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Biomechanical Indicators as a Basis for Designing Specific Exercises of Smash Hit in Sitting Volleyball

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Abstract: The current research aims to study biomechanical qualities of smash hit in sitting volleyball as a basis for designing a specific exercises program. The researcher used the descriptive approach (case study) with video-based 2D biomechanical analysis using Simi Motion Analyses Software. One sitting volleyball player of "Al-Mustakbal" Sports Club was chosen to participate in this research. The player performed (3) trials of smash hit and the best one was chosen for motion analysis. Results indicated that: （1）**Comparison of Effects of Amiodarone versus Verapamil in Prevention of Atrial Fibrillation Post Coronary Artery Bypass Grafting. (1)** Means and standard deviations of biomechanical variables of the smash hit in sitting volleyball were calculated for specific moments. （2） There are statistically significant correlations among some biomechanical variables and the performance level of smash hit during specific moment in sitting volleyball.

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Key words: Biomechanical Indicators - Specific Exercises - Smash Hit - Sitting Volleyball

1. Introduction and Research Problem:

Sports training aims to lead the athlete to optimum possible sports level in a specific sports activity during competitions. To achieve this aim, sports training works on preparing and improving physical, technical, tactical and mental aspects equally among elite athletes in various sports (Berikaa, M. & Al-Sokkary, K. 2002: 45).

Biomechanics is the science of studying and analyzing human motor performance with the aim of reaching best mechanical solutions for the problem under investigation in addition to generalizing knowledge about optimum performance in various sports. This is to establish principles of biomechanics. Biomechanics studies are significant in modifying and improving performance of most athletic skills as the major tasks of biomechanics in sport include analyzing specific sports performance, clarifying it and improving it during the stages of learning and training to make the movement as efficient as possible. (Al-Shahhat, Mahmoud M. 2005: 5).

Volleyball is a popular sport as it is very interesting and includes defensive and attack skills that players should learn and master in matches and training. Training of volleyball is not different from other games as it depends on preparing training methods and using scientific ways to improve performance and achieve best results (Abdullah, Badawi A. 2007: 52).

Volleyball is also very popular among handicapped in the Arab World. This leads to the necessity of improving technical and physical performance in addition to game play. This can never be achieved but with programmed training. Individuals with motor and mental disabilities represent nearly 10% of the world population. Sport for handicapped is one of the optimum methods for integrating the handicapped into his/her community and turning him/her into a successful productive individual (Ibrahim, Marwan A. 2002: 33-34).

Sitting volleyball attracts the attention of audience as it includes very interesting skills, especially all types of serve (including overhead serve) as this skill may distinguish winners from losers. This means that it should be mastered to achieve the best results. Therefore, it is necessary to take care of this skill by those who are concerned with the training and learning processes of motor skills to improve its technical level either through concentrating on it during training or through using modern technologies to identify the details of this skill and most influential variables in its successful or failure performance. (Al-Zahrani, Abd Al-Rahman Ben Musaaed 2000)

Sports biomechanics is the cornerstone for improving technical motor performance of athletes as it analyzes human movements according to physical (kinematic) description in addition to identifying the causes (technique) of sports movements. This makes such moves more economic and effective in effort (Al-Fadli, Sareeh A. 2010: 27).

Specific exercises are very recent in the world of sports training. Introducing these exercises improved performance greatly as many equipment appeared to help applying this principle with the aim of training working muscles in a skill and improving physical abilities using the same correct motor path of the actual skill during training (Al-Shorbagy, Nabil H. 2000: 69).

Abd El-Khalek, Essam El-Din (2005) indicated that specific exercises are these sports movements that are similar in formation to technical performance of the performed skills according to force, velocity, timeframe of force and direction of muscular work. Therefore, it is considered as a direct means for preparing the performance level and improving training status of an athlete. The individual movement should be consistent with the type of specific sports activity in motor coordination, sequence of motor performance and direction of this performance. It should be considered during preparation and competitions stages. The function of specific exercises is to improve specific physical and motor qualities necessary for the practiced activity in addition to mastering motor performance and practicing it in several forms through elaborating the technical components of the practiced activity and improving them quickly (Abd El-Khalek, Essam El-Din 2005: 21).

Several studies indicated that specific exercises are the most recent trend in sports training as it works on improving the motor path of performance applied through mechanical analysis of performance in addition to diagnosing major causes of mistakes. Applying specific exercises corrects these mistakes and helps athletes to reach optimum performance level (Abdu, Desouky M. 2004) (Al-Tayeb, Mahmoud M. 2004).

The human musculoskeletal system has several biomechanical qualities. When applying rules of biomechanics on body movement we should consider these qualities and study all biomechanical conditions and variables affecting it. This means we should achieve optimum technique for any athletic skill and this technique should reflect biomechanical rules according to mechanical preparation and qualities of the system. Barow (2000) indicated that evaluation of motor performance is done through three dimensions, the most important of which is the mechanical one as it is objective and depends on studying mechanical qualities that help improving athletic technique through correcting and improving it according to training theories (Barow 2000: 68).

Experts of biomechanics indicated that we should never depend on subjective evaluation for movements. Instead, evaluation should be objective and based on analysis using equipment as this analysis may lead us to discover many variables like distance, time, velocity and force in addition to other variables. Accordingly, studying mechanical aspects of movement is necessary for knowing movement causes and diagnosing significant aspects of it according to internal and external forces. (Hussam El-Din, T. & Hamad, M. 1997)

As a coordinator for Office of Handicapped and Short individuals in Youth and Sports Directorate of North Sinai – Egypt, and through following competitions of sitting volleyball, the researcher noticed a limitation in the overhead serve skill for some players who depend totally on this skill due to the nature of their handicap. This had negative effects on game results of the team in its competitive matches outside the governorate although the team had good performance level in other skills. This limitation leads to wasting many points during competitions as either the ball hits the nets or its hits incorrect place of the court or even gets out of the court.

Aims:

The current research aims to study biomechanical qualities of smash hit in sitting volleyball as a basis for designing a specific exercises program through identifying:

1. Biomechanical qualities of the smash hit.
2. Designing a specific exercises program using most relevant exercises to the smash hit.

Hypotheses:

1. What are the biomechanical qualities of the smash hit in sitting handball?
2. Is it possible to design a specific exercises program using most relevant exercises to the smash hit in sitting handball?

2. Methods:

Approach:

The researcher used the descriptive approach (case study) with video-based 2D biomechanical analysis using Simi Motion Analyses Software.

Participant:

One sitting volleyball player of "Al-Mustakbal" Sports Club was chosen to participate in this research. The player performed (3) trials of smash hit and the best one was chosen for motion analysis.

Data collection tools and equipment:

Tools for motion analysis:

- A computer set
- Simi Motion Analyses Software
- Calibration box (1 m x 1 m x 1 m)

- Two "Fastec Imaging" video cameras (250 f/sec)
- Two tripods
- Two (32 GB) "Scan Disk" flash cards
- Electric cables
- Laser jet printer
- Markers

The Motion Analysis Software:

The researcher performed motion capture and analysis in Motion Analysis Lab of Faculty of Physical Education – Kafr El-Sheik University using "Simi Motion Analyses Software". The software is designed for detecting and analyzing motion. The researcher used this software for the following reasons:

- It runs through protection unit plugged into the computer and this increases data saving and accuracy.
- It can shoot in open air and inside halls
- One, two or three cameras can be used
- (2D) or (3D) analysis can be performed
- It can analyze the whole-body motion or part of it
- It instantly records movements without stop
- Data acquired is very accurate
- It can extract several kinematic indicators including:
  - ❖ Linear variables (displacement – velocity – acceleration)
  - ❖ Angular variables (angles – angular velocity – angular acceleration)
  - ❖ Body center of mass and links (displacement – velocity – acceleration)

This unit is a modern one for quick video-based motion analysis and it works as follows:

- Stages of performance for the skill and recommended specific exercises to be analyzed are recorded
- Uploading the video file and running the video to be analyzed
- Dividing the skill and recommended specific exercises to be analyzed into fixed moments
- Identifying anatomical points, links and tool to be analyzed (21 points)
- Calibration box file is uploaded on the video file after identifying anatomical points and moments
- Identifying anatomical points coordinates during the selected moments
- Identifying center of mass for the body and links during the selected moments
- Extracting the selected biomechanical qualities in a digital form

Pilot study:

The researcher applied the pilot study on (5) players on 3-1-2019 to fulfill the following objectives:

- Verifying the suitability of recording place and validating tools used
- Identifying the best time for shooting and degree of light
- Identifying places of cameras and shooting angles
- Preparing electric plugs and other preparations for biomechanical analysis
- Validating the motion analysis system and biomechanical variables to be extracted
- Coordinating measurement process
- Identifying the motor path of the skill under investigation
- Identifying the motor path of the recommended specific exercises
- Identifying any problems that may appear during actual process

Results indicated the following:

1. **Preparation of place:** The researcher verified that approach, throw and jump are all safe without causing the player any harm. In addition, the range of motion for the skill was identified and the calibration box and cameras are fixed in their places.
2. **Preparing the player:** The player's weight and height were measured and markers for video recording were put on body joints (19 joints).

Main study:

According to the results of the pilot study, the researcher applied the main study on 9/10-1-2019 at 3:00 p.m. at Motion Analysis Lab of Faculty of Physical Education – Kafr El-Sheik University.

Calculating data of the skill:

Using "Simi Motion" software, the researcher analyzed anatomical points of the player's body using (2D) video analysis and extracted the following variables:

- Linear displacements on (X-Z) axes and resultant displacements.
- Linear velocities on (X-Z) axes and resultant velocities.
- Linear accelerations on (X-Z) axes and resultant accelerations.
- Internal angles
- Angular velocities
- Angular accelerations

Calculating data of the recommended specific exercises:

Using "Simi Motion" software, the researcher analyzed anatomical points of the player's body using (2D) video analysis and extracted the following variables:

- Linear displacements on (X-Y) axes and resultant displacements.
- Linear velocities on (X- Y) axes and resultant velocities.
- Linear accelerations on (X- Y) axes and resultant accelerations.
- Internal angles
- Angular velocities
- Angular accelerations.

Results and Discussion:

First indicator:

Table (1) showed that left knee horizontal acceleration is very significant with contribution percentage of (61.546%). Results also indicated direct correlation between left knee horizontal acceleration and smash hit (0.963). this is a strong correlation meaning that the more left knee horizontal acceleration increases the more smash hit improves.

Predicative equation came as follows: Smash Hit = 24.959 + (0.235 x 117.364) = 64.275 m.

Y = A + (B1 x X1)

Second indicator:

Table (1) showed that left wrest vertical acceleration is very significant with contribution percentage of (95.321%). Results also indicated direct correlation between left wrest vertical acceleration and smash hit (0.946). this is a strong correlation meaning that the more left wrest vertical acceleration increases the more smash hit improves.

Predicative equation came as follows: Smash Hit = 3.037 + (0.566 x 117.364) + (-1.563 x 3.57) = 64.7 m

Y = A + (B1 x X1) + (B2 x X2)

Third indicator:

Table (1) showed that left hand vertical acceleration is very significant with contribution percentage of (42.443%). Results also indicated direct correlation between left hand vertical acceleration and smash hit (0.945). this is a strong correlation meaning that the more left wrest vertical acceleration increases the more smash hit improves.

Predicative equation came as follows: Smash Hit = 2.720 + (0.588 x 117.364) + (-1.361 x 3.257) + (-0.204 x 14.283) = 64.382 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Fourth indicator:

Table (1) showed that resultant hit acceleration is very significant with contribution percentage of (42.443%). Results also indicated direct correlation between resultant hit acceleration and smash hit (0.9.26). this is a strong correlation meaning that the more resultant hit acceleration increases the more smash hit improves.

Predicative equation came as follows: Smash Hit = 2.583 + (0.567 x 117.364) + (-1.361 x 3.257) + (-.0325 x 14.283) + (0.049 x 84.505) = 64.19 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4)

Fifth indicator:

Table (1) showed that left wrest resultant acceleration is very significant with contribution percentage of (42.443%). Results also indicated direct correlation between left wrest resultant acceleration and smash hit (0.9.26). this is a strong correlation meaning that the more left wrest resultant acceleration increases the more smash hit improves.

Predicative equation came as follows: Smash Hit =0.448 + (0.132 x 117.364) + (0.478 x 3.257) + (-0.235 x 14.283) + (0.041 x 84.505) + (0.474 x 107.704) = 68.43 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4) + (B5 x X5)

Table (1): Regression analysis of biomechanical indicators and performance level of smash hit during the moment of left hand leaving the ground.

Biomechanical indicators	mean	constant	standard error	F	Regression					contribution percentage
left knee horizontal acceleration	117.364	24.959	42.315	12.804	0.335					61.546%
Left wrest vertical acceleration	3.257	3.037	15.794	71.164	0.566	-1.563				95.312%
Left hand vertical acceleration	14.283	2.720	16.162	45.539	0.588	-1.361	-0.204			95.793%
Resultant hit acceleration	84.505	2.583	17.240	30.082	0.567	-1.318	-0.325	0.049		96.010%
Left wrest resultant acceleration	107.704	0.448	8.015	115.187	0.132	-0.748	-0.253	0.041	0.474	99.310%

First indicator:

Table (2) showed that left wrest resultant acceleration is very significant with contribution percentage of (42.443%). Results also indicated negative correlation between left wrest resultant acceleration and smash hit (-0.949). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 53.178 + (-0.319 x 34.980)

Y = A + (B1 x X1)

Second indicator:

Table (2) showed that wrest hand vertical acceleration is very significant with contribution percentage of (99.768%). Results also indicated negative correlation between left wrest vertical acceleration and smash hit (-0.946). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.171 + (-0.068 x 34.980) + (20.719 x 2.982)

Y = A + (B1 x X1) + (B2 x X2)

Third indicator:

Table (2) showed that hand vertical acceleration is very significant with contribution percentage of (99.960%). Results also indicated negative correlation between left hand vertical acceleration and smash hit (-0.943). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.27 + (-0.095 x -34.980) + (6.338 x 2.982) + (17.999 x 2.338) = 64.57

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Fourth indicator:

Table (2) showed that final resultant acceleration is very significant with contribution percentage of (99.986%). Results also indicated negative correlation between final resultant acceleration and smash hit (-0.929). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.010 + (-0.166 x 34.980) + (3.268 x 2.982) + (19.271 x 2.338) + (-6.089 x -0.612) = 64.34 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4)

Fifth indicator:

Table (2) showed that left wrest resultant acceleration is very significant with contribution percentage of (99.998%). Results also indicated negative correlation between left wrest resultant acceleration and smash hit (-0.916). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.001 + (-0.037 x -34.980) + (-1.931 x 2.982) + (3.004 x 2.338) + (-1.271 x -0.612) + (55.601 x 1.097) = 64.33 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4) + (B5 x X5)

Table (2): Regression analysis of biomechanical indicators and performance level of smash hit during the moment of Breaking Contact with the ground (Power Position)

Biomechanical indicators	mean	constant	standard error	F	Regression					contribution percentage
left knee horizontal acceleration	-34.980	53.178	62.032	1.681	-0.319					17.360%
Left wrest vertical acceleration	2.982	0.171	3.513	1505.619	-0.068	20.719				99.768%
Left hand vertical acceleration	2.338	0.027	1.584	4946.008	-0.095	6.338	17.999			99.960%
Resultant hit acceleration	-0.612	0.010	1.020	8953.053	-0.166	3.268	19.271	-6.089		99.986%
Left wrest resultant acceleration	1.097	0.001	0.443	37995.029	-0.037	-1.931	3.004	-1.271	55.601	99.998%

First indicator:

Table (3) showed that left knee resultant acceleration is very significant with contribution percentage of (99.131%). Results also indicated negative correlation between left knee resultant acceleration and smash hit (-0.926). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.552 + (12.622 x 5.053) = 64.33

Y = A + (B1 x X1)

Second indicator:

Table (3) showed that left hand vertical acceleration is very significant with contribution percentage of (99.268%). Results also indicated negative correlation between left hand vertical acceleration and smash hit (-0.921). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.471 + (27.817 x 5.053) + (-25.19 x (3.045) = 64.27 m

Y = A + (B1 x X1) + (B2 x X2)

Third indicator:

Table (3) showed that final resultant hit acceleration is very significant with contribution percentage of (99.867%). Results also indicated direct correlation between final resultant hit acceleration and smash hit 0.921). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.074 + (-2.572 x 5.053) + (20.771 x 3.045) + (4.447 x 3.149) = 64.328 m

Y = A + (B1 x X1) + (B2 x X2) = (B3 x X3)

Fourth indicator:

Table (3) showed that left wrest resultant acceleration is very significant with contribution percentage of (99.869%). Results also indicated direct correlation between left wrest resultant acceleration and smash hit (0.916). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.073 + (-7.260 x 5.053) + (27.625 x 3.045) + (5.507 x 3.149) + (0.024 x 21.826) = 65.37 m

Y = A + (B1 x X1) + (B2 x X2) = (B3 x X3) + (B4 x X4)

Table (3): Regression analysis of biomechanical indicators and performance level of smash hit during the moment of hitting the ball

Biomechanical indicators	mean	constant	standard error	F	Regression					contribution percentage
left knee horizontal acceleration	5.053	0.552	6.361	912.519	12.622					99.131%
Left wrest vertical acceleration	3.045	0.471	6.241	474.731	27.817	-25.19				99.268%
Left hand vertical acceleration	3.149	0.074	2.878	1497.563	-2.572	20.771	4.447			99.867%
Resultant hit acceleration	21.826	0.073	3.125	952.098	-7.260	27.625	5.507	-0.024		99.869%
Left wrest resultant acceleration	2.545	0.003	0.685	15878.474	1.655	15.028	-2.606	0.023	0.039	99.995%

First indicator:

Table (4) showed that horizontal angular velocity is very significant with contribution percentage of (27.980%). Results also indicated direct correlation between horizontal angular velocity and smash hit (0.862). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 46.569 + (-0.044 x -429.803) = 65.48 m

Y = A + (B1 x X1)

Second indicator:

Table (4) showed that left knee angle is very significant with contribution percentage of (99.926%). Results also indicated negative correlation between left knee angle and smash hit (-0.857). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.033 + (0.003 x -429.803) + (0.511 x 130.660) = 65.51 m

Y = A + (B1 x X1) + (B2 x X2)

Third indicator

Table (4) showed that left knee angular velocity is very significant with contribution percentage of (99.958%). Results also indicated direct correlation between left knee angular velocity and smash hit (0.847). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.022 + (0.002 x -429.803) + (0.514 x 130.660) + (0.000 x 161112.854) = 66.32 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Fourth indicator:

Table (4) showed that left knee angle is very significant with contribution percentage of (99.99%). Results also indicated direct correlation between left knee angle and smash hit (0.771). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.005 + (0.002 x -429.803) + (0.180 x 130.660) + (0.000 x 16112.854) + (0.319 x 131.239) = 64.52 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Table (4): Regression analysis of angles, angular velocities and performance level of smash hit during the moment of left hand leaving the ground

Biomechanical indicators	mean	constant	standard error	F	Regression				contribution percentage
Left ankle horizontal angular velocity	-429.803	46.569	58.819	3.108	-0.044				27.980%
Left knee angle	130.660	0.033	2.017	4720.477	0.003	0.511			99.926%
Left knee angular velocity	16112.854	0.022	1.645	4729.742	0.002	0.514	0.000		99.958%
Left knee angle	131.239	0.005	0.856	13112.141	0.002	0.180	0.000	0.319	99.990%

First indicator:

Table (5) showed that left ankle horizontal angular velocity is very significant with contribution percentage of (32.302%). Results also indicated negative correlation between left ankle horizontal angular velocity and smash hit (-0.896). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 44.792 + (-0.001 x -17924.64) = 63.71 m

Y = A + (B1 x X1)

Second indicator:

Table (5) showed that left knee angle is very significant with contribution percentage of (33.817%). Results also indicated negative correlation between left knee angle and smash hit (-0.935). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 43.829 + (-0.001 x 17924.46) + -0.001 x -10711.1) = 63.71 m

Y = A + (B1 x X1) + (B2 x X2)

Third indicator:

Table (5) showed that left knee angular acceleration is very significant with contribution percentage of (99.843%). Results also indicated negative correlation between left knee angular acceleration and smash hit (-0.911). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.103 + (0.00 x -17924.46) + (0.00 x -10711.1) + (0.500 x 118.500) = 63.81 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Fourth indicator:

Table (5) showed that left knee angle is very significant with contribution percentage of (99.998%). Results also indicated direct correlation between left knee angle and smash hit (0.896). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.01 + (0.01 x 17924.46) + (0.00 x -10711.1) + (0.120 x 118.500) + (0.459 x 108.948) = 64.75 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4)

Table (5): Regression analysis of angles, angular velocities and performance level of smash hit during the moment of breaking contact with the ground (power position)

Biomechanical indicators	mean	constant	standard error	F	Regression				contribution percentage
Left ankle horizontal angular velocity	-17924.46	44.792	57.027	3.817	-0.001				32.302%
Left knee angle	-10711.1	43.829	60.278	1.788	-0.001	-0.001			33.817%
Left knee angular velocity	118.500	0.103	3.167	1274.788	0.000	0.000	0.500		99.843%
Left knee angle	108.948	0.001	0.405	58692.969	0.000	0.000	0.120	0.459	99.998%

First indicator:

Table (6) showed that left wrest horizontal angular velocity is very significant with contribution percentage of (99.922%). Results also indicated direct correlation between left wrest horizontal angular velocity and smash hit (0.955). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.082 + (0.547 x 119.353) = 65.63 m

Y = A + (B1 x X1)

Second indicator:

Table (6) showed that left knee angle is very significant with contribution percentage of (99.953%). Results also indicated negative correlation between left knee angle and smash hit (-0.882). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.042 + (0.561 x 119.353) + (0.00 x -55847.06) = 66.99 m

Y = A + (B1 x X1) + (B2 x X2)

Third indicator:

Table (6) showed that left knee angular acceleration is very significant with contribution percentage of (99.978%). Results also indicated negative correlation between left knee angular acceleration and smash hit (-0.867). This is a strong negative correlation.

Predicative equation came as follows: Smash Hit = 0.017 + (0.535 x 119.353) + (0.00 x -55847.06) + ()0.00 x 12859.05) = 63.87 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3)

Fourth indicator:

Table (6) showed that left knee angle is very significant with contribution percentage of (99.987%). Results also indicated direct correlation between left knee angle and smash hit (0.811). This is a strong direct correlation.

Predicative equation came as follows: Smash Hit = 0.012 + (0.554 x 119.353) + (0.00 x -55847.06) + (0.00 x 12859.05) + (0.00 x 86479.414) = 66.13 m

Y = A + (B1 x X1) + (B2 x X2) + (B3 x X3) + (B4 x X4)

Table (6): Regression analysis of angles, angular velocities and performance level of smash hit during the moment hitting the ball

Biomechanical indicators	mean	constant	standard error	F	Regression				contribution percentage
Left ankle horizontal angular velocity	119.353	0.082	1.938	10226.785	0.547				99.922
Left knee angle	-55847.06	0.042	1.605	7454.039	0.561	0.000			99.953
Left knee angular velocity	12859.05	0.017	1.186	9102.669	0.535	0.000	0.000		99.978
Left knee angle	86479.414	0.012	0.987	9865.825	0.554	0.000	0.000	0.000	99.987

Conclusions:

According to statistical treatment of data, the researcher concluded the following:

- Means and standard deviations of biomechanical variables of the smash hit in sitting volleyball were calculated for specific moments.
- There are statistically significant correlations among some biomechanical variables and the performance level of smash hit during specific moment in sitting volleyball.

Recommendations:

According to this research aim, hypotheses, methods, and results, the researcher concluded the following:

- Using the means of biomechanical indicators in evaluating the current performance level of smash hit in sitting volleyball.
- Using the correlations among biomechanical indicators and the performance level of smash hit in designing specific exercises for the smash hit in sitting volleyball.
- Applying the regression equations practically on biomechanical indicators contributing in the performance level of the smash hit in sitting volleyball periodically as an indicator for achievement in progressing towards the desired level.

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