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Quantitative analysis using an artificial neural network of the most important bio-kinematic variables to determine the effectiveness of the long jump

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Abstract
The purpose of this paper is to using a neural network to identify the most important bio-kinetic variables to determine the level of achievement of advanced youth in the long jump event, and identifying the differences between the bio-kinetic variables that contribute to determining the level of achievement between the categories of young people and advanced for the long jump event. The researcher used the descriptive method with correlational and comparative relationships to suit the nature of the research problem. The research community was determined from the jumpers participating in the Iraqi Clubs and Institutions Championships for the year 2023, as the researcher chose the research sample in a deliberate manner, namely the top six jumpers for the two categories of youth and advanced participating in the two championships above. 40 successful attempts for the youth category and 36 successful attempts for the advanced were analyzed, and thus the total number became there are 76 attempts for the youth and advanced categories. One of the most important results reached by the researcher is that: The starting angle variable came in first place in terms of its importance in determining achievement for the youth group, while the leaning time variable came in first place in terms of its importance in determining achievement for advanced students, and the contribution rate of the independent variables to the dependent variable (achievement competition) for young people reached (58%), while the contribution rate for advanced reached (65%). One of the most important recommendations recommended by the researchers is that: Necessity of applying theoretical models extracted using artificial neural networks in training programs for trainers to evaluate the level of achievement, and providing biomechanical feedback based on the importance of arranging the values of biomechanical variables in models for determining achievement for the effectiveness of the long jump for young people and advanced students.

Keywords: Long jump event, students, artificial neural network

Introduction
Physical education science is considered one of the advanced sciences in our modern era, based on the use of the latest statistical methods and advanced equipment in artificial intelligence. What distinguishes these sciences is their direct connection to human phenomena, which are considered among the most complex phenomena in scientific research. By human phenomenon, we mean societies and samples of athletes. The use of mathematical models using artificial neural networks specifically has become an important field in current research and studies, due to their great importance. This is due to the complexity of the kinetic phenomena of the movement of the athletic body, which we observe through the technical performance of sports movements. Analyzing the relationships between a group of variables in a scientific and logical manner It leads to clarifying its content, understanding its phenomena, and the possibility of predicting and controlling it.

Many scientific experiments have been conducted in the field of athletics, specifically in the long jump event, including those related to the mechanical and physical aspects and other important fields. We are now addressing in this research this vital activity and its specificity in jumping events and from a statistical standpoint related to kinematic variables. This event began to develop in terms of digital achievement (jump distance) until it reached a distance of (8.95) m, the best distance achieved by the American jumper (Mike Pawk) as a world record.

As for the best achieved distance of (7.68) m, the jumper (Walid Turki) is named as the best Iraqi achievement. It is known that achievement does not stop at certain numbers, as we notice that many international, Asian and Arab records have been broken in various events, and this indicates hard work, special care and field research in the field of specialization.

The long jump event is one of the technical events that requires special specifications in terms of bio-kinetics that must be met by the jumper in order to be able to reach the farthest possible horizontal distance and thus reach the pinnacle of athletic achievement. It is known that the jumper during performance is subject to the laws of ballistics, given that the athlete's body is a jump, and among the factors that help to increase the distance of the jump are (speed of the jump, the angle of the jump, and the height of the jump point). From the researcher's point of view, these factors depend on many kinematic variables to achieve integration. These factors include (Body angles and parts. Horizontal and vertical speeds in certain proportions. The rise and fall of the center of gravity of the body's mass at appropriate moments. The amount of obstruction and the time during the ascent process. Method of performance) all of these variables require an accurate digital system that can determine the interconnected relationships with each other so that the jumper can achieve the best distance. Many variables may have greater proportions than others in achieving the achieved distance, and the large number of these variables makes (performance) tainted by ambiguity in determining the identity of these. Variables. With quantitative analysis based on artificial intelligence, which is considered one of the most important advanced scientific statistical methods to detect and predict the importance of these variables, we are thus able to focus on them during training. Hence the importance of conducting this research through quantitative analysis using an artificial neural network of the most important bio-kinematic variables to identify the level of achievement of long jump effectiveness.

Research problem

The development of the level of sporting achievement in all sporting activities and events has become the most important matter for everyone, considering that sporting achievement is linked to the development and progress of societies, especially since the countries of the world have begun to deal with a codified scientific method to win titles and medals at the international level.

Through the researcher's experience in the field of specialization, he noted that the level of performance of Iraqi jumpers in local championships does not rise to the level of ambition for the young and advanced categories, given that this event is a technical event in which many bio-kinematic variables are involved, and most jumpers commit many mistakes during competition, including those related to errors in performance. Among them are related to technical matters that the coach did not notice during training because the nature of the event performance takes place very quickly. The process of judging the validity of the performance during training is from the perspective of self-evaluation by the coach, but it is assumed that the judgments are made accurately through the use of continuous quantitative analysis of the jumper in addition to Determine which of the important variables should be focused on and given more attention. Through this research, the most important biomechanical variables were identified using artificial neural network technology, through which we can know the precise and influential details that may be the main reason for developing the level of achievement for the effectiveness of the long jump.

Research objective

- Using a neural network to identify the most important bio-kinetic variables to determine the level of achievement of advanced youth in the long jump event.
- Identifying the differences between the bio-kinetic variables that contribute to determining the level of achievement between the categories of young people and advanced for the long jump event.

Research hypotheses

- There are statistically significant differences between some bio-kinetic variables that contribute to determining the level of achievement in the long jump event for young people and advanced students.
- There is a difference in the quantitative values of the bio-kinetic variables that contribute to determining the level of achievement in the long jump event for young people and advanced students.

Research fields

- **Human field:** Jumpers participating in the Iraqi Clubs and Institutions Championship from the youth and advanced categories.
- **Spatial area:**
- **Time field:** (20/2/2023) to (21/8/2023)
- **Spatial field:** Stadium of the College of Physical Education and Sports Sciences/University of Baghdad.

Research methodology and field procedures

Research Methodology

The researcher used the descriptive method with correlational and comparative relationships to suit the nature of the research problem.

Community and sample research: The research community was determined from the jumpers participating in the Iraqi Clubs and Institutions Championships for the year 2023, as the researcher chose the research sample in a deliberate manner, namely the top six jumpers for the two categories of youth and advanced participating in the two championships above. 40 successful attempts for the youth category and 36 successful attempts for the advanced were analyzed, and thus the total number became there are 76 attempts for the youth and advanced categories.

Homogeneity of the research sample

Table 1: Shows the homogeneity of the members of the research sample for the youth group in some anthropometric measurements

Variables	Measuring unit	Mean	Std. Deviations	Skewness
Training age	Year	4.11	0.51	0.58
Bottom limb length	Cm	94.4	0.49	-0.37
Total length	Cm	176	0.824	0.376
body mass	Kg	70.12	2.34	-0.31

Table 2: Shows the homogeneity of the members of the research sample for the category of advanced in some anthropometric measurements

Variables	Measuring unit	Mean	Std. Deviations	Skewness
Training age	Year	5.91	1.92	0.55
Bottom limb length	Cm	96.62	5.06	-0.54
Total length	Cm	180.32	3.49	0.48
body mass	Kg	73.67	1.43	0.51

Search variables

Through the researcher's review of many previous scientific studies, bio-kinetic variables that have a significant relationship with the performance of the long jump event were adopted, and 15 independent variables and the achievement variable were adopted as the dependent variable, as follows: Step length 2 - Step length 1 - Horizontal speed of step 1 - Vertical speed of step 1- Angle of approach - Horizontal displacement of the center of gravity of the body - Time of support - Maximum bending of the knee angle - Angular velocity of the free leg - Angle of push - Height of the center of gravity at the moment of departure - Angle of departure - Angle of inclination of the torso when rising - Angle of inclination of the torso when landing - Angle of the knee at Landing - distance of completion.

Exploratory experiment

The exploratory experiment was conducted with the assistance of the assistant staff on February 28, 2023, on a sample of three jumpers. Two cameras were used at a speed of (480 images per second) to identify the locations of the cameras in terms of distance and height above ground level, as well as the spatial level. For movement.

First main experiment

The first main experiment for the youth category was conducted to coincide with the date of the Iraqi Clubs and Institutions Championship on 3/3/2023 with the help of the assistant work staff. Some anthropometric measurements were taken of the members of the research sample before the start of the competition and according to the timetable for the program prepared by the Races Organizing Committee. The researcher implemented imaging procedures according to the measurements reached in the exploratory experiment, and the work was done using a camera with a frequency speed of 480 images/second.

Second main experiment

The second main experiment for the applicant category was conducted to coincide with the date of the Iraqi Clubs and Institutions Championship on 4/3/2023, following the same steps that were taken in the first main experiment.

Statistical methods

The researcher used the statistical package (SPSS) and a group of other programs to process the results he obtained from the main experiment, as follows:

1. Arithmetic mean.
2. Standard deviation.
3. Twisting.
4. Simple connection.
5. T-test for independent samples.
6. Regression model (RRIDEG REGRESSION).
7. Contribution percentage (Adjusted R2).
8. Autocorrelation (DW).
9. Mean sum of squares of the residuals (MSE).
10. Variance inflation factor (VIF).
11. Coefficient of determination (R2).

Results and Discussion

Presentation of the results of descriptive statistics for the youth research sample

Table 3: Shows the results of descriptive statistics for the youth research sample

Variables	Mean	Std. Deviations	Median	Skewness	Minimum value	Maximum value
Step length 2	2.346	0.147	2.37	-0.544	2	2.6
Step length1	2.214	0.155	2.215	0.227	1.97	2.61
Horizontal speed of step 1	9.277	0.365	9.33	-0.518	8.432	9.811
Vertical speed of step1	9.334	40.229	2.59	6.000	2.34	244
Approach angle	56.722	2.894	57	-0.238	51	62
Horizontal displacement of the center	33.306	3.786	34	-0.532	23	40
Reliance time	0.125	0.009	0.13	-0.224	0.11	0.14
Maximum knee flexion angle	140.639	7.160	141	-0.073	120	161
Angular velocity of the free leg	681.722	10.979	683	-0.974	650	699
Thrust angle	63.778	4.029	65	-0.514	57	69
The height of the center of gravity at the moment of launch	121.917	3.722	122	0.288	114	130
Departure angle	19.778	1.376	20	0.495	17	23
The angle of inclination of the torso when standing	20.944	1.866	21	0.448	18	25
The angle of inclination of the torso when landing	29.750	2.156	30	0.089	26	34
Knee angle when landing	152.722	7.756	153.5	0.237	136	167
Completion distance	6.200	0.482	6.13	0.548	5.41	7.22

Presentation, the results of the fixed limit value, parameter values, variance inflation factor, and arrangement of variables for the research sample, the youth group

Table 4: Shows the results of the constant limit value, parameter values, variance inflation factor, and arrangement of variables for the research sample, the youth group.

Sequence Variables	Variables	Parameter value	Contrast inflation factor	Ranking
	Fixed limit	-0.093971		
1	Step length 2	-0.307865	1.73891	2

2	Step Length1	-0.21442	4.61347	3
3	Horizontal speed of step 1	-0.121489	1.74851	5
4	Vertical speed of step1	0.167047	2.30108	4
5	Approach angle	-0.00998904	3.40812	9
6	Horizontal displacement of the center	0.0129322	1.63982	7
7	Reliance time	0.0095263	2.15165	10
8	Maximum knee flexion angle	-0.0031053	2.1039	14
9	Angular velocity of the free leg	0.000146989	1.42233	15
10	Thrust angle	0.0100378	1.484	8
11	The height of the center of gravity at the moment of launch	0.00558379	2.24005	12
12	Departure angle	0.308055	1.96235	1
13	The angle of inclination of the torso when standing	-0.00821082	3.36886	11
14	The angle of inclination of the torso when landing	0.0333348	1.14144	6
15	Knee angle when landing	0.00359265	1.91082	13
Coefficient of determination (R2)		74.2978		
Contribution ratio % (Adjusted R2)		58.2339		
Autocorrelation (DW)		2.16124		
Mean Sum of Squares of the Residuals (MSE)		0.05539		

Presentation, the results of descriptive statistics for the sample of advanced

Table 5: Shows the results of descriptive statistics for the sample of advanced

Variables	Mean	Std. Deviations	Median	Skewness	Minimum value	Maximum value
Step length 2	2.369	0.142	2.42	-0.340	2.1	2.6
Step length1	2.222	0.137	2.17	0.448	1.97	2.61
Horizontal speed of step 1	9.064	0.347	9.11	-0.186	8.45	9.67
Vertical speed of step1	2.652	0.194	2.625	0.149	2.34	2.98
Approach angle	56.200	3.283	56	0.212	51	62
Horizontal displacement of the center	32.475	4.332	33	-0.216	23	40
Reliance time	0.14	1.877	0.13	6.324	0.11	12
Maximum knee flexion angle	140.575	7.609	139	0.471	120	161
Angular velocity of the free leg	662.895	107.294	681.5	-6.162	6.78	699
Thrust angle	64.050	3.714	65	-0.611	57	69
The height of the center of gravity at the moment of launch	118.950	5.747	119	0.455	110	134
Departure angle	18.875	1.017	19	-0.046	17	21
The angle of inclination of the torso when standing	21.050	3.679	20	2.631	17	36
The angle of inclination of the torso when landing	30.200	1.698	30	0.068	27	33
Knee angle when landing	154.425	4.904	154	-0.128	140	165
Completion distance	5.939	0.364	5.895	0.327	5.31	6.8

Presentation the results of the fixed limit value, parameter values, variance inflation factor, and ranking of variables for the research sample, applicant category.

Table 6: Shows the results of the fixed limit value, parameter values, variance inflation factor, and ranking of variables for the research sample, applicant category

Sequence Variables	Variables	Parameter value	Contrast inflation factor	Ranking
	Fixed limit	**-10.9389**		
1	Step length 2	-0.235261	1.65714	4
2	Step length1	0.360553	3.99544	3
3	Horizontal speed of step 1	0.398468	1.73595	2
4	Vertical speed of step1	0.0011528	1.29184	15
5	Approach angle	-0.009578	2.43731	10
6	Horizontal displacement of the center	0.0165325	1.64364	9
7	Reliance time	-21.7292	1.77695	1
8	Maximum knee flexion angle	0.0066073	1.88425	13
9	Angular velocity of the free leg	0.0073631	1.60539	12
10	Thrust angle	-0.001358	2.09931	14
11	The height of the center of gravity at the moment of launch	0.0452458	1.69656	8
12	Departure angle	0.189167	2.17732	5
13	The angle of inclination of the torso when standing	0.0452521	1.56444	7
14	The angle of inclination of the torso when landing	-0.055542	2.35841	6
15	Knee angle when landing	0.0095659	1.39147	11
Coefficient of determination (r2)		79.8807		
Contribution ratio % (adjusted r2)		64.7912		
Autocorrelation (dw)		1.98077		
Mean sum of squares of the residuals (mse)		0.0912315		

Presentation the results of the arithmetic means, standard deviations, the calculated t value, and the type of significance for the kinematic variables for the two research samples, young and advanced.

Table 7: Shows the results of the arithmetic means, standard deviations, the calculated t value, and the type of significance for the kinematic variables for the two research samples, young and advanced.

Variables	Youth category of		Category of advanced		T Calculated	Type Sig
	Arithmetic means	Standard deviations	Arithmetic means	Standard deviations		
Step length 2	2.369	.14221	2.346	.1469	.697	Non sig
Step length1	2.222	.137	2.214	0.155	.234	Non sig
Horizontal speed of step 1	9.064	.347	9.277	0.364	2.619	Sig
Vertical speed of step1	2.652	.194	9.334	40.228	1.051	Non sig
Approach angle	56.200	3.283	56.722	2.894	.732	Non sig
Horizontal displacement of the center	32.475	4.332	33.305	3.785	.885	Non sig
Reliance time	.1428	1.877	0.1252	0.008	3.183	Sig
Maximum knee flexion angle	140.575	7.609	140.638	7.160	.038	Non sig
Angular velocity of the free leg	662.895	107.294	681.722	10.979	1.047	Non sig
Thrust angle	64.050	3.714	63.777	4.029	.306	Non sig
The height of the center of gravity at the moment of launch	118.950	5.747	121.9167	3.721	2.638	Sig
Departure angle	18.875	1.017	19.777	1.375	3.274	Sig
The angle of inclination of the torso when standing	21.050	3.679	20.944	1.866	.155	Non sig
The angle of inclination of the torso when landing	30.200	1.698	29.75	2.1564	1.016	Non sig
Knee angle when landing	154.425	4.904	152.722	7.755	1.156	Non sig
Completion distance	5.939	.364	6.20	0.481	2.762	Sig

The tabular t value is at 74 degrees of freedom and with a confidence level of 0.05 = 1.993

By presenting the results, it is clear that the values of the data inflation factor (VIF) did not exceed the value (10), which means that the independent variables have no linear interference between them, which will contribute to the accuracy of building the model. (Al-Jaoun, (2008) [1] On the other hand, this coefficient shows, through its large number, the number of variables that are related to it, which means the importance of its representation of other variables. Also, the model is far from autocorrelation (DW) since the value is limited to between (1.5-2.5), and the square The multiple correlation coefficient between the independent variables on the one hand and the dependent variable (distance of completion) (R2) is considered acceptable to indicate the importance of the model, as the higher the value indicates the accuracy of the model, and the independent variables in the model explain (74%) of the variables affecting the dependent variable. The percentage of contribution appeared in the form as (58%). Also, the small value of (MSE) indicates the close spread of the values on the regression line, and this means that the youth model is more stable than the advanced model. As can be seen by arranging the variables according to the parameter values (beta), the launch angle variable came in first place in terms of importance. As for the advanced' model, the results showed that the values of the data inflation factor (VIF) did not exceed the value (10), which means that the independent variables have no linear interference between them, which will contribute to the accuracy of building the model. On the other hand, this factor shows, through its large number, the number of variables. Which is related to it, which means the importance of its representation of other variables, and the model is far from autocorrelation (DW) because the value cancels out (1.98077), and the square of the multiple correlation coefficient between the independent variables on the one hand and the dependent variable (distance of completion) (R2) is considered acceptable for showing The importance of the model is that the higher the value indicates the accuracy of the model, and the independent variables in the model explain (80%) of the variables affecting the dependent variable, while the percentage of contribution appeared in the model in the amount of (65%). Also, the small value of (MSE) amounting to (0.0912315) indicates the close spread of the values on the regression line, and this means that the advanced' model is a stable model. As can be seen by arranging the variables according to the values of the parameters (beta), the variable of reference time came in first place in terms of importance. The researchers believe that the designed models have a great impact in representing achievement, but it is clear that the percentage of contribution in the two models was not of a high value, and this is what was confirmed by "that the process of building the model and applying it to a problem in reality is not an easy process because it needs to be followed up to reach the final image of the model. What is required, and this has led many interested people, is the process of building iterative models through which the structure of the model is improved more accurately. However, building a model that represents reality in all its details and ramifications is something difficult to achieve in practice due to the difficulty of imagining and understanding reality accurately" (Ayasrah, (2010) [3].

Discussing the results of the differences in the bio-kinetic variables involved in the two models for young people and advanced people

By displaying the results in Table (7), significant differences appeared between the two groups (youth and advanced) and in favor of the advanced in each of the following (horizontal speed of step 1, lean time, height of the center of gravity at the moment of departure, angle of launch, and completion). The researchers attribute these differences to the applicant group they had greater fluidity in the last two steps, as well as high fluidity compared to the youth group when getting up, and this is clear from the results shown. Therefore, the basis upon which the application of motor fluidity is relied upon is high coordination between the amounts the jumper needs to

push the force during the moments of time (the moments of touching the ground and leaving it).) Especially in the last steps of the approach phase, while ensuring the least change in momentum amounts between the moments of support and propulsion, which gives continuity from the beginning of the movement until its end, meaning no loss of the acquired speed, and this depends on the movement absorption phase and the final propulsion phases. The researchers believe that the reason for these differences is that the variable aerodynamics has a direct relationship to the change in the momentum of the body, and the momentum is the mass of the body multiplied by its speed, and since the mass of the body is constant, the relationship is the change in the speed of the body acquired before and after the moment of support, which is affected by the angles of the body and the moment of inertia. As well as the renewed force push at the moment of support This was confirmed by "The flow of movement is related to the compatibility of force instructions with each other with external forces" (Meinel, (1987) [5] One of the important elements in the last steps of the approximate run is the development of horizontal momentum, which is developed through the generation of propulsion. Propulsion is defined as the result of the force used during the time in which the force worked. This means that an increase in the production of force leads to a decrease in the time of action of that force and will increase Payment value. (Karim, 2006) [4] As for the variable of reference time, the differences were clear between the two categories and in favor of the advanced points out that "the period of time during which the jumper's foot touches the ground is of great importance because it is the decisive moment in estimating the amount of change in time and momentum due to the body's ability to generate force to increase speed or change direction upon contact". (Alwan, (2008) [2].

Increasing the time of support with the ground in indicates that the jumper uses greater flexion in the knee joint of the rising leg to absorb the reaction force of the ground. That is, the more the jumper achieves during this stage the shorter period of time for his foot to contact the ground, the greater the investment of total mechanical energy for this stage with loss and dissipation. Energy is less, and this will result in movement transfer to the stage of getting up in the best movement position for the jumper, as good movement transfer is the speed in the movement performance of the player in terms of the interconnection of the movement with its parts without interruption or slowness that leads to loss of energy, and here, achieving high movement speed comes at the expense of The shortest period of time and therefore the best movement, and this of course requires the jumper to have high technique at this stage

Conclusions and Recommendations

Conclusions

- The starting angle variable came in first place in terms of its importance in determining achievement for the youth group, while the leaning time variable came in first place in terms of its importance in determining achievement for advanced students.
- The contribution rate of the independent variables to the dependent variable (achievement competition) for young people reached (58%), while the contribution rate for advanced reached (65%).
- There are six parameters with a negative sign in the youth model and five parameters with a negative sign in the advanced model.
- Significant differences appeared between the results of bio-kinetic variables for young people and advanced, in favor of the advanced.

Recommendations

- Necessity of applying theoretical models extracted using artificial neural networks in training programs for trainers to evaluate the level of achievement.
- Providing biomechanical feedback based on the importance of arranging the values of biomechanical variables in models for determining achievement for the effectiveness of the long jump for young people and advanced students.
- Bio-kinetic variables can be developed (increase or decrease for some members of the youth group according to the advanced' model).

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