EFFECT OF PLYOMETRIC EXERCISES PROGRAM ON KINETIC ENERGY, SOME KINEMATIC VARIABLES, AND SHOOTING ACCURACY FOR FOOTBALL PLAYERS UNDER THE AGE OF 17

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Abstract

Plyometric exercises considered one of the important means for developing the strength and speed of skillful performance of footballers, and since the shooting skill is an important skill in football, the impact of plyometric exercises on developing this skill must be studied. The current study aims to analyze the effect of plyometric exercises on kinetic energy, some kinematic variables, ball speed, and shooting accuracy for football players under the age of 17. 18 players under the age of 17 participated and formed one group, and their arithmetic means were as follows: (Age: 16.5 ± 4 months, Height: 168 ± 7 cm, Mass: 65 ± 3 kg, Training Age: 5.8 ± 1.8 years). Pre- and post-test was applied to them in skill of zigzag running between cones and then shooting at the goal to measure shooting accuracy in addition to kinetic energy and some kinematic variables, after applying a plyometric exercises program for 8 weeks / 3 times a week by 90 minutes per training session. Videography and Kinovea program were used for kinetic analysis and a number of statistical treatments such as arithmetic means, standard deviations, normal distribution indicators, and T-test to conclude results. The results indicated that there was a statistical effect of plyometric exercises program on increasing kinetic energy, kinematic variables, and shooting accuracy**.** In light of study results researchers recommended the need to use plyometric exercises for football players under the age of 17 to develop their performance in shooting skill after running with ball.

Key words: Plyometric. Kinetic energy. Kinematic variables. Shooting accuracy. Football. Under the Age of 17.

Abstracto

Los ejercicios pliométricos se consideran uno de los medios importantes para desarrollar la fuerza y la velocidad del desempeño hábil de los futbolistas, y dado que la habilidad de tiro es una habilidad importante en el fútbol, se debe estudiar el impacto de los ejercicios pliométricos en el desarrollo de esta habilidad. El presente estudio tiene como objetivo analizar el efecto de los ejercicios pliométricos sobre la energía cinética, algunas variables cinemáticas, la velocidad de la pelota y la precisión de tiro para jugadores de fútbol menores de 17 años. Participaron 18 jugadores menores de 17 años y formaron un grupo, y su aritmética las medias fueron las siguientes: (Edad: 16,5 ± 4 meses, Altura: 168 ± 7 cm, Masa: 65 ± 3 kg, Edad de entrenamiento: 5,8 ± 1,8 años). Se les aplicó pre y post test en destreza de carrera en zigzag entre conos y luego lanzamiento a portería para medir precisión de tiro además de energía cinética y algunas variables cinemáticas, luego de aplicar un programa de ejercicios pliométricos durante 8 semanas / 3 veces al día. semana en 90 minutos por sesión de entrenamiento. Se utilizaron videografías y el programa Kinovea para el análisis cinético y una serie de tratamientos estadísticos, como medias aritméticas, desviaciones estándar, indicadores de distribución normal y prueba T para concluir los resultados. Los resultados indicaron que hubo un efecto estadístico del programa de ejercicios pliométricos sobre el aumento de la energía cinética, las variables cinemáticas y la precisión de tiro. A la luz de los resultados del estudio, los investigadores recomendaron la necesidad de utilizar ejercicios pliométricos para jugadores de fútbol menores de 17 años para desarrollar su rendimiento en la habilidad de tiro después de correr con el balón.

Palabras clave: Pliometría, energía cinética. Variables cinemáticas. Precisión de tiro. Fútbol y menores de 17 años.

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Abstrato

Os exercícios pliométricos são considerados um dos meios importantes para o desenvolvimento de força e velocidade no desempenho habilidoso de jogadores de futebol, e como a habilidade de arremesso é uma habilidade importante no futebol, o impacto dos exercícios pliométricos no desenvolvimento desta habilidade deve ser estudado . O presente estudo tem como objetivo analisar o efeito de exercícios pliométricos na energia cinética, algumas variáveis cinemáticas, velocidade da bola e precisão do chute para jogadores de futebol menores de 17 anos. Participaram e formaram um grupo 18 jogadores menores de 17 anos, e suas médias foram as seguintes: (Idade: 16,5 ± 4 meses, Altura: 168 ± 7 cm, Massa: 65 ± 3 kg, Idade de treinamento: 5, 8 ± 1,8 anos). Eles passaram por um pré e pós-teste sobre a capacidade de correr em zigue-zague entre cones e depois chutar ao gol para medir a precisão do chute, além da energia cinética e algumas variáveis cinemáticas, após a aplicação de um programa de exercícios pliométricos por 8 semanas / 3 vezes por semana a 90 minutos por sessão de treinamento. Videografia e software Kinovea foram usados para análise cinética e vários tratamentos estatísticos como médias aritméticas, desvios padrão, indicadores de distribuição normal e teste t para concluir os resultados. Os resultados indicaram que houve um efeito estatístico do programa de exercícios pliométricos no aumento da energia cinética, variáveis cinemáticas e precisão de arremesso. Diante dos resultados do estudo, os pesquisadores recomendaram o uso de exercícios pliométricos para jogadores de futebol com menos de 17 anos para desenvolver seu desempenho na habilidade de arremesso após correr com a bola.

Palavras-chave: Pliometria. Energia cinética. Variáveis cinemáticas. Precisão do remate. Futebol e Sub 17.

Introduction

Plyometric exercises are essential, important, and required to improve performance in a variety of sports, most notably football, which requires multiple physical performance skills, including running, jumping, and shooting with a continuous change in directions (1). This wide range of high-intensity exercises also aim to create physiological and biomechanical adaptations that reflect positively on performance of athletes (2).

Plyometric exercises depend on mobilizing a large force in the front thigh muscles and tendons by raising tension within them by an eccentric muscle contraction and then releasing a large amount of energy when shifting muscular work to central work, which increases the speed and strength of foot (3). This process goes through three basic stages, according to (4):

1. Eccentric phase: In which the force is loaded, mobilized, and accumulated through an eccentric contraction at the origin of muscle, where the muscle spindles are extended and stimulated.

2. Amortization phase: It is a short period of time starting from the end of mobilization in eccentric contraction and ending with the onset of concentric contraction.

3. Concentric phase: It is a concentric muscular movement through which the amount of energy mobilized in muscle appears.

Based on fact that the two elements (velocity - strength) are the main goal to be developed with plyometric exercises, this can be linked to the concept of kinetic energy, which is physically equal to: (K.E. = 1/2 m v2), i.e. half the product of multiplying mass by square of speed. We find that element of speed, which can develop by plyometric, works to raise the kinetic energy. In other words, an increase in muscle mass means an increase in strength, which indicate that there is a significant correlation between both sides of kinetic energy equation with plyometric exercises (5).

Therefore, plyometric exercises are supposed to improve kinetic energy, which is part of mechanical energy and expresses the effort exerted by player by using its performance speed related to its mass. This kinetic energy is partially

distributed to the parts of one skill in light of a total energy volume. The bigger the volume, the greater the opportunity for player to meet the physical and skill performance requirements (6).

Kinetic energy is the physical concept that expresses the transformation of mechanical energy into mechanical work. The kinetic energy alone in player is not enough, but must appear in form of skillful behavior (mechanical work) (7). This skillful behavior based on mechanical variables, whether in terms of kinetics or kinematics, and differ in their form, nature, and elements according to skill required from player to perform inside the pitch (8).

Accordingly, the importance of kinematic variables that arise from transformation of kinetic energy into mechanical form appears (7). These variables also describe the external form of the internal kinetic work and thus give descriptive numerical values, which are the basis for models of successful skillful performance of players, including football ones (9).

The angle of shooting foot, angular velocity of joints in it, foot circumferential velocity, and others are all kinematic variables that reflected in the speed, strength, and shooting accuracy of ball (10).

From the foregoing, the current study seeks to link successive basic concepts such as kinetic energy, kinematic variables, and ball speed, which affect the success of football players' performance of shooting skill, and to investigate the impact of an eight-week training program based on plyometric exercises on these concepts.

Therefore, this study assumes that there is a statistically significant effect of plyometric exercises over a period of 8 weeks on kinetic energy, some kinematic variables, ball speed, and shooting accuracy for football players under the age of 17.

Method and Procedure

This study used the method of application and re-application on a sample of 18 players under the age of 17 years, and their arithmetic means were as follows: (Age: 16.5 ± 4 months, Height: 168 ± 7 cm, Mass: 65 ± 3 kg, Training Age: 5.8 ± 1.8 years). They underwent a test of running between cones for a distance of 12 meters, then shooting from outside the penalty area, to measure the shooting accuracy. Then they had an 8-week training program based on plyometric exercises. Finally, the zigzag running test and shooting from outside the penalty area were re-applied, as both shooting tests were filmed through video cameras. The following are the details of tests and filming procedures:

First: the 12-meter zigzag run test and shooting from outside the penalty area:

1. The players have warmed up enough to take the test.
2. Each player was asked to run a full distance of 12 m, including running for 10 m between 5 cones, the distance between each one and the other is 2 m, then aiming directly at the goal.
3. Each player made 3 attempts. The attempt with the highest points was calculated and analyzed.
4. The test goal divided into 3 areas, as follows:

- The two upper corners of goal and set 5 points for them. (0.813 m×2.44m)
- The two bottom corners of goal and set 3 points for them. (0.813 m×2.44m)
- The rest of areas in goal and set 1 point for them. Figure 2 shows the divided goal (Figure 1).

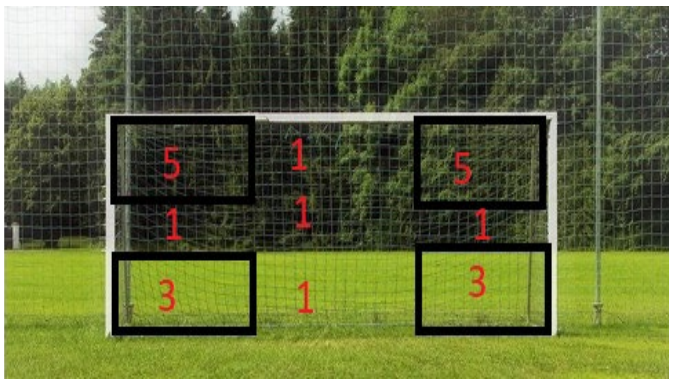

Figure 1: Goal Areas.

Filming Procedures

1. The first camera placed on the right side axis and perpendicular to the player performing the zigzag run and shooting test. Where the camera was at a distance of 5.33 m from the shooting location, with a lens height of 1.07 m.
2. The second camera placed next to the first one, at a distance of 2 m from it, with a lens height of 1.06 m. The aim was to photograph the motor performance in the event that player left the frame of first camera, since the study test based on movement and not on a completely fixed and defined area.
3. All cameras were of type (Canon EOS 80D), with a speed of 500 photos / sec.
4. The zigzag running and corner kick shooting accuracy tests filmed before and after applying the training program.
5. Data of video clips has downloaded to Lenovo THINKPAD E15 GEN 4 NEW Intel Core.
6. Video clips analyzed using the motion analysis program Kinovea 0.9.5.
7. Ball speed was determined using Stalker Sport 2 Radar.Study Application Steps:

First: Pre-tests

The two researchers have conducted a pre-test on the study sample, and took the means of age, height, mass, and training age for the purpose of sample equivalence.

Second: Application of plyometric program

After making sure of sample equivalence in the pre-measurements, the plyometric program was applied to this sample consisting of (18) players. The program consisted of (24) training units, and each unit lasted (90) minutes. So that the entire training was characterized by the use of plyometric exercises, body weights and medicine balls for a period of (8) weeks, with adjusting the variables of training load (strength, volume, intensity), and the application of proposed plyometric training program was started.

Third: Post-tests

After applying proposed program to the study sample, which lasted for (8) weeks, the two researchers conducted the post-test for study, with the same conditions, standards, and places as the pre-test.

Results:

The above table highlights the values of some descriptive statistical indicators of research variables (in the pre-measurement). When reviewing the values of coefficient of variation indicator, it is clear that its maximum value has achieved in the kinematic variable, accuracy, reaching (37.70). Moreover, since this value (the largest among others of this indicator) was less than 50%, this indicates the existence of homogeneity among research members in values of variables shown, and that the dispersion expressed through the standard deviation values is small and reflects the natural difference in performance of individuals (Table 1).

Research Hypothesis Test

The research based on the following main hypothesis

There is a statistically significant effect of plyometric exercises on kinetic energy and mechanical variables affecting shooting accuracy of football players under the age of 17.

Researcher identified the behavior nature of research variables data and approached it to the normal distribution as a prerequisite for applying T-test for related samples. As it is known, that T-test is a parametric test that estimates the standard difference between two values representing two arithmetic means. Thus, it enjoys importance and preference compared to other non-parametric statistical tests. Both basic coefficients of skewness and kurtosis were used to describe the behavior of data distribution in the pre-measurement. The following table presents the results and values of these two indicators (Table 2):

The above table shows the values of the two indicators of the normal distribution. The first is a skewness coefficient that describes the tail of a data distribution curve for a given variable so that the description skewed either to the right or to the left. Usually values of this indicator accepted if they are between -3 to +3. Returning to the values shown in the table, it is clear that the largest value that appeared was (-1.74). Although this value is the largest, it falls within the acceptable range of this indicator.

Table 1: Homogeneity of research sample in variables of kinetic energy and some mechanical variables affecting shooting accuracy among football players under the age of 17 in pre-measurement (n = 18).

Variables	Min. Value	Max. Value	Arithmetic Mean	Standard Deviation	Coefficient of Variation
Kinetic energy (joule)	83.10	89.10	86.73	1.55	1.79
Circumferential velocity of kicking foot (m / sec.)	12.22	17.23	15.89	1.20	7.55
Extension of knee at the moment of shooting (deg.)	136.00	141.00	138.44	1.50	1.08
Angular velocity of knee (deg. /sec.)	1202.00	1332.00	1283.78	39.72	3.09
Angular momentum ($kg \cdot m^2 s^{-1}$)	127.00	147.00	140.17	4.27	3.05
Ball speed (m / sec.)	14.90	17.40	16.43	0.93	5.66
Accuracy out of 5	1.00	3.00	2.44	0.92	37.70

Table 2: Indicators of normal distribution of research variables in the pre-measurement (n = 18).

Variables	Skewness Coefficient	Kurtosis Coefficient
Kinetic energy (joule)	- 0.74	0.75
Circumferential velocity of kicking foot (m / sec.)	-1.74	4.28
Extension of knee at the moment of shooting (deg.)	-0.41	-0.71
Angular velocity of knee (deg. /sec.)	-1.27	0.73
Angular momentum ($kg \cdot m^2 s^{-1}$)	-1.43	5.11
Ball speed (m / sec.)	-0.31	-1.63
Accuracy out of 5	-1.08	-0.94

Table 3: T-test results to estimate the significance of plyometric exercises effect on kinetic energy and mechanical variables affecting shooting accuracy for football players under the age of 17 (n = 18).

Variables	Pre		Post		Difference Significance Test	
	Arithmetic Mean	Standard Deviation	Arithmetic Mean	Standard Deviation	T Value	Significance Level
Kinetic energy (joule)	86.73	1.55	95.18	0.72	21.63	0.000 *
Circumferential velocity of kicking foot (m / sec.)	15.89	1.20	20.93	0.91	15.65	0.000 *
Extension of knee at the moment of shooting (deg.)	138.44	1.50	141.33	1.71	7.02	0.000 *
Angular velocity of knee (deg. /sec.)	1283.78	39.72	1438.44	12.42	17.39	0.000 *
Angular momentum ($kg \cdot m^2 s^{-1}$	140.17	4.27	182.61	3.27	31.30	0.000 *
Ball speed (m / sec.)	16.43	0.93	20.23	0.65	17.38	0.000 *
Accuracy out of 5	2.44	0.92	3.89	1.41	3.42	0.000 *

When reviewing the values of the kurtosis coefficient indicator, which describes the peak of a data distribution curve for a given variable, whether it is a pointed top, a flat top, or a peak with a moderate arc shape, we find that the results of this indicator express a moderate arc peak if its value is (8) or less. By returning to the values shown in the table, it is clear that the maximum value for this indicator was (4.28). Since this value (the largest among others of this indicator) was less than the maximum allowable for this indicator, the values reflect moderate arc peaks for research variables in pre-measurement.

Accordingly, and through these results, the behavior of research variables data may be described as a behavior that approximates the normal distribution, which allows use and application of the parametric T-test (Table 3).

Table 3 shows T-test results to estimate significance of plyometric exercises effect on the kinetic energy and mechanical variables affecting shooting accuracy for football players under the age of 17. By reviewing T-test values calculated between pre and post measurements of the kinetic energy variable, it turns out that they amounted to (21.63), and the significance of both means difference of circumferential velocity of kicking foot variable was (15.65), while significance level of difference between the pre and post measurements means of extension of knee variable was (7.02), and amounted to (17.39) for the angular velocity of knee variable, as well as to (31.30) for the angular momentum variable, and finally to (17.38) for the ball speed variable. As for the calculated value of T for the accuracy variable, it amounted to (3.42).

And when comparing significance level values calculated for these variables with the value 0.05, it turns out that all of them were less than 0.05, which indicates the acceptance of research hypothesis (alternative hypothesis) entitled Effect of Plyometric Exercises on Kinetic Energy and Mechanical Variables Affecting Shooting Accuracy for Football Players Under the Age of 17. As this difference or effect was the result of post measurement with the best (largest) arithmetic mean (Figure 2).

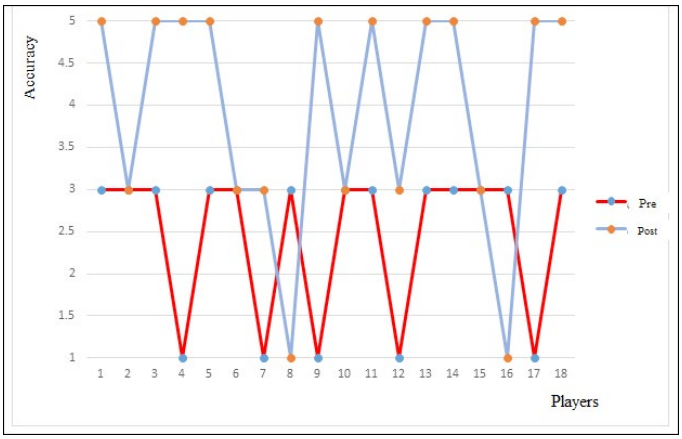

Figure 2: A graphic representation of accuracy variable values for players in both pre and post measurements.

Discussion

Returning to the study results, we find that the training program based on plyometric exercises was effective in improving accuracy by developing all mechanical variables that related to shooting accuracy. As the accuracy increased from 2.44 to 3.89 out of 5, thanks to improving shooting accuracy in the plyometric training program. When considering the element of shooting accuracy, we find that it related to factors of force and speed, so in order to reach a model that balances them we should increase shooting accuracy. Force alone is not enough and speed alone without force not enough. Whereas, in light of mass stability of ball (football) and according to the force equation:

Force = mass × acceleration

We find that increasing shooting force mainly related to ball acceleration, in light of mass stability. Here, we point out that plyometric training program

increased the players' strength as a result of accelerating their performance, which can be proved through all mechanical variables that study addressed. Whereas, circumferential velocity of kicking foot, angular velocity of knee, and angular momentum have increased by a statistically significant amount, which is reflected in the increase in ball speed. Returning to ball speed, we find that it was 16.43 m/s, and after the training program, it became 20.23 m/s. This speed is ideal, especially when shooting from outside the penalty area at the age of 17, as is the case of this study, and this is consistent with (11). It can also be noted that the angle of knee at the moment of shooting and its increase from 138.44 to 141.33 degrees also gave a greater range of motion to knee joint to give additional strength and momentum for shooting, based on the development of thigh quadriceps muscle and the anterior leg muscles due to plyometric training program applied by the players. The knee angle of kicking foot is very important to guarantee the success of kick according to (12).

In addition, it can say that plyometric exercises increase performance momentum, according to momentum equation:

Momentum = mass × velocity. Therefore, plyometric exercises increase muscle mass and strength as well as players' speed in the age group 17 years as indicated in (13). So increasing momentum is a logical consequence of plyometric training program. On the other hand, the increase in momentum indicates an increase in energy stored in kinetic performance, which shown by the result of this study through the increase in performance kinetic energy from 86.73 to 95.18 joule.

Conclusion

The plyometric exercises for football players of the age group of 17 years are able to provide them with the strength and speed they need in the skill of shooting at the goal, and thus improve their performance accuracy. Accordingly, the physical trainer and supervisors of sports teams in football game, especially at young ages, must develop training based on the plyometric exercises for players and measure the impact of these exercises on their performance of the various skills in football, especially shooting skill.

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