

<http://dx.doi.org/10.16926/sit.2023.02.03>

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The Effect of the Quadriceps Muscle Fatigue After an ISOTONIC Contraction on Some Kinematic Variables and the Accuracy of Soccer Players' Performance of the Corner Kick

How to cite [jak cytować]: Alkhawaldeh I. (2023): *The Effect of the Quadriceps Muscle Fatigue After an ISOTONIC Contraction on Some Kinematic Variables and the Accuracy of Soccer Players' Performance of the Corner Kick*. Sport i Turystyka. Środkowoeuropejskie Czasopismo Naukowe, vol. 6, no. 2, pp. 47–58.

Wpływ zmęczenia mięśnia czworogłowego uda po skurczu izotonicznym na niektóre zmienne kinematyczne i dokładność wykonania rzutów różnych przez piłkarzy

Streszczenie

Zmęczenie mięśni jest przyczyną niskich umiejętności piłkarzy, dlatego w tym badaniu starano się ustalić wpływ zmęczenia mięśnia czworogłowego, będącego wynikiem skurczu izotonicznego, na niektóre zmienne kinematyczne i dokładność wykonania rzutu różnego przez piłkarzy. Test dokładności rzutu różnego i ćwiczenia Leg Press przeprowadzono na próbie 8 międzynarodowych piłkarzy, a ich średnie to wiek: $26,8 \pm 2,3$ lat, wzrost: 174 ± 12 cm, masa: 71 ± 6 kg, wiek treningowy: $14,6 \pm 1,8$ roku. Wykonanie testu rzutu różnego zostało nagrane trzema kamerami i przy użyciu programu Kinovea do analizy kinematycznej. Wyniki wykazały negatywny wpływ zmęczenia mię-

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śnia czworogłowego po skurczu izotonicznym na zmienne kinematyczne i celność rzutu różnego. Wyniki badań pokazały konieczność podniesienia zdolności piłkarzy w zakresie wytrzymałości siły mięśniowej w mięśniu czworogłowym w jak największym stopniu ze względu na wpływ tego elementu na umiejętność wykonania, w tym dokładność rzutu różnego.

Słowa kluczowe: zmęczenie mięśni, skurcz izotoniczny, rzut różny, zmienne kinematyczne, dokładność.

Abstract

Fatigue in muscles is a reason for the low skill performance of soccer players so this study sought to find out the effect of the quadriceps muscle fatigue resulting from an isotonic contraction on some kinematic variables and the accuracy of soccer players' execution of the corner kick. A test for the accuracy of the corner kick and the leg press exercise was used on a sample of 8 international soccer players, and their means were as follows: age: 26.8 ± 2.3 years, height: 174 ± 12 cm, mass: 71 ± 6 kg, training age: 14.6 ± 1.8 years. The performance of the corner kick test was videotaped by three cameras and Kinovea program for kinematic analysis was used. The results showed a negative effect of the quadriceps muscle fatigue after isotonic contractions on kinematic variables and on the accuracy of corner kicks. The study results point to the necessity of enhancing the ability of soccer players in terms of endurance of muscle strength in the quadriceps muscle to the highest possible extent due to the importance of that element in their skillful performance, including the accuracy of the implementation of corner kicks.

Key words: fatigue, isotonic, corner kick, kinematic, accuracy.

Introduction

Sports physiologists describe muscle fatigue as a sharp decrease in muscle strength resulting from performing exercises of high intensity, which reduces the efficiency of these muscles [15]. It can also be said that muscle fatigue is a decrease in the strength or accuracy of performance resulting from the lack of the muscle's ability to produce the energy needed for the muscle's work based on this performance, as this fatigue can be central in the brain and spinal cord or peripherally connected to the nerves and muscles involved in physical activity or responsible for the performance of a kinesthetic skill [16].

Where decentralized or topical fatigue leads to a change in neuromuscular compatibility and reduces the speed of nerve excitability to the working muscles, it also reduces the efficiency of the response of the working muscle to this nervous excitation [5].

Topical muscle fatigue occurs as a result of high or continuous mechanical resistance that the muscles work against, which leads to a kind of functional fatigue leading to several problems that reduce the efficiency of muscular work, the most important of which is energy metabolism within the muscle and thus reduce the contractile force of the muscle [8].

As for isotonic muscle contractions, they work to cause muscle contractions that cause a change in the length of the muscles during the succession of contractions, which leads to a change in the angle of the joint associated with these muscles, in light of the fact that the level of tension remains constant throughout the kinesthetic pathway [11].

Testing or training the muscles taking into account isotonic contractions is considered the largest operator of the working muscles and the kinesthetic units within them, as it increases muscle contractions through central and non-central contractions successively [12]. As studies have indicated, according to [17], isotonic contractions create a large muscle effort within the quadriceps femoris muscle and the biceps femoris in an appropriate manner that can be relied upon as an endurance test or exercise to develop endurance force or increase muscular strength.

It is worth noting that isotonic contractions, whether central or non-central, lead to an excitation that appears in the Magnetoencephalography (MEG) as a reflection of the nervous kinesthetic activity of the muscles under the influence of this contraction [18].

Soccer players suffer from local topical muscle fatigue the musculi extremitatis inferioris such as: vastus intermedius, vastus medialis, vastus lateralis, hamstring, rectus femoris and tensor fasciae latae. The study shall show to what extent it impacts the quality of the players' skillful performance, especially when performing the skills of passing or kicking balls, whether in fixed or moving positions [10].

As for the kinematic variables, they are considered an important factor in the success of passing the ball in terms of controlling the speed of the foot and thus controlling the speed of the ball and its direction, as the pelvic and knee angles work through the angular velocities of these joints to form a circumferential velocity of the kicking foot that moves to the ball. Thus, such variables cannot be ignored, especially when studying the accuracy of kicking the ball in a soccer game [2].

As for the corner kick skill, it is of great importance for match results. This fixed offensive position (fixed kick) contributes to determining 76% of match results. The corner kick is a mechanically closed skill that is subject to the complete control of the kicker, which means that the accuracy of his performance depends on internal factors. An accurate corner kick leads to a sound offensive position that increases the chances of scoring a goal [9].

What increases the importance of the accuracy of executing the corner kick is the fact that if it is executed incorrectly, the damage may not consist in the loss of an opportunity to score a goal, but may mean an opportunity to create a counter-attack for the opposing team, as a result of which the team that missed the corner kick may receive a goal [4].

Despite the foregoing importance of executing the corner kick, there are very few studies dealing with it from the mechanical point of view and the fatigue variable, as confirmed by (1), although this skill contributes to scoring goals for teams by 40%, as confirms [9].

Hence the importance of the current study, which sought to determine the effect of muscle fatigue in the quadriceps on some kinematic variables and the accuracy of executing the corner kick in the swinging style against the goal, which is the most frequently executed one among soccer players, as indicated by [14].

The Leg Press exercise was chosen as a safe exercise, especially in the case of using medium or below maximum intensity, as is the case in this study, which used an intensity of 10 RM. This exercise also works through isotonic muscle contractions, and thus it is similar to the feet muscle contractions movement of the soccer player during the match [11].

Study Objectives

1. Determining the effect of lower limb muscle fatigue after an isotonic contraction on some kinematic variables and the accuracy of football players' performance of the corner kick.
2. The extent to which the kinematic variables under study related to the accuracy of the corner kick performance before and after the fatigue of the muscles of the lower extremities after an isotonic contraction.

Hypotheses

1. The fatigue of the quadriceps muscle after an isotonic contraction has a negative, statistically significant effect at the significance level ($\alpha = 0.05$) on some kinematic variables and the accuracy of soccer players' corner kick performance.
2. There is a statistically significant correlation between the significance level ($\alpha = 0.05$) of the kinematic variables under study and an accurately performed corner kick before and after the quadriceps muscle fatigue after an isotonic contraction.

Method and Procedures

This study was conducted with the use of the test and re-test method on a sample of 8 international soccer players who are specialists in the corner kick.

Their means were as follows: age: 26.8 ± 2.3 years, height: 174 ± 12 cm, mass: 71 ± 6 kg, training age: 14.6 ± 1.8 years, and they were fully aware of the study procedures. The corner kick accuracy test was applied to them, then they were subjected to an isotonic contraction experienced in the quadriceps muscle, followed by the corner kick accuracy re-test, where the performance of the corner kick was filmed.

Corner Kick Test

1. After a warm up, the players were asked to perform a corner kick in the opposite direction of the goal swing. They had 5 attempts at their disposal.
2. The test area consisted of 3 circles inside each other. The penalty point is the central circle.
3. The area of the circles was as follows:
 - A small circle has a radius of 1.5 m.
 - A middle circle has a radius of 3 m.
 - A large circle has a radius of 4.5 m.
 - The ball that falls into the small circle has 3 points, the medium one has two points, and the largest one gets one point. The circumference of each circle is considered subordinate to it in terms of points.
 - The ball that does not touch the circles has no points.

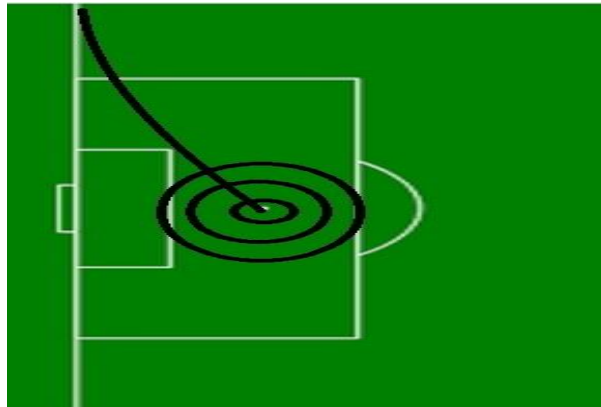


Figure 1. The corner kick test area

Isotonic contraction

A test was applied to ensure that the players experience the quadriceps fatigue as a result of an isotonic contraction. It is safe and sound to conduct this

type of test [17] on all the players, after some warm-up, applying the leg press exercise of ten repetitions, with a performance intensity of 10 RM. The amount of 1 RM for each player had been checked beforehand in their recent data, which is periodically collected in their clubs.

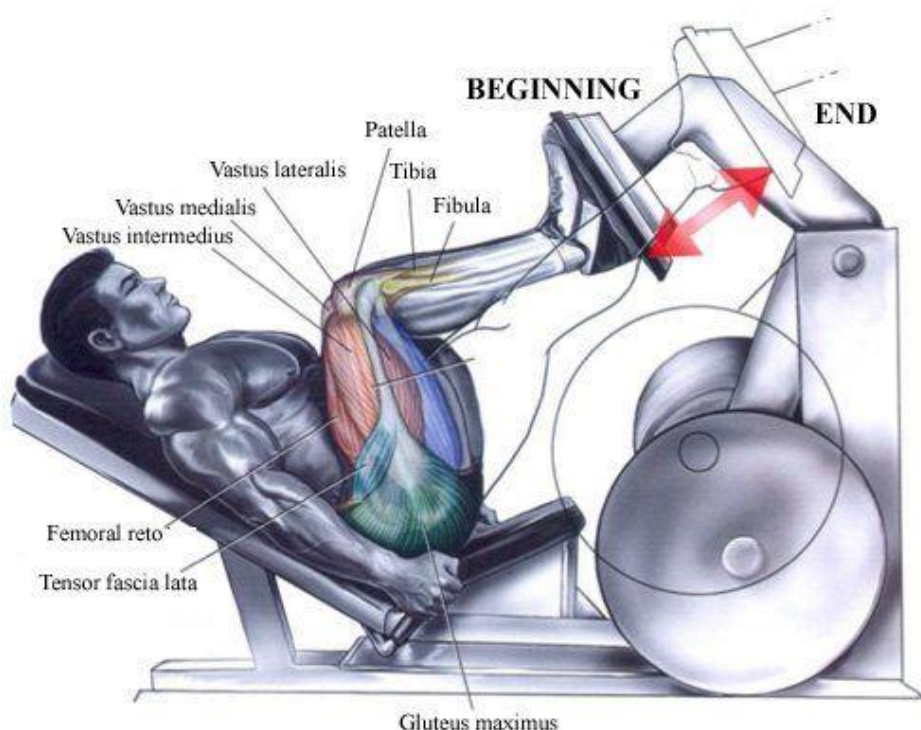


Figure 2. The Leg Press exercise used to reach fatigue [15]

Procedures

1. The first camera was placed on the right side axis to the player performing the corner kick to test the accuracy of the corner kick, at a distance of 4.15 m and a height of 0.96 m.
2. The second camera was placed next to the first one, as it moved away from it at a distance of 4.5 m, and a height of 1.26 m.
3. The third camera was placed in the middle of the goal line, directed towards the test circles.
4. The cameras were Canon EOS 80 D – speed of 500 images/second.
5. The images were analyzed using Kinovea 0.9.5 software.
6. Stalker Sport 2 Radar.

Results

H01 results

Table 1. The Wilcoxon test estimating the significance of the effect of quadriceps fatigue after an isotonic contraction on some kinematic variables and the accuracy (n = 8)

Kinematic Variables	Before Fatigue		After Fatigue		Difference Test	
	Mean	SD	Mean	SD	Z	Significance Level
Knee Extension	156.18	1.61	128.70	11.59	-2.521	0.012
Hip flexion	265.60	2.86	228.20	20.64	-2.521	0.012
Ball Angle	25.18	1.82	16.98	1.61	-2.533	0.011
Max. Ball Height	3.16	0.03	2.06	0.24	-2.521	0.012
Ball Speed	21.78	2.01	15.90	1.68	-2.524	0.012
Ball Flight Time	2.47	0.09	1.72	0.15	-2.521	0.012
Knee Angular Velocity	1281.60	2.70	861.80	78.54	-2.521	0.012
Accuracy of 15	13.63	0.92	7.38	0.92	-2.565	0.010

The results of the Wilcoxon test explain the significance effect of quadriceps fatigue after an isotonic contraction on some kinematic variables and the accuracy of the corner kick. By reviewing the Z-test significance level values calculated between the two measurements before and after fatigue for the knee extension variable, it was found out that it reached the value of 0.012. The average difference in the order of the knee extension variable before and after muscle fatigue of the lower extremities reached the value of 0.012. The value of the significance level of the average difference in the ranks of the ball launch angle variable was 0.012. It was also reached for the variable of the maximum ball height (0.012). It amounted to 0.012 for the ball velocity variable as well. Likewise, it reached the value of 0.012 for the ball flight time variable. The value of the knee angular velocity variable was 0.012. As for the accuracy variable, the value of the significance level of the difference between the average ranks of this variable was 0.010.

As for the accuracy result, it turns out that it was affected by muscle fatigue, as its value decreased, i.e. the value of the mean became 7.38 degrees in comparison to 13.63 degrees when free of muscle fatigue.

While comparing the above values of the significance level with the value of 0.05, it becomes clear that the calculated values were the lowest, which means that there are statistically significant differences in the kinematic variables before and after muscle fatigue.

H02 results

Table 2. The relationship of kinematic variables to corner kick accuracy before and after quadriceps muscle fatigue (n = 8)

Relationship Direction	Before Fatigue		After Fatigue	
	Relationship Value	Significance Level	Relationship Value	Significance Level
Knee Extension Accuracy	0.045	0.045	-0.295	0.477
Hip flexion Accuracy	0.472	0.047	-0.485	0.223
Ball Angle Accuracy	0.289	0.047	-0.211	0.66
Max. Ball Height Accuracy	0.533	0.040	0.204	0.627
Ball Speed Accuracy	0.173	0.041	-0.103	0.809
Ball Flight Time Accuracy	0.514	0.043	-0.077	0.856
Knee Angular Velocity Accuracy	0.089	0.044	0.281	0.500

The results from the table review the values of the relationships between the kinematic variables and the corner kick in soccer before and after the quadriceps muscle fatigue. We can note that all the values of these relationships investigated between the kinematic variables and the accuracy of the corner kick before muscle fatigue were statistically significant because the significance level values were less than 0.05.

Regarding the values of the relationships between the kinematic variables and the accuracy of the corner kick in soccer after muscle fatigue, they were negative (reverse), and all the values of the significance level of these relationships calculated between the kinematic variables and the accuracy of the corner kick were not statistically significant because the values of the significance level were greater than (0.05).

Discussion

The H01 results show us that the kinematic values before fatigue differed from those after fatigue, which resulted in a decrease in the performance accuracy value from 13.63 to 7.38. Furthermore, the kinematic variables addressed in the study are reflected as an integrated model on the final skill output (kinematic foot), which here is the accuracy of executing the corner kick, and this is something that is considered logical, so changing the values of the kinematic variables resulted in a difference in accuracy.

The numerical values demonstrate that the knee extension decreased from 156.18 degrees to 128.70. That means that the skillful performance lost its kinetic dynamics on an angular path of 27.48 degrees as one of the most im-

portant variables related to the amount of torque is the angle between the center of force (the muscles of the leg front) and the length (of the leg) [7]. We also notice a decrease in the angular velocity of the knee from 1281.60 degrees per second to 861.80, i.e. the time of knee extension became longer and this change in the angular velocity resulted in a decrease in the speed of the foot and thus a decrease in the speed of the ball, namely from 21.78 m/s to 15.90 m/s. Thus, this led to a decrease in the ball's arc and its flight time, and the ball did not reach the most accurate place according to the study's test, as physically the ball in the corner kick is considered a projectile subject to the laws of ballistics. The decrease in the exit angle of the ball with the decrease in its speed reduces the maximum height that the ball can reach. Therefore, here we find a decrease in the maximum height of the ball, which was 3.16 m before fatigue and decreased to 2.06 m after fatigue. According to [13], every skill performance has appropriate values. The height of the ball in kicks or passes may not need to reach the maximum height, but it must fit the nature of the skill and the goal skill serves to deliver the ball to the test area.

As for the H02 results, we found out that the kinematic variables persisted in their relationship with the accuracy of executing the corner kick before the occurrence of *musculi extremitatis inferioris* fatigue, but after fatigue this relationship disappeared, and this result agrees with the result of the first hypothesis where the interruption of the relationship or its change between the skill and its kinematic variables related to its performance means a skill defect [3].

The corner kick is performed by the player resting on one foot with a lateral rotation of the pivot foot from the level of the pelvis, accompanied by moving the kicking foot from the back to the front in an angular path to the medial side, which is controlled by the thigh of the kicking foot with a bend in the knee joint that turns with the start of the kinesthetic path to an extension. The whole process is based on muscular work and is reflected in the kinematic variables that describe this movement physically, such as angles and angular velocities, and here fatigue in the driving force of this skill, i.e. the muscles, led to a defect in the performance system as a whole. The change in the kinematic performance variables reflected a drop in performance accuracy whose final mechanical goal is the corner kick played high and deep inside the penalty area.

Conclusion

The negative impact of the fatigue of the quadriceps muscle after an isotonic contraction on the players' performance means a decrease in the players' ability constituting an important physical component for soccer players, i.e. the endurance of force in the muscles of the lower extremity. This means that the repeti-

tion of the players' muscular performance at a level below its maximum intensity leads to a decrease in the quality of their technical performance, especially with regards to such an important skill like executing the corner kick, which requires accuracy, especially when the penalty area is crowded with defensive players. It is valid to improve the ability of soccer players in terms muscle strength endurance in the quadriceps muscle to the highest possible extent and to continue the endurance and strength training of the quadriceps muscle throughout the season, both during the preparatory and the competition period.

This can be achieved through the development of training programs for muscular strength endurance so that the training load is formed in them in terms of training intensity and training volume in a way that improves the ability of the neuromuscular system to repeat muscular contractions without reaching fatigue affecting young players', young people' and even adults' performance.

It should also be noted that tests measuring the quality of the skill performance of players under different conditions such as fatigue or low mental focus should take into account their mechanical performance variables. The importance of these studies lies in giving the technical managers and team coaches valid information on the players' physical and mental condition before they enter the competition zone.

STATEMENT OF ETHICS

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and approved by the *Medical Scientific Research Ethics Committee, Mutah University, (7 MARCH 2022, ALKARAK, JORDAN)*. All participants provided written informed consent to participate in this study

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interests with respect to the research, authorship, and/or publication of the article *The Effect of the Quadriceps Muscle Fatigue After an ISOTONIC Contraction on Some Kinematic Variables and the Accuracy of Soccer Players' Performance of the Corner Kick*.

FUNDING

The author received no financial support for the research, authorship, and/or publication of the article *The Effect of the Quadriceps Muscle Fatigue After an ISOTONIC Contraction on Some Kinematic Variables and the Accuracy of Soccer Players' Performance of the Corner Kick*.

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