the sample has a clear effect in decreasing the standard error, being the size of the sample is equal in all the variables, so the standard deviation is the important indicator in its determining.

The researcher uses to normality assessment measures (Skewness and Kurtosis) to describe natural distribution principles of the studied variables in more comprehensive way where its use goes beyond the description. So, skewness is from coefficients which gives inference to normal distribution. The distribution is normal if its value is less than (z) value for big samples which are (1,96±) at significant level (0.05). while in case of the increasing in this value, the distribution is skew either to the right middle and becomes positive or to its left and becomes negative (Mansfield:1987, 544). The table shows that the distribution of all variables are normal represented on both sides of the center where the values are varying between positive and negative.

Concerning kurtosis, it is the degree of data accumulation to the center. In another words, it is data repetition in distribution range. Whenever the repetition of the close values to the center is more, the kurtosis value becomes positive. And the opposite also if the distant values to the center repeated, the kurtosis value becomes negative (Groeneveld:1984,391). The table shows that all kurtosis values for (moment of inertia, angular momentum, kinetic energy, the skilled performance test scores) variables are accepted respectively.

4.2 **Presenting, Analyzing, and Discussing the Results of the Correlation Relations of the Matrix.**

Table (2) Shows simple correlation matrix

Variables	Moment of inertia	Angular momentum	Kinetic energy	The result
Moment of inertia				
Angular momentum	0.016			
Kinetic energy	-0.042	0.271		
The scores	-0.099	0.310	0.628	

Table (2) shows the values of calculated correlation relations and the significant level for each of them. The values are distributed between significant and non- significant. The significant values are (0.05) or less which are either direct relationship or inverse one. In the first side it is direct relationship, where the relations (Kinetic energy × skilled performance test scores), then (Angular momentum× skilled performance test scores), then (Kinetic energy × Angular momentum), with calculated values (0.62), (0.31), (0.27) respectively. This could be explained as the following:

Concerning Kinetic energy variable, we observe that it gets the highest value of calculated simple correlation among other variables with (skilled performance test scores). This means this increasing is associated with increasing in the skill test result. This is logical from mechanic point of view, because Kinetic energy is considered as mechanical indicator more effective than skillful performance. Since it reflects the energy produced by the moving striking limb or implement during the skill, and given that kinetic energy depends on the square of the velocity, any increase in arm or racket speed leads to a significant increase in generated energy. This, in turn, improves the ability to perform a powerful and effective smash (Hall:2019:391-392). in addition, the increasing in Kinetic energy reflects better skill of passing the power and energy through Kinetic chain from the close parts to the distant parts reaching to the racket and shuttlecock. This what makes it more connected with skilled performance test scores than other variables which describe partial part of Kinesis (energy) like moment of inertia and angular momentum (King:2020, 9-10).

While the second variable is angular momentum, it gets the second highest average among other variables with skilled performance test scores. This refers to that rotational momentum represents important indicator in explaining the performance effectiveness, even if its influence was less than Kinetic energy. Mechanically, this could be explained as angular momentum reflects It reflects the player's capacity to produce and control the rotational motion of the striking arm as part of the kinetic chain. Since the trunk, shoulder, elbow, and wrist movements all facilitate the proximal-to-distal transfer of momentum toward the racket, a more efficient and precisely timed transfer at the moment of impact significantly increases the chances of a better skill outcome (Bartlett:2007:133-136). Despite this, angular momentum does not guarantee high performance unite unless it transfers to effective speed in the top of the racket and shuttlecock, that is why it gets the second highest correlation after kinetic energy (King:2020:9-10).

While the third highest positive statistical correlation value is for angular momentum and kinetic energy. This means the increasing in angular momentum is associated with increasing in kinetic energy. In other words, a distinct mechanical relationship exists between the angular momentum generated during the movement and the magnitude of the resultant kinetic energy. Mechanically, this is interpreted by the fact that angular momentum is a function of the moment of inertia and angular velocity, while rotational kinetic energy relies on the moment of inertia and the square of the angular velocity. Therefore, an increase in angular velocity acts as a shared determinant that effectively raises both parameters (Knudson:2021:135-139). In the badminton smash stroke skill, the fast coordinated movement for striking arm and racket leads to increasing in angular momentum, at the same time increases the kinetic energy at the moment of striking, that is why this relationship reflects the player's skill in producing effective rotational motion and transferring it to mechanical energy leads to improve the skillful performance (King:2020:8-10).

While the second side (inverse relationships) are (Moment of inertia × skilled performance test score) then (Moment of inertia × kinetic energy) with calculated values (0.10), (0.04) respectively. This could be explained as the following:

Concerning moment of inertia, it gets highest average among other variables with skilled performance test scores. Mechanically, this is explained as follows: a higher moment of inertia means greater resistance of the limb or tool to changes in its rotational motion. This makes the striking arm or racket less able to accelerate quickly at the moment of performance unless adequate muscular torque compensates for this rise. Hence, the resulting skill performance is likely to slightly decrease with an increased moment of inertia, because executing an effective smash depends more on high rotational speed and accurate timing than on greater rotational resistance (Bartlett:2007:133-136).

And this agrees with the mechanical principle that says moment of inertia represents the body's resistance to change its rotation case. Whenever its mass increases or stay away from the rotation axis, rotating the body or accelerating it increases too. In fast-paced motor skills requiring the rotation of the striking limb, an increase in the moment of inertia can restrict angular velocity unless sufficient muscular or biomechanical compensation takes place. This accounts for the weak negative correlation observed between the moment of inertia and the skilled performance test scores (Jacaranda:2017:41).

While the other variable (moment of inertia) gets the second highest average among other variables with (kinetic energy). This could be explained by that the increasing of moment of inertia does not necessarily mean increasing in kinetic energy in the actual performance, because rotational kinetic energy depends on moment of inertia from one side, and on square of angular velocity from other side. If moment of inertia is increased but angular velocity is decreased because of difficulty in acceleration, the kinetic energy has not increased, rather it tends to slight decrease. That is why the relation appears here as inverse relationship, as indicator to increasing in rotational resistance might limit the produced speed, so the final energy is decreased or not increased noticeably (OpenStax:2019:498).

New study shows the effect of moment of inertia of the racket in smash stork, where the increasing in moment of inertia of the racket might decrease racket head speed, while the shuttlecock speed might also increase due to different factors including the point of impact the effective mass upon contact. This supports the explanation that said the increasing in moment of inertia is not always a positive factor in the rapid skill because it might decrease the player's ability to rotate the racket especially if there is no muscular strength or enough techniques to compensation (Towler:2023:1-2).

Table (3) Multiple Correlation Values

Model	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
Kinetic Energy	0.972	0.971	1.22917	0.972	1680.468	1	49	0.001
Kinetic Energy+ Angular momentum	0.988	0.987	0.82162	0.016	61.668	1	48	0.001

Table (3) shows the multiple correlation values for independent variables in the followed variable. The results show two models with ascending values; the first includes one independent variable with the followed variable which is moment of inertia which shows correlation value reaches (0.001), while the second model is that the moment of inertia interferes with angular momentum to form multiple accurate correlation reaches (0.001) which is significant value too.

Table (4) Significance of the Models

ANOVA[a]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Kinetic energy	59.076	1	59.076	84.838	<.001[b]
	33.424	48	0.696		
	92.500	49			
Kinetic energy+ Angular momentum	60.212	2	30.106	43.824	<.001[c]
	32.288	47	0.687		
	92.500	49			

This table tests the significance of the models using analysis of variance (ANOVA), which operates by dividing the sum of squares by the square of the means—that is, the between-groups variance over the within-groups variance. The first model includes the relationship between Kinetic energy and skilled performance test score, this happens by verification of (F) value which is (84.838) which is significant value at significant level less than (0.001) which means the model is acceptable, where if anyone want to use a model of one variable, he could depend on his variable.

While the second model, the calculated (F) value is (43.824) which is significant value at significant level less than (0.001). this means the reliability of adapting of the second model which consists (kinetic energy + Angular momentum) × skilled performance test score.

THE CONCLUSIONS:

1. Iraqi national team player achieves highest level in kinetic energy variable among other kinematic variables.

2. The kinetic energy variable with skilled performance test score achieve highest correlation significant direct value.

3. calculated values vary to kinematic variables between significant and non- significant in its effect on the followed variable.

4. smash stroke is characterized by accuracy depending on the results and it gets scientific coefficient comparing with other tests.

5. it is possible to consider the Computer Vision technology is the best than traditional means to get kinematic data to perform in performing of the badminton smash stroke skill in Iraqi national team player.

Recommendations:

1.The necessity of concentration on the training process in developing kinetic variables which records highest in smash stroke skill performance.

2. adapts the Computer Vision in data analysis for the future studies instead of traditional ways of analysis.

3. adapts smash stroke test in the coming studies for examining the same skill.

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Appendix (1)

The mechanic and programmatic Description for extracted variables from kinetic analysis System depending on Computer Vision.

kinetic analysis System in this study depends on serial and software structure starting with file video download and processing it frame by frame. Then, extracting the main anatomical landmarks of the body and converting them into quantitative variables with kinematic and mechanical significance. This system mixes the technologies of computer vision, engineering computer, and engineering calculations, temporal processing, and some simplified physical derivations, which enable the transition from raw visual motion to a set of numerical indicators that are scientifically interpretable.

In the first stage, the program starts reading the video by using (Open CV) library where this stage initiates for the coming processing by transferring the visual performance to a series of temporal isolated frames. In this stage, the role of the library not only open the file and reading the frames, but also extends to include the extraction of structural and temporal features of the video., and the first is frames rates per second (FPS), frames dimensions, and frames total number. In addition, this stage gets particular significance because the frames rate represents the basis which all the next temporal calculations build upon where the temporal break between two frames is considered as a revised value (FPS), Consequently, any angular velocity or instantaneous change in the variables depends directly on the accuracy of this temporal extraction.

Then, the system moves to computational perception of motion where it uses the (Media Pipe Holistic) model to extract the main features of the body from each frame. These anatomical landmarks are represented by the fundamental skeletal joints, including the shoulders, elbows, wrists, hips, knees, and ankles, along with additional hand-specific markers necessary to calculate wrist joint angles more accurately. The researcher refers to that the model does not produce direct mechanical measures. Rather, it yields positional coordinates of the anatomical points within the image. In other words, the initial computational step does not measure the angles themselves, but provides the raw data from which these angles will be subsequently derived. This constitutes an important methodological foundation, because measurement in this system is based on first estimating the landmarks and then interpreting the geometric relationships among them.

In order to make these extracted objects computable, it should be transferred from relative ratio which is generated by the model to actual coordinates by pixel within the frame dimensions. After this step, the major landmarks are saved in an organized structure which allows to call them according to their anatomical position such as the shoulders, elbows, knees, and others. this structure represents the transitional stage between computer vision level and geometric analysis level. Hence, it is possible to treat these landmarks as vector quantities inter-segmental distances, and joint angles with a two-dimensional distances Cartesian coordinate system.

After this stage, the geometric derivation for kinematic variables starts. And the major algorithm depends the calculating the angle on three anatomical landmarks where the middle is the center to be measured while the other two are the orientation of the two bony segments articulating at this joint. This is accomplished by constructing two vectors originating from the midpoint and extending toward the respective distal endpoints, which are then normalized into unit vectors. Subsequently, the dot product of these two normalized vectors is computed, and the inverse cosine (arcos) function is applied to derive the joint angle in radians. Finally, the angle is converted from radians to degrees. Following this computational protocol, the joint angles for the (elbows, shoulders, hips, knees, ankles, and wrists) are systematically calculated. This approach is considered as unified concerning arithmetic principle despite the landmarks differences which enter in each angle.

The angle of left elbows for example, depending on the relation among the left shoulder, left elbows, and left wrists where the angle at the elbow represents the degree of flexion or extension at this joint as it shows in the image. The same thing is applied with right elbows with replacing of left landmarks by right one. The left shoulder angle is calculated by the relation of the left elbows, left shoulders, left hips while the right shoulder angle is calculated by the relation of the right elbows, right shoulders, right hips. While the two angles of the hips are derived from shoulder, hip, and knee in each side. While the knee two angles are extracted from the relation of hip, knee, and ankle. Accordingly, any angular variable in this system is direct product of geometric representation of the positional structure of the joint within the two dimensional level of the image.

While trunk inclination angle does not calculate in the same way because it does not represent local joint angle among three parts of the body. Rather, it represents the angle of the trunk axis relative to the vertical reference. For this purpose, the midpoint of the shoulders is calculated first, followed by the computation of the hip midpoint. A vector is then constructed connecting the hip midpoint to the shoulder midpoint. Thereafter, the angle between this vector and a vertically oriented reference line is measured. This method permits the quantification of trunk inclination as a holistic kinematic unit, rather than as the summation of discrete, individual joint flexions. The researcher considers this variable is necessary from biomechanical side because it describes the position of trunk in pictorial space which is connected with the trunk's job in directing the mass center and in shift the motion from the two lower limb to the two higher limb.

Concerning the two angles of wrist. For the system, the major landmarks of arm are not enough, but it mixes them with extracting landmarks of the land from the same model. This is due to wrist is a joint requires hand direction representation not the wrist position only. So the wrist angle is calculated by the relation of elbow, wrist, and point lies in the basis of middle finger. This programmatic selection is considered as significant methodological decision because it increases the anatomical meaning of extracted angles and makes them close to real represent of hand's position in relating to forearm. This is also applied to left wrist and right wrist together.

While the angles of the ankles or the feet, they are measured by the relation of knee, ankle, and the front of foot from each side. In this way, the express the angle between the leg and the foot. This variable has a special importance in support, loading, and propulsion mechanism because it describes the last ring from the lower limb which is directly connected with the land. Therefore, its entrance in the analysis does not limited to description of the joint itself, rather it extends to describing the mechanical strategy which the player depends in support, loading, and propulsion.

After the extraction of the raw angle values of each frame, the system begins to build temporal variables which are deriving from them. The first of these variables is the range of motion which is not considered in this program not because it is limited partial stage range but cumulative rang from the beginning of analyzed part of the video to the current frame. The algorithm works here by saving the less value for each angle and the highest value appeared for it, then calculating the difference between them. In this sense, the motion range represents the actual used angular amplitude in the analyzed temporal window. The importance of this analysis lies in that it transfers long temporal chain of angles to indicator summarizes the motion extension in each joint. The researcher sees it should be described as cumulative range is necessary because its value is different from calculated range for a controlled sub-stage like striking stage if the video has not already divided.

Concerning instantaneous for each angle, it has calculated by measuring the difference of the same angle in two successive frames divided on time interval between them. In this way, the system produces indicator which expresses the rate of angle change with time. It is worth noting here that the overall instantaneous angular velocities for all measured angles are computed within this system in degrees per second, as the angular difference is taken directly from the angle values expressed in degrees, without undergoing conversion into radians. Moreover, the algorithm employs the absolute value of this angular difference; consequently, the resulting output reflects only the magnitude of the angular rate of change, rather than its directional sense. Accordingly, this variable does not differentiate between flexion and extension, nor does it distinguish between an increase and a decrease in inclination; it merely quantifies the magnitude of the temporal change in the joint's angular position. After completing the extraction of angular and temporal variables the program proceeds to the calibration step and the conversion of linear units. Being all the extracted coordinates are in pixel unite, they are treated an approximate pixel-to-centimeter conversion factor has been adopted, based on shoulder width. The algorithm operates by measuring the pixel distance between the left and right shoulders within the frame and then dividing an assumed actual shoulder width (equal to 40 cm) by this pixel distance.

This produces cm/pixel coefficient which later on is used in shifting some linear units from image format (pixel) to linear metric format. depending on this coefficient, the distance between the two feet is measured by measuring the pixel distance between the two ankles then multiplying them by cm/pixel coefficient. This variable represents increase in the support base which is an important indicator in explaining base support stability. It is worth noting here that the program shoes this value in the video and in the results file.