SPORT TK-EuroAmerican Journal of Sport Sciences
https://revistas.um.es/sportk Online ISSN: 2340-8812
Received: **23/05/2022.** Accepted: **02/07/2022.** Published: **13/09/2022**

The impact of reaching the anaerobic threshold on some kinematic variables related to the accuracy of shooting the penalty kick among footballers

Ibtehal M. Alkhawaldeh[1]*

[1] Department of Sports Training, Faculty of Sports Sciences, Mutah University, Jordan

*Correspondence: Ibtehal Mohammad Alkhawaldeh; dr.khawaldeh@mutah.edu.jo

ABSTRACT

The aim of this study was to identify the correlation of the kinematic variables in the accuracy of shooting the penalty kick among footballers before and after reaching the anaerobic threshold, and also to identify the impact of reaching the anaerobic threshold on some kinematic variables related to the accuracy of shooting the penalty kick among football players. We used the experimental approach using the divided goal to determine the accuracy extent of shooting the penalty kick in addition to Cunningham and Faulkner Anaerobic Treadmill Test. The study sample consisted of 12 football players from the Jordanian Professional Football League for the year 2021, who are specialized in performing penalty kicks in their clubs. Their average age was 25.1± 4.1 years, average weight 71±2.2 kg and average foot weight 10.9±1.6. The study used Canon Eos 80D cameras, lactate Scout Cortex device and Kinovea 0.8.15 software to analyze the performance. The data was processed through the Statistical Package for the Social Sciences (SPSS). Our study showed that there is a statistically significant relationship at $\alpha = 0.05$ of the kinematic variables before and after the player reaches the anaerobic threshold with the accuracy of shooting the penalty kick. The results also revealed that there is a statistically significant negative impact at $\alpha = 0.05$ for reaching the anaerobic threshold on some kinematic variables related to the accuracy of shooting the penalty kick among football players. In conclusion, the kinematic variables of the study and the accuracy of shooting the penalty kick were negatively affected by reaching the anaerobic threshold at a level that exceeds 4.2 mmol/L.

KEYWORDS

Anaerobic Threshold; Kinematic Variables; Penalty Kick; Football; Shooting Accuracy

1. INTRODUCTION

Football is one of the sport games that have a prominent position all over the world; indeed, it is the most popular sport in the world with 211 international football federations that are under the supervision of the international football federation (Abdelkader et al., 2021).

Practicing football requires developing several tactical, technical, psychological and physical skills in order to reach the highest possible performance among players and the team as a whole (Lees et al., 2010).

Football involves many skills, including the skill of shooting the ball towards the goal; it is the main skill to score goals and win the matches, relying on speed, power, and accuracy to achieve an ideal performance (Rusdinan, 2020).

When the footballer shoots the ball more quickly, based on the contact between the player's foot and the ball in as well as the motion's shape and speed, the goalkeeper will have less chance to catch the ball. Therefore, the success of shooting the ball is based on a number of mechanical variables should be addressed and analyzed (Memarbashi & Hossaini, 2010) based on the science of biomechanics that investigates and analyzes the physical movement anatomically, physically and physiologically (Bartlett, 2018).

The penalty kick is considered as one of the most influential fixed kicks in the final score of matches, where the accuracy and success in shooting the ball is an important issue in winning the matches. Since 1976, the penalty kicks were adopted as a final solution after a tie to determine the winner in the matches of knockout stage in football championships. The percentage of success in performing the penalty kicks reached 75-85% in the professional matches (Bar-Eli et al., 2007).

As for the mechanical perspective, in order to ensure the successful scoring of the penalty kick, the player should follow a mechanical model that is based on a number of kinetic and kinematic variables, such as the site of the focus foot, the speed of angular joints in the shooting foot as well as the kinetic momentum acquired by approaching and shooting angle, and other variables relating to the shooting accuracy of the penalty kick (Wesson, 2002).

Lee (2001); Dorge et al. (2002) and Russel et al. (2011) conducted several studies which confirmed the correlation of a number of kinematic variables, such as the trunk slope, knee joint angle, player's approaching speed, ball speed, and the accuracy of shooting the penalty kick in the game of football.

Within the physiological context, anaerobic threshold is considered as one of the scales, where exceeding this threshold indicates that the player reached a stage of fatigue. This threshold is related to the anaerobic system of producing energy, where using the Adenosine triphosphate (ATP) and Phosphocreatine (PC) to produce energy results in the production of the lactic acid; when the concentration of lactic acid in the blood reaches (4.2 mmol/L), it indicates exceeding the anaerobic threshold, and this refers to reaching 80% of maximum oxygen consumption (Vo2 max) (Kenny et al., 2020).

Exceeding the anaerobic threshold indicates an increase in the amount of lactic acid and thus a decline in the hydrogen number (PH) concentration, which is normally reached (7.1). This hinders the production of energy inside the muscles by hindering the neuro-muscular work. It also results in a defect in the electromechanical power in the muscle; therefore, leads to a reduction in the performance and adjustment abilities among players (Mohre et al., 2005).

When considering the game of football, we can see that it is a game that depends on producing energy according to a shared system between the aerobic and anaerobic processes. The duration of the game of football makes it as an aerobic system; however, the technical skills included in the game of football are viewed as anaerobic ones (Stolen et al., 2012). Generally, Brodie (1986) suggested that it is difficult to find a sport that depends on producing a certain energy, where the ratio of dependency differs from one sport to another according to the sport's type, duration, skills and shape. For example, the game of football has a performance intensity that ranges from low to high according to the consumption of oxygen.

Stolen et al. (2005); Brodie (1986) and Evaggelos et al. (2012) suggested that football is performed in intermittent periods during the total time of the match in times that range from 1-5 seconds, where the player performs skills, such as sprinting, high jump, rapid sliding, as well as running by the ball and kicking it. These skills are performed by a high intensity in terms of time. Therefore, performing them frequently with the continuity of the match time will lead to reaching the anaerobic threshold resulting from the increased accumulation of lactic acids.

Blumchen (2009); Hoff (2005) and Klissouras & Pigozzi (2009) suggested that the footballer reaches the anaerobic threshold due to the anaerobic activity. Also, Kellis & Vrabas (2006) suggested that the player may exceed the anaerobic threshold and reach (7 mmol/L) of lactic acid concentration in the blood. Evaggelos et al. (2012) illustrated the percentage of kinetic and skilled activities during the match as follows: running (36.9%), walking (24.8%), rotation (18.6%), sprinting (11.2%), running with the ball (6.5%) and back running (2%), which means dividing work between aerobic and anaerobic energy systems.

The current study is distinguished from the other studies by adopting the anaerobic threshold based on the level of lactic acid concentration in the blood as an important physiological variable that indicates the occurrence of electrochemical changes inside the muscle after applying a physiological protocol and a n aerobic test, which is Cunningham and Faulkner Anaerobic Treadmill Test (an international test to measure reaching the anaerobic threshold) .

This study is the first of its kind in the Hashemite Kingdom of Jordan applied to professional footballers. It aims to identify the correlation of the kinematic variables in the accuracy of shooting the penalty kick among footballers before and after reaching the anaerobic threshold. The study also aims to identify the impact of reaching the anaerobic threshold on some kinematic variables and the accuracy of shooting the penalty kick.

Accordingly, the researcher formulated the two study hypotheses as follows:

H1: there is no statistically significant relationship at (α=0.05) between the kinematic variables before and after reaching the anaerobic threshold among players.

H2: there is no statistically significant impact at (α =0.05) for reaching anaerobic threshold on some kinematic variables and on the accuracy of shooting the penalty kick among footballer players.

2. METHODS

2.1. Study Design and Participants

The study used the experimental approach in which field and physiological experiments were applied in order to achieve the study objectives. The study sample consisted of 12 footballers from the Jordanian football league for the year 2021, who are specialized in performing penalty kicks in their clubs and they all use their right foot in shooting the ball. Their average age was (25.1 ± 4.1 years), average weight (71 ± 2.2 kg), and average foot weight (10.9 ± 1.6).

2.2. Study Procedures

We present the study procedures steps in a sequential and detailed way:

Step 1: The players performed the penalty kicking accuracy test by kicking 5 penalties towards a goal that is divided into 9 sections (1-9), where the highest test score was 45 (Abubshara & Fattah, 2021) (Figure 1).

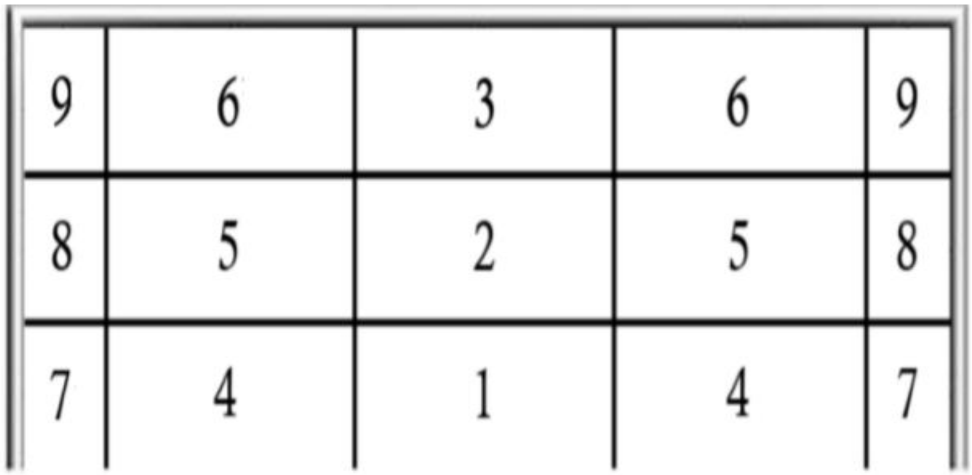

Figure 1. The shape of the divided goal for the test of the accuracy of shooting the penalty kick.

Step 2: The players performed Cunningham–Faulkner test for the anaerobic threshold using the treadmill (Cunninghamand & Faulkner, 1969). The procedures are presented as follows:

- warming up for several minutes using the treadmill at a speed of 10 km/h with a slope angle of 0.
- leaving the treadmill device and performing lengthening exercises to complete the warm up process.
- setting the treadmill at a speed of 80 miles /h, with a slope angle of 20%.
- time starts when the player runs without help.
- the player continues running until he finishes the test voluntarily or when he holds the device's pillars.
- the player is encouraged over the whole performance period.

Step 3: The researcher took blood samples directly from the players from the earlobe after finishing Cunningham – Faulkner test to determine the lactic acid concentration in the blood using Lactate Scout (Cortex) / Leipzig – Germany (Table 1).

Table 1. The concentration of lactic acid in the blood among the players and the time at which each player reaches the anaerobic threshold is the time of ending the test (Cunningham – Faulkner Anaerobic Treadmill Test)

Subject	Lactic acid level in the blood immediately after completing the Cunningham and Faulkner Anaerobic Treadmill Test	Time of total performance until exhaustion and voluntary stoppage of work according to the Cunningham and Faulkner Anaerobic Treadmill Test
1	5.4 mmol/l	10.81 min
2	5.9 mmol/l	11.19 min
3	5.2 mmol/l	10.91 min
4	5.4 mmol/l	10.81 min
5	5.5 mmol/l	10.38 min
6	5.7 mmol/l	10.11 min
7	5.1 mmol/l	10.14 min
8	5.1 mmol/l	10.51 min
9	5.3 mmol/l	9.11 min
10	5.4 mmol/l	9.23 min
11	5.5 mmol/l	10.01 min
12	5.7 mmol/l	10.11 min

Step 4: Repeating the test of the test of the accuracy of shooting the penalty kick.

Step 5: The researcher took photos of the players' performance for the test of the accuracy of shooting the penalty kick before and after reaching the anaerobic threshold using two cameras Canon Eos 80D with a speed of 500 photos/second in order to find out the kinematic variables which were analyzed and calculated using Kinovea 0.8.15 (Figure 2).

Taking photos was performed based on the following model:

- The first camera was placed in the right side of the lateral axis of the player shooting the penalty kick at a distance of (7.20) m and a height of (0.78) m.
- The second camera was placed behind the player shooting the penalty kick at a distance of (5.75) m and a height of (0.92) (Figure 2).

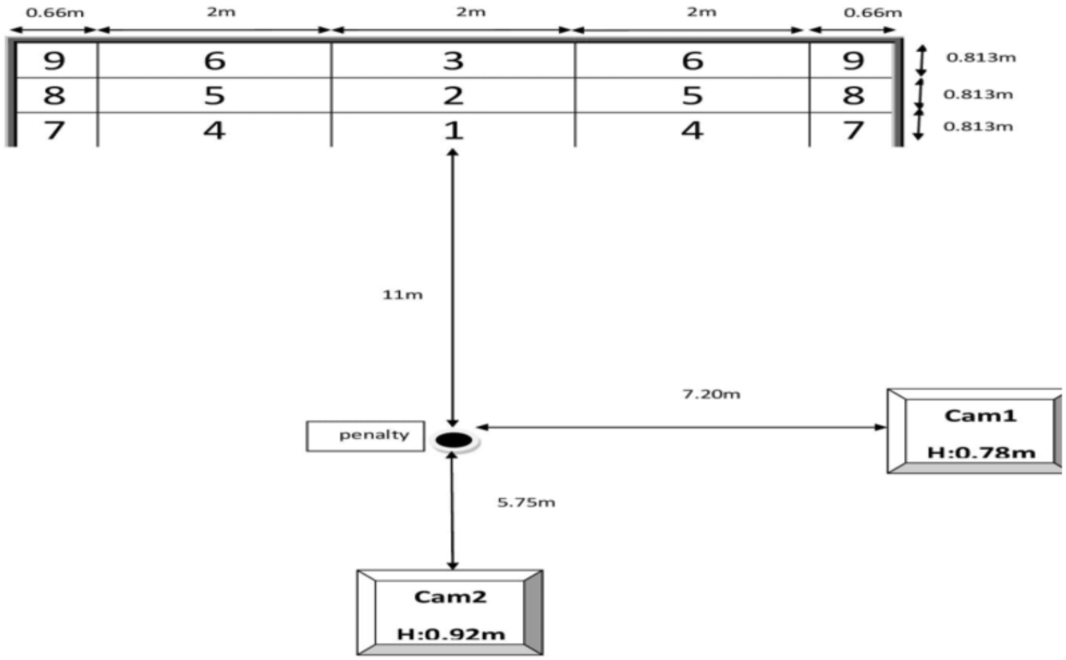

Figure 2. The camera shooting method to test the accuracy of the penalty kick, the divided goal, the dimensions of the goal sections and the points assigned to each section

Step 6: The player shoots five penalty kicks from the penalty point towards the goal illustrated in Figure 1. It is a divided goal with legal dimensions according to the law of football. Then the player applies Cunningham – Faulkner test, the lactic acid percentage is calculated, and the shooting test is performed again.

2.6. Statistical Analysis

The search data was processed through the Statistical Package for the Social Sciences (SPSS). The following statistical analyses were performed: descriptive, Spearman correlation coefficients, and Wilcoxon test. For all the statistical tests, a p-value of <0.05 was considered statistically significant.

3. RESULTS AND DISCUSSION

We begin the presentation of the results by describing the values of the kinematic variables and the accuracy of shooting the penalty kick before and after the player reaches the anaerobic threshold (Table 2).

Table 2. Descriptive statistics for the kinematic variables and accuracy prior the anaerobic threshold

Kinematic variables	Min value	Max value	Range	Mean	SD
Approach velocity (m/s)	2.62	2.77	0.15	2.73	0.05
Ball velocity (m/s)	25.17	25.73	0.57	25.47	0.17
Knee's angular velocity (deg/sec)	309.33	450.33	141.00	431.69	38.65
Knee's angle shooting leg (deg)	132.67	137.00	4.33	135.69	1.11
Trunk angle (deg)	105.00	108.00	3.00	106.78	0.99
Ankle angle (deg)	71.33	72.00	0.67	71.61	0.31
Distance between the ball and balance foot (m)	0.31	0.33	0.02	0.32	0.01
Contact time between shooting leg and ball (s)	0.19	0.22	0.03	0.21	0.01
Accuracy (out of 45)	38.67	41.67	3.00	40.31	1.08

NOTE: SD (Standard Deviation)

The results of Table 2 show that the mean value of the approach velocity was (2.73±0.05) (m/s), the mean value of the ball velocity variable was (25.47±0.17) (m/s), it was ((431.69±38.65) (rev/min) for the knee's angular velocity, (135.69±1.11) (deg) for the knee's angle shooting leg; the mean value of the trunk angle) was (106.78±0.99) (deg), and the observed mean value of the ankle angle was (71.61±0.31) (deg). Concerning the mean value of the distance between the ball and balance foot was (0.32±0.01) (m) and the mean value of the contact time between shooting leg and ball variable was (0.21±0.01) (s), while the accuracy variable reached a mean value of (40.31±1.08).

By referring to the digital values in the previous table, we can see that they are almost similar to the digital values mentioned in a study by Ricardo et al. (2016), where the approach speed was (2.91) m/sec in comparison to (2.62) m/sec in the current study, whereas the speed of the ball was (25.47) as compared to (25.17) in the current study. The digital values in the study by AbdelKader et al. (2021) were more approximate in terms of the knee angle, which was (130.6) degrees as compared to 132.67) degrees in the current study, and in terms of the distance between the ball and the focus foot, with (0.29) as compared to (0.31) in the current study. The values were almost similar with the work by Abubshara & Fattah (2021) in terms of the angular speed of the knee, with (348) degrees/ sec as compared to (431.69) degrees/ sec in the current study.

And now, the following table (Table 3) shows the descriptive statistics for the kinematic variables and accuracy after the threshold.

Table 3. Descriptive statistics for the kinematic variables and accuracy after the anaerobic threshold

Kinematic variables	Min value	Max value	Range	Mean	SD
Approach velocity (m/s)	1.47	1.60	0.14	1.51	0.04
Ball velocity (m/s)	17.17	19.77	2.60	18.00	0.80
Knee's angular velocity (deg/sec)	224.67	235.00	10.33	230.69	2.92
Knee's angle shooting leg (deg)	120.33	125.00	4.67	122.67	1.91
Trunk angle (deg)	165.33	173.00	7.67	169.47	2.24
Ankle angle (deg)	49.33	54.00	4.67	52.36	1.23
Distance between the ball and balance foot (m)	0.17	0.19	0.02	0.18	0.01
Contact time between shooting leg and ball (s)	0.31	0.37	0.06	0.33	0.02
Accuracy (out of 45)	18.00	20.33	2.33	19.22	0.81

NOTE: SD (Standard Deviation)

The results from Table 3 show that the mean value of the approach velocity was (1.51±0.04) (m/s), the mean value of the ball velocity variable was (18.00±0.80) (m/s), it was (230.69±2.92) (rev/min) for the knee's angular velocity, (122.67±1.91) (deg) for the knee's angle shooting leg, the mean value of the trunk angle was (169.47±2.24) (deg), and the observed mean value of the Ankle angle was (52.36±1.23) (deg). Concerning the mean value of the distance between the ball and balance foot, it was (0.18±0.01) (m) and the mean value of the contact time between shooting leg and ball variable was (0.33±0.02) (s), while the accuracy variable reached a mean value of (19.22±0.81).

So, the digital values in Table 3 showed the kinematic variables and the accuracy of shooting the penalty kick after reaching the anaerobic threshold, and as we can see, the differences in the values are apparent between the stages before and after reaching the anaerobic threshold when comparing tables 3 and 4.

Next, we present and discuss the results of the first and second study hypothesis, where the first one states: there is no statistically significant relationship at (α =0.05) between the kinematic variables before and after reaching the anaerobic threshold among players. Table 4 shows the extent of correlation between the kinematic variables before and after the player reaches the anaerobic threshold with the accuracy of shooting the penalty kick.

Table 4. Spearman correlation coefficients between the kinematic variables and accuracy prior and after the anaerobic threshold

Kinematic variables	Correlation coefficient		Z	p value
	Prior	After		
Approach velocity (m/s)	0.115	0.258	0.315	0.376
Ball velocity (m/s)	0.097	- 0.335	0.946	0.172
Knee's angular velocity (rev/min)	0.557	0.463	0.17	0.394
Knee's angle shooting leg (deg)	0.050	0.497	1.051	0.147
Trunk angle) deg)	0.300	- 0.270	1.244	0.107
Ankle angle (deg)	- 0.054	0.221	0.591	0.277
Distance between the ball and balance foot (m)	- 0.094	0.195	0.619	0.268
Contact time between shooting leg and ball (s)	0.223	0.334	0.812	0.209

NOTE: significance level = $p \leq 0.05$

Table 4 shows the differences between the correlation values prior and after the threshold using "z" test. The probability values related to "z" test for the approach velocity was (0.376), the probability value of the ball velocity variable was (0.172), it was (0.394) for the knee's angular velocity, and (0.147) for the knee's angle shooting leg. The probability value of the trunk angle was (0.107), and the observed probability value of the ankle angle was (277). Concerning the probability value of the distance between the ball and balance foot it was (0.268) and the probability value of the contact time between shooting leg and ball variable was (0.209). After comparing these probabilities to (0.05), it was clear that all the mentioned probabilities were > 0.05, suggesting that the two correlation values of the mentioned variables are not considered to be significant (prior and after) the anaerobic threshold.

The results revealed that there are no statistically significant differences in the relationship of the values of kinematic variables with the accuracy of shooting the penalty kick before and after reaching the anaerobic threshold, which means the continuous correlation of the relationship between the kinematic variables with the accuracy of shooting the penalty kick before and after reaching the anaerobic threshold. However, the existing difference is related to the shape of the relationship for some variables, the relationship before the anaerobic threshold in the variables of ball speed, angular speed of the knee, knee angle, pelvis angle was positive, but it turns to become negative after the anaerobic threshold. On the contrary, the variables of ankle angle and the distance between the ball and focus foot had a negative relationship before the anaerobic threshold, which turned to become positive after the anaerobic threshold.

This finding can be explained based on the fact that reaching the anaerobic threshold doesn't necessarily mean the lack of relationship between the accuracy of shooting the penalty kick and the kinematic variables; the mechanical model of shooting is a continuous one and affects the skill performance regardless its digital values, where the relationship exists, but its nature changes. This finding agrees with Kellie et al. (2006); Abubshara & Abdel Fattah (2021) and Lee (2018) which revealed that even though the players reached a state of fatigue, the correlation continues in terms of the impact of kinematic variables on the accuracy of shooting. However, the difference between the current study findings with other studies lies in the negative form of the relationship between some variables and the accuracy of shooting. A case that might be attributed to the nature of the mechanical model, which differs from one sample to another based on reducing or increasing certain mechanical values. It could also be attributed to the difference in the investigated kinematic variables among studies, where excluding certain variables and including others entails coming up with different results that change the form of the relationship between the kinematic variables and skilled performance.

Hence, we should verify the continuous existing relationship between each kinematic variable and the accuracy of shooting before and after reaching the threshold, since when there is no relationship for a certain kinematic variable with the accuracy of shooting, especially after reaching the anaerobic threshold, that variable should be excluded from the second hypothesis due to the lack of its effect. Accordingly, we may refuse the first hypothesis, which suggested that there is no statistically significant relationship at (α =0.05) between the kinematic variables before and after reaching the anaerobic threshold among players and accept the alternative hypothesis, stating "there is a statistically significant relationship at (α =0.05) between the kinematic variables before and after reaching the anaerobic threshold among players".

Now, as for the second hypothesis which states that there is no statistically significant impact at (α =0.05) for reaching anaerobic threshold on some kinematic variables and on the accuracy of shooting the penalty kick among footballers, Table 5 shows the results of Wilcoxon test to identify whether there are differences in the values of some kinematic variables and the accuracy of shooting the penalty kick among footballers attributed to reaching the anaerobic threshold.

Table 5. Wilcoxon test results for the differences in kinematic variables and accuracy prior and after the anaerobic threshold

Kinematic variables	Rank sign	Rank sum	N	Rank mean	Z	p value
Approach velocity (m/s)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Ball velocity (m/s)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Knee's angular velocity (rev/min)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Knee's angle shooting leg (deg)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Trunk angle) deg)	Negative	0.00	0	0.00	3.061	0.002
	Positive	78.00	12	6.50		
Ankle angle (deg)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Distance between the ball and balance foot (m)	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		
Contact time between shooting leg and ball (s)	Negative	0.00	0	0.00	3.061	0.002
	Positive	78.00	12	6.50		
Accuracy	Negative	78.00	12	6.50	3.061	0.002
	Positive	0.00	0	0.00		

NOTE: significance level = $p \leq 0.05$

From Table 5 we can notice that the probability value related to "z" test for the approach velocity was (0.002), the probability value of the ball velocity variable was (0.002), it was (0.002) for the knee's angular velocity, and (0.002) for the knee's angle shooting leg; the probability value of the trunk angle was (0.002), and the observed probability value of the ankle angle was (0.002). Concerning the probability value of the distance between the ball and balance foot, it was (0.002) and the probability value of the contact time between shooting leg and ball variable was (0.002). It was clear that all the mentioned probabilities were < 0.05, suggesting that the mean values differed significantly (prior and after) the threshold and were in favor of the (prior the threshold).

Table 5 revealed that reaching the anaerobic threshold affected all the kinematic variables and had a negative effect on the accuracy of shooting the penalty kick among footballers. It is noteworthy that since the accuracy of shooting the penalty kick is based on the values of the kinematic variables as stated in the second hypothesis and as suggested by the previous studies (Wesson, 2002; Dorgeet al., 2002 and Memarbashi & Hossaini, 2010). It is logical that the effect in the kinematic variables when the player reaches the anaerobic threshold will affect the accuracy of shooting the penalty kick, where the results revealed a negative effect for the accuracy of shooting, which was (40.31) before anaerobic threshold and (19.22) after reaching the anaerobic threshold. This means a considerable decline in the accuracy of shooting the penalty kick, which is contrary to the negative physiological effect of the anaerobic threshold on the skilled performance, where the previous studies (Kellis et al., 2006 and Bangsbo, 2014) suggested that the increase of lactic acid in blood and muscles, which is accompanied by reaching the anaerobic threshold results in a decrease in the neuro-psychological adjustment due to a defect in the muscular electricity and the slowness of changing the nervous signals into chemical ones, and causes difficulties in the muscular contractions which are the base of skilled performance. At the same time, this defect in the muscular activity is accompanied by disruption in the blood plasma due to the increased blood acidity. This, in turn, reduces Hemoglobin correlation with oxygen and reduces the percentage of the oxygen that reaches muscles that already suffer from a rise in lactic acid; this also reduces the saturation of myoglobin that exists in muscles with oxygen, and disrupts the nutrition of the working muscles.

According to the mechanical perspective, we can say that the physiological disorder leads to a biomechanical disorder, where the kinetic transformation from the trunk to the thigh and then to the leg becomes less effective either in terms of speed or power direction that is distracted during the process of kinetic transfer due to a weakness in the contraction of the working muscles of the leg because of reaching the anaerobic threshold. This finding was confirmed by Hamilton (2008) who suggested that the mechanism of kinetic transmission through which power is transmitted to the organ that performs the skill is exposed to a defect when there is any muscular problem, since muscles are the medium for transmitting the kinetic power. Abubshara & Fattah (2021) suggested that the decline in the power of the working muscles on the knee joint leads to a negative impact on the ball's speed and on the determination of the power necessary to shoot the ball and that reduces the accuracy of shooting.

As for the variable of approaching speed, it is noteworthy that reaching the anaerobic threshold is negatively reflected on the speed of muscular contraction which, in turn, reduces the player's approach speed and reduces the necessary kinetic momentum due to the muscular fatigue resulting from a rise in the percentage of lactic acid. Mizrahi et al. (2000) also suggested that the approach speed to shoot the ball declines after the player reaches fatigue stage.

As for controlling the activity angles, including knee angle and ankle angle at the moment of shooting the ball, we should refer to the adjustment-perceptual disorder in performing the skill resulting from the high acidity in blood and muscles and to the defect in the muscular memory. Indeed, such defects are mostly noticed among elite footballers who failed to score critical penalty kicks due to reaching the anaerobic threshold despite reaching the mechanical stage of performance. Mohr et al. (2005) suggested that the values of the angles of muscular activity, determining the site of focus foot and the time of foot contact with the ball are included within the perceived mechanical system by players. However, according to the results of the current study, we find that those values differed and that reduced the accuracy of shooting, since the contact time between the shooting foot and the ball increased from (0.21) seconds to (0.33) seconds. This means less dynamic movement. Also, the increased distance of the focus foot from the ball from (0.33) m to (0.18)m will reduce the width of pelvis, where the approach of the two feet reduces the width of the pelvis (Hamilton, 2008). This leads to reducing the extent of swinging the shooting foot and thus a defect in the skilled performance.

The results of the current study agreed with studies by Abubshara & Abdel Fattah (2021); Wesson (2002); Memarbashi & Hossaini (2010) and Kellis et al. (2006). Accordingly, we reject the second hypothesis stating "there is no statistically significant impact at (α =0.05) for reaching the anaerobic threshold on some kinematic variables and on the accuracy of shooting the penalty kick among footballers" and substituting it with the alternative hypothesis stating "there is a statistically significant impact at (α =0.05) for reaching the anaerobic threshold on some kinematic variables and on the accuracy of shooting the penalty kick among footballers."

4. CONCLUSIONS

The kinematic variables of the study and the accuracy of shooting the penalty kick were negatively affected by reaching the anaerobic threshold at a level that exceeds 4.2 mmol/L. This means that even though the sample individuals are considered as specialized in performing penalty kicks in their clubs, reaching the anaerobic threshold increases the opportunity of failing to score a goal and reduces the winning chance, especially when adopting penalties in the excluding matches. Accordingly, coaches should postpone reaching the anaerobic threshold among those players by intensifying the programs and training loads that are based on the system of producing anaerobic energy. Brodie (1986) and Kenny et al. (2010) suggested that players should be trained based on aerobic and anaerobic energy-production systems. Also, Bagsbo (2014) suggested that delaying the time of reaching to the anaerobic threshold and fatigue is considered as an important physiological requirement among footballers.

Based on the previous findings, the study recommended the necessity of urging those specialized in physical preparation in the professional football clubs to focus on the anaerobic exercises that increase the player's ability to get rid of the lactic acid by using it as a source of energy and preventing the increase of its concentration in blood and muscles as suggested by Stolen et al. (2012). According to Kenny et al. (2020), the well-trained muscles can use the lactic acid as a source of energy by inserting it to coli cycle which, in turn, delays the emergence of the anaerobic threshold. Also, adopting the anaerobic training system increases the players' tolerance to high levels of lactic acid concentration without affecting their performance.

5. REFERENCES

1. Abdelkader, G., Arguz, A., Kusuma, M. N. H., Erkmen, N., Calişkan, O., & Madani, R. (2021). Kinematical characteristics of accurate penalty-kicking for Turkish football players in goalkeeper confrontation. *Acta Kinesiologica*, *15*(2), 112-119.
2. Abubshara, J., & Fattah, O. A. (2021). Does Fatigue have an Effect on the Correlative Relationship between Kinematic Variables of the Penalty kick in Soccer? *International Journal of Innovation, Creativity and Change, 15*(6), 658-670.
3. Bangsbo, J. (2014). Physiological demands of football. *Sports Science Exchange*, *27*(125), 1-6.
4. Bar-Eli, M., Azar, O. H., Ritov, I., Keidar-Levin, Y., & Schein, G. (2007). Action bias among elite soccer goalkeepers: The case of penalty kicks. *Journal of Economic Psychology*, *28*(5), 606-621. https://doi.org/10.1016/j.joep.2006.12.001
5. Bartlett, R. (2018). *Introduction to Sports Biomechanics*. Routledge
6. Blumchen, G. (2009). The Maya ball game. Comparison of the physical load with modern ball games. *Cardiology, 113*(4), 231-235.
7. 7- Brodie, D. A. (1986). Physiology of exercise and sport. *British Journal of Sports Medicine, 20*(4), 186.
8. Cunningham, D. A., & Faulkner, J. A. (1969). The effect of training on aerobic and anaerobic metabolism during a short exhaustive run. *Medicine and Science in Sports, 1*(2), 65-69.
9. Dorge, H. C., Anderson, T. B., Sorensen, H., & Simonsen, E. B. (2002). Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. *Journal of Sports Sciences*, *20*(4), 293-299. https://doi.org/10.1080/026404102753576062
10. Evaggelos, M., Christos, P., Konstantinos, M., Ioannis, G., Evaggelos, B., & Aristomenis, S. (2012). The effect of training, playing position, and duration of participation on aerobic capacity in soccer players. *Journal of Physical Education and Sport, 12*(2), 188 -199.
11. Hamilton, N. (2008). *Kinesiology: Scientific Basis of Human Motion*. McGraw-Hill.

12. Hoff, J. (2005). Training and testing physical capacities for elite soccer players. *Journal of Sports Sciences*, *23*(6), 573-82.
13. Kellis, E., Katis, A., & Vrabas, S. (2006). Effects of an intermittent exercise fatigue protocol on biomechanics of soccer kick performance. *Scandinavian Journal of Medicine & Science in Sports 16*(5), 334-344. https://doi.org/10.1111/j.1600-0838.2005.00496.x
14. Klissouras, V., & Pigozzi, F. (2009). Genetic limits of sport performance: Quo vadis? *The Journal of Sports Medicine and Physical Fitness*, *49*(1), 1-5.
15. Lee, H. (2018). *The Effects of Fatigue on Biomechanics of Soccer Shooting*. Master of science in athletic training, Bridgewater State University.
16. Lees, A., Asai, T., Andersen, H., & Nunome, T. (2010). The biomechanics of kicking in soccer: A review. *Journal of Sports Sciences, 28*(8), 805-817. https://doi.org/10.1080/02640414.2010.481305
17. Meamarbashi, A., & Hossaini, S. (2010). Application of novel inertial technique to compare the kinematics and kinetics of the legs in the soccer instep kick. *Journal of Human Kinetics, 23*(1), 5-13.
18. Mizrahi, J., Verbitsky, O., Isakov, E., & Daily, D. (2000). Effect of fatigue on leg kinematics and impact acceleration in long distance running. *Human Movement Science*, *19*(2), 139-151.
19. Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: A brief review. *Journal of Sports Sciences*, *23*(6), 593–599. https://doi.org/10.1080/02640410400021286
20. Rusdiana, A., Ray, H. R., & Syahid, A. M. (2020). Effect of Fatigue on the Kinematic Variables of Jump Header Performance in Soccer. *Journal of Physical Education & Sport, 20*(2), 649 - 657.
21. Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer. *Sports Medicine*, *35*(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004
22. Wesson, J. (2002*). The science of soccer*. CRC Press.
23. Kenney, W. L., Wilmore, J. H., & Costill, D. L. (2020). *Physiology of Sport and Exercise*. Human Kinetics.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.