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Does Fatigue have an Effect on the Correlative Relationship between Kinematic Variables of the Penalty kick in Soccer?

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The aim of the present study was to identify the effect of fatigue on the correlative relationship between the penalty kinematic variables. To achieve that, the quasi-experimental approach has been applied to nine (9) male soccer players. Each player has kicked ten (10) balls from the penalty point, five (5) balls before and five (5) balls after the application, so that the total number of attempts was ninety (90) shots. The study sample was videotaped by using tow Canon 6D video cameras which reached a speed 60 f/s, one placed vertically at the lateral level and the other placed vertically behind the player and on the front level. Furthermore, a total of 74 successful attempts were analysed by using the Kenova kinematic analysis program (0.8.27 x64). The results of the study showed a statistically significant difference in the values of kinematic variables pre and post the application of the fatigue protocol and for the benefit of measurement. Also, the accuracy of the kick variable was the most variable affected by fatigue (29.3) %. In addition, the effect of fatigue was studied on the correlative relationship between the kinetic variables under study.

Key words: *Kenova analysis program, ball speed, approach speed, approach time*

Introduction

Soccer is one of the most popular games in the world, and it is very popular in the global and local levels. This is evident in the number of players in different clubs, as well as in various tournaments held around the world. The observer of this sport sees that it has progressed very quickly in various physical, psychological, technical and planning aspects, where these aspects overlap together in order to reach the highest levels of sports. According to FIFA statistics, there are 265 million players, in addition to the huge numbers of followers of this sport. Also,

it has many skills such as pass, shooting and dribbling (Lees et al., 2010). On the other hand, scoring goals is one of the most difficult skills in contemporary soccer, because it requires that the player be able to perform all skills efficiently and accurately within a specific area and the soccer player makes an intermittent effort and this effort changes every 3-5 seconds; in addition it is sometimes very intense and sometimes very comfortable (Sterzing, 2010). Furthermore, the penalty kick is one of the most exciting sports events in soccer, and its implementation is linked to many factors: psychological, physiological, technical and biomechanical (Gilbourne, 2002). McGarry & Franks (2000) stated that the success rate of the penalty kicks in the European Championships was 85.2 % during the original time of the match, and 75.2 % after the expiry of the original time. Also, Bar-Eli et al (2007) stated that the success rate of the penalty kicks among professional soccer players was between 75 and 85%. In addition, Finnoff et al (2000) stated that the percentage of penalty kicks that failed in official competitions ranged from 25-33%.

The accuracy of the penalty kick is an important component, which can be defined as the ability to kick the ball in a specific area (Finnoff et al., 2000). The penalty kick is one of the best opportunities that can be given to the player to score in the opponent's goal because of its proximity to the goal (11 m), the absence of harassment of defenders and the large area of the goal. As mentioned earlier, there are many factors associated with the implementation of the penalty kick, including fatigue that indicates a decrease in the ability of the muscles to produce the energy or failure to maintain the strength resulting from continuous muscle contraction (Gandevia, 2000), where the effect of fatigue is manifested by the negative effects on the maximum strength, and thus the power (Mohr et al., 2002). The results of many studies indicate that fatigue affects the performance of complex skills and leads to a decrease in the strength of muscles that work on the knee joint; it also affects the ball speed and the compatibility and cognitive abilities of the player (Rodacki et al., 2001; Ricardo et al., 2016; Kellis et al., 2006). These negative effects may be due to the physiological changes caused by the high intensity which players are exposed due to the high and immediate effort, changes in metabolism and to the decrease of neuromuscular conduction (Mohr et al., 2005; Ismail et al., 2010; Seyed et al., 2010). Also, the higher blood lactate and decreased muscle glycogen negatively affect neuromuscular conduction, which affects the player's coordinative abilities, which affects the various skills in soccer where studies have indicated that the concentration of blood lactate during the game ranges between 7 and 8 mmol / L (Kellis et al., 2006). In order to kick a successful penalty, it is necessary to focus on the mechanical variables that influence on the performance and it is very important in guiding and controlling the training process by identifying these mechanical variables (Lees et al., 2010).

Biomechanical techniques are an important tool for the coaches, because they help to identify the characteristics of skills and improve mechanical effectiveness in body parts changing during the implementation of various skills, and to identify the effect successful performance variables (Amiri-Khorasani et al., 2010). For example, Orloff et al (2008) stated that the

difference in the foot position when the penalty kick is occurring affects the ball speed and Bar-Eli (2007) stated that the distance between the foot and centre of the ball ranges from 28-5 cm; also, Tamaka et al (2006) ; Wessom (2002) stated that the ball speed depends primarily on the speed of the foot at the contact moment and the foot position at the kicking moment, where the high foot speed and the smallest distance between the ball and the feet increase the speed of the ball and cause the establishment of high momentum. Also, studies indicate that there is a strong and positive correlation between the foot velocity and the ball velocity (r = 0.94) and the leg angular velocity is also related to the ball velocity (Hussain and Arshed, 2012).

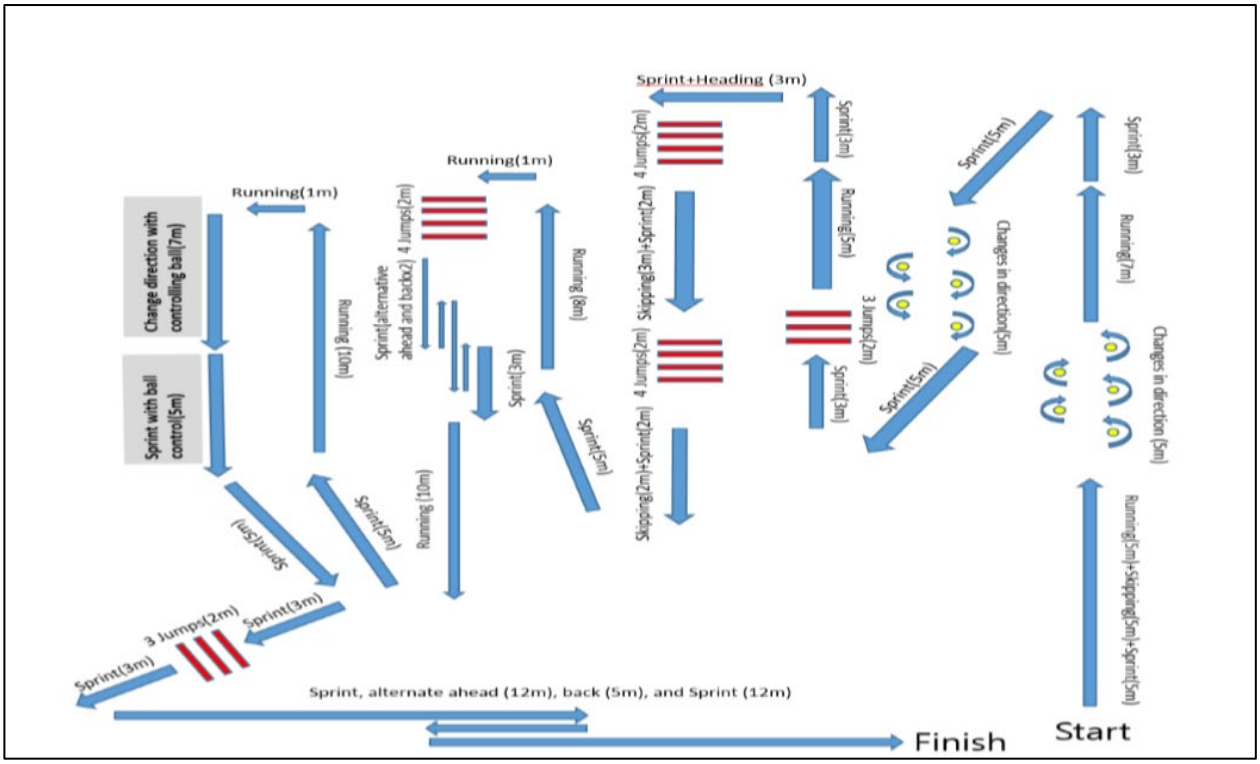
The study problem arose through the researcher's follow-up of the soccer statistics, where they found that 50% of the goals recorded in the games are made through fixed kicks, including the penalty kick. Studies have indicated that the success rate of implementing the penalty is lower in the extra runs or at the end of the game. Therefore, it is urgent to pay attention to the analysis of this kick in similar conditions of the competitions to identify the changes that can occur after fatigue. Also, the researchers found that there were few studies that were interested in the kinematic analysis of the penalty kick after the application of the fatigue protocol. Therefore, the researchers conducted this study with the aim of identifying the more kinematics variables under study that are affected by fatigue, and to answer the following question: Does the fatigue affect the correlative relationship between the kinematic variables of the l penalty kick? In order to provide the data that can contribute to the modification of training programs, the changes that may result from fatigue are taken into account.

Materials and methods

The quasi- experimental approach has been applied on nine (9) male soccer players (age=22 ±2.4 years, mass = 70±3 kg, height = 1.72±0.06 m and training age= 8±1.2 years). Each player has kicked ten (10) balls from the penalty point, five (5) balls per the application of the Fatigue Protocol, and five (5) balls post the application, so that the total number of attempts is ninety (90) shots. The study sample was videotaped by using tow Canon 6D video cameras which reached a speed of 60 f/s, one placed vertically at the lateral level and the other placed vertically behind the player and on the front level. Furthermore, 74 successful kicks were analysed by using Kenova kinetic analysis program (0.8.27 x 64).

Marks were placed on the body joints (ankle, knee, pelvis, shoulder), as well as the heart beats were measured before the fatigue protocol application by using the Garmine clock, where the fatigue protocol used for the study sample, which is from a set of high intensity exercises, was explained, such as jumping, directional change, agility, and maximum speed; the number of heart beats to 90 % of the maximum heart beat was calculated by the following equation: HRmax = 207 – (0.7 x Age), where the heart strokes ranged from 175-185 bpm depending on the age of the player (Figure 1).

Figure 1. The fatigue protocol



To measure the level of accuracy, the researchers divided the goal into 15 areas distributed to the goal centre, 3 regions take numbers 1-3 and 6 areas on both sides of the centre, and take numbers 4-6 and 6 areas beside the right and left operators and take the numbers 7-9. The area of the areas is 1-6 2 ^{x} 0.80 m, and 0.66-0.81 m for areas 7-9, so that the player will kick 5 balls at the goal before the fatigue protocol application, and 5 balls after the application of the protocol, so as to calculate the number in the box before and after the application of the protocol, knowing that the maximum degree that the player can achieve is 45 degrees (Figure 2).

Figure 2. Demonstrates the accuracy test used

9	6	3	6	9
8	5	2	5	8
7	4	1	4	7

As shown in Table 1, description of Independent and dependent study variables

Table 1. Description of Independent and dependent study variables

Variables	Symbol	Variable type	Variable description
fatigue protocol	**FP**	independent	which is from a set of high intensity exercises
approach distance/ m	**D**	dependent	the distance from the player starting with the ball
approach time / s	**T**	dependent	the time from the player starting to the foot touch of the ball
approach speed/ m/s	**SA**	dependent	approach distance/ approach time
the speed of the foot of the leg kick/ m/s	**SF**	dependent	the speed of the foot at the kicking moment
ball speed/ m/s	**SB**	dependent	ball speed at the release kicking moment
the knee angular speed at the kicking moment/ º/s	**SN**	dependent	the difference between the knee angle when the foot reached the maximum range and the knee angle at the kick moment divided by the time of movement
the ball release angle/ º	**AB**	dependent	the angle between the imaginary line of the ball after the release of two images and the imaginary line parallel to the ground
the angle of the knee of the leg at the ball touch moment/º	**AN**	dependent	the angle between the imaginary line extending from the pelvis to the knee and the phantom line extending from the knee to the ankle
the trunk angle at the kick ball moment/º	**AT**	dependent	the angle between the imaginary line extending from the pelvis to the shoulder and the phantom line extending from the pelvis to the knee
maximum horizontal displacement of the foot kick leg/ m	**DH**	dependent	the straight line extending from the maximum point reached by the foot and the ball
the level of kick accuracy%	**AK**	dependent	the percentage of the total scores obtained by the player in 5 attempts compared to the maximum limit that can be achieved (45)

As shown in Table 2, the homogeneity of the descriptive statistics indicators of the kinetic variables under study are shown.. It is known that the torsion is a measure of the level of data distribution and its relation to the natural data distribution curve (default). The values of the torsion coefficient are usually accepted as between the values -3 and +3. Some reference points consider that the range of acceptable values of the torsion coefficient should be limited between -1 – 1+. By reviewing the torsion values, the greatest value has been shown to be -0.62) for the trunk angle of the kicking moment. Within the normal range values of the torsion coefficients ranging 0.62- - 1.56.

Table 2. The homogeneity of the kinetic variables under study

variables	minimum	maximum	mean	sd	skewness
approach distance/ m	1.41	2.25	1.72	.22**0**	1.56
approach time / s	0.54	0.88	.66**0**	.10**0**	0.96
approach speed/ m/s	1.86	3.59	2.66	.51**0**	0.68
the speed of the foot of the leg kick/ m/s	15.75	21.40	18.59	1.78	0.08
ball speed/ m/s	16.9	23.6	20.79	2.12	-0.31
the knee angular speed at the kicking moment/ º/s	237	449	348.3	67.8	-0.07
the ball release angle/ º	15	26	19.33	3.31	1.05
the angle of the knee of the leg at the ball touch moment/º	130	149	138.3	7.07	0.65
the trunk angle at the kick ball moment/º	155	169	163.3	5.74	-0.62
maximum horizontal displacement of the foot kick leg/ m	0.97	1.31	1.11	.09**0**	0.64
the level of kick accuracy%	47	76	59.2	10.40	0.18

In order to process the sample data, the researchers used means, standard deviations, skewness, t-test and the correlation coefficient.

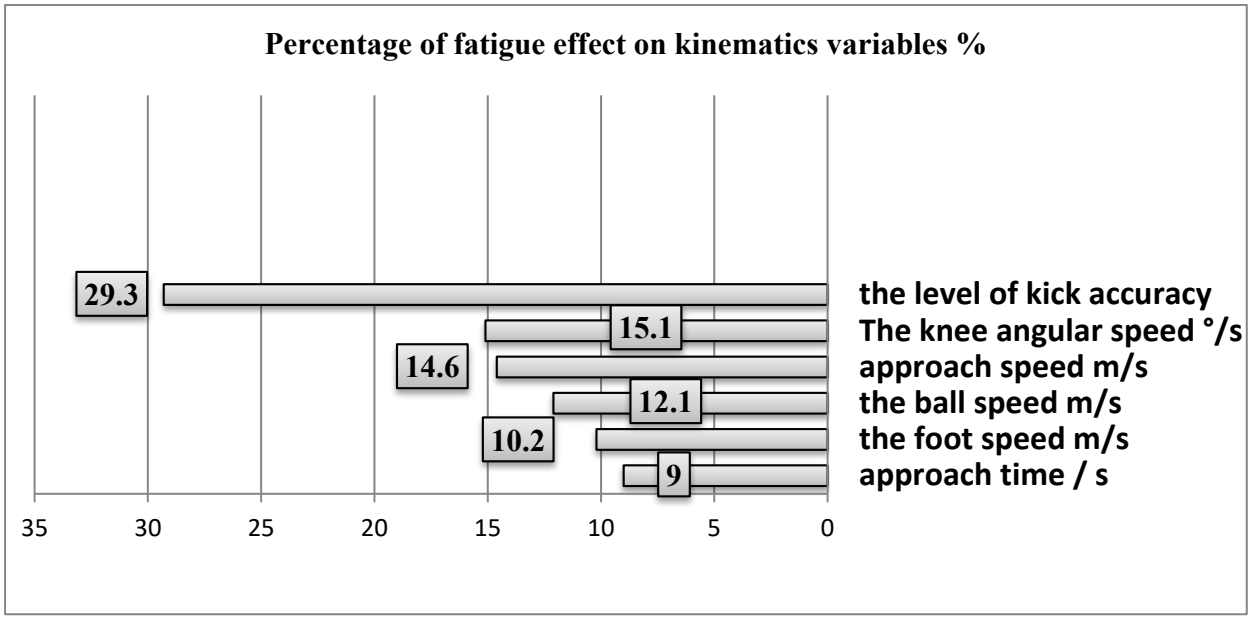
Results

As shown in Table 3 and Figure 3, the more kinematics variables under study are affected by the fatigue protocol.

Table 3. Effect of the fatigue protocol on kinematics variables

Variables	Differences between the means	Percentage variance %
approach distance/ m	0.06	8
approach time / s	0.06-	9
approach speed/ m/s	0.39	14.6
the speed of the foot of the leg kick/ m/s	1.91	10.2
ball speed/ m/s	2.52	12.1
The knee angular speed at the kicking moment/ °/s	52.7	15.1
the ball release angle/ °	0.11-	0.05
the angle of the knee of the leg at the ball touch moment/°	4.11	0.30
the trunk angle at the kick ball moment/°	4.00	0.25
maximum horizontal displacement of the foot kick leg/ m	0.10	0.90
the level of kick accuracy%	17.4	29.3

Figure 3. Percentage of fatigue effect on kinematics variables



In order to verify the effect of the fatigue protocol on correlative relationships between kinetic variables, the researchers applied the Pearson correlation coefficient on these variables pre and post the application of the fatigue protocol. The following tables show the correlation coefficients between the kinetic variables under study (Tables 4, 5)

Table 4. The correlation matrix between the kinetic variables before fatigue protocol

Variables	D	T	SA	SF	SB	SN	AB	AN	AT	DH	AK
D	1	-0.04	0.74*	0.005	0.109	-0.17	0.71*	-0.36	-0.35	0.74*	0.24
T	-0.04	1	-0.66	-0.40	-0.37	-0.56	0.19	0.101	-0.38	0.095	-0.03
SA	0.74*	-0.66	1	0.33	0.35	0.27	0.37	-0.29	-0.12	0.503	0.267
SF	0.005	-0.40	0.33	1	0.97*	0.52	0.05	-0.23	0.15	0.50	0.58
SB	0.11	-0.36	0.35	0.97*	1	0.49	0.13	-0.30	0.22	0.60	0.58
SN	-0.17	-0.56	0.27	0.52	0.49	1	0.05	-0.36	0.51	-0.17	0.49
AB	0.71*	0.19	0.36	0.05	0.13	0.05	1	-0.24	-0.39	0.50	0.38
AN	-0.36	0.10	-0.28	-0.23	-0.30	-0.36	-0.24	1	-0.41	-0.29	-0.08
AT	-0.34	-0.38	-0.11	0.15	0.22	0.51	-0.39	-0.41	1	-0.28	0.04
DH	0.74*	0.09	0.50	0.50	0.60	-0.17	0.50	-0.29	-0.28	1	0.50
AK	0.24	-0.03	0.26	0.68*	0.58	0.69*	0.38	-0.08	0.04	0.50	1

* Correlation is significant at the 0.05 level

Table 5. The correlation matrix between the kinetic variables after fatigue protocol

Variables	D	T	SA	SF	SB	SN	AB	AN	AT	DH	AK
D	1	0.05	-0.64	0.54	0.36	0.20	0.63	0.35	-0.43	0.72*	0.18
T	0.05	1	-0.68*	0.43	0.37	0.04	0.45	0.59	-0.20	0.40	0.29
SA	-0.64	-0.68*	1	-0.68*	-0.320	-0.03	-0.64	-0.88*	0.23	-0.55	-0.21
SF	0.54	0.43	-.68	1	.80	0.16	0.73*	0.56	-0.07	0.76*	0.55
SB	0.36	0.37	-0.32	0.80*	1	0.48	0.54	0.12	-0.08	0.81*	0.58
SN	0.20	0.04	-0.03	0.16	0.48	1	-0.258	-0.27	-0.03	0.19	0.35
AB	0.63	0.45	-0.64	0.73*	0.54	-0.26	1	0.49	-0.50	0.84*	0.24
AN	0.35	0.59	-.88*	0.56	0.12	-0.27	0.49	1	0.09	0.24	-0.09
AT	-0.43	-0.20	0.23	-0.07	-0.08	-0.03	-0.50	0.09	1	-0.40	-0.07
DH	0.72	0.40	-0.55	0.76*	0.81*	0.19	0.84*	0.24	-0.40	1	0.52
AK	0.18	0.29	-0.21	0.55	0.58	0.35	0.24	-0.09	-0.07	0.52	1

* Correlation is significant at the 0.05 level.

Discussion

The conclusion of 74 penalty kick attempts indicated that the negatively affected fatigue protocol on the kinematics variables mean, where the speed of approaching 2.66 m/s to 2.27 m/s, was due to the impact of fatigue protocol on approaching distance and the approaching time variables; it is known that the speed of approaching is the result of dividing the approach distance on the approach time. Additionally, the knee angular velocity was affected, which decreased from 348.3 to 295.5°/s, with reference to this velocity associated with the maximum horizontal displacement of the foot kick and the knee angle of the leg kick at the ball kick moment and the time of foot movement to the ball kick, where we observe the lower leg knee angle from 138.3 to 134.2 °. Similarly, the means have indicated low foot and ball speed post the fatigue protocol application, where many studies suggest that fatigue leads to a decrease in the strength of the muscles which operate on the knee joint and this is related with the ball speed (Mizrahi et al., 2000; Ricardo et al., 2016; Hussain and Arshed, 2012). These negative effects may be due to the physiological changes caused by the high intensity which players are

exposed due to the high and immediate effort, changes in metabolism and to the decrease of neuromuscular conduction (Mohr et al., 2005; Ismail et al., 2010; Seyed et al., 2010). It should be noted that the success kicking factors depends on the maximum extension of the leg knee joint kicking, and shortening the radius of the leg kick, which aims to reduce the torque of inertia to increase the knee joint angular velocity. This indicates the emergence of differences in the kinematic variables mean to a decrease in the interest of the coaches in the implementation of the penalty kick after high-intensity training or after the completion of the training unit.

One of the most striking results is that the kick accuracy level is one of the more stressful variables, and by a percentage of 29.3%, due to the correlation between the accuracy level and all kinetic parameters which were affected by the fatigue protocol. In addition, accuracy is affected by the muscular nervous system and the compatibility and cognitive abilities among the players, where these abilities are negatively affected through a gradual reduction of the muscle strength, high lactate level in the blood and glycogen decrease in the muscles. Furthermore, the angular velocity variable was an effect of fatigue protocol at 15.1%. Here we can clarify that this variable is a summary of variables as maximum horizontal displacement of the foot kick leg, the angle of the knee at the ball touch moment and the time of the foot movement from the maximum range until the moment of contact with the ball. Also, the researchers found a difference in the number of attempts that achieved a score between 6 and9 with 24 kicks before the fatigue protocol and 15 kicks after the protocol, and a difference in the number of attempts that achieved (1-5) with 15 kicks before the protocol and 23 kicks after the protocol, noting the increase in the number of failed attempts after fatigue from 6 to 10.

By reviewing the relational relationships between the kinematics penalty variables, the researchers observed that there were 6 relational relationships before the application of the fatigue protocol, where the largest correlation coefficient was between the foot speed and the ball speed ($r = 0.94$) and consistent with the results of studies that indicated a strong correlation between foot speed and ball speed ($r = 0.94$) (Hussain and Arshed, 2012). Interestingly, the number of these relationships has risen after the fatigue protocol, which has reached 9 relational relationships. It was the largest correlation coefficient between the ball speed and the leg maximum horizontal displacement ($r= 0.81$). This confirms that fatigue indicates a decrease in the ability of the muscles to produce the energy or failure to maintain the strength resulting from continuous muscle contraction (Gandevia, 2000). The effect of fatigue is manifested by the negative effects on the maximum strength, and thus the power (Mohr et al., 2002). Also, the higher blood lactate and decreased muscle glycogen negatively affect neuromuscular conduction, which affects the player's coordinative abilities. Note that there is no correlation between kinematics variables and the penalty level accuracy after the fatigue protocol application.

Conclusions

To develop the abilities of the coaches and the training process, attention should be given to the details that may affect the performance. The results of this study indicated that the fatigue protocol negatively affects all the kinetic variables under study and this reflects the correlation between these variables. To keep up with these results, such as training the penalty kicks after the high intensity training, or after the completion of the training unit to the adaptation of the players with these loads so as not to adversely affect the accuracy of the penalty kick in the competitions, is the key to a win or loss in some competitions.

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