Jambura Health and Sport Journal
Vol. 6, No. 2 Agustus 2024
p-ISSN: 2654-718X, e-ISSN: 2656-2863

PENGARUH KELELAHAN AEROBIK TERHADAP KINEMATIKA GERAKAN *LANDING* PADA ATLET SEPAK BOLA

THE EFFECT OF AEROBIC FATIGUE ON LANDING MOVEMENT KINEMATICS IN SOCCER ATHLETES

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ABSTRAK

Sepak bola merupakan salah satu jenis olahraga yang paling digemari saat ini dan menjadi tempat kompetisi baik tingkat regional maupun internasional di dunia. Kelelahan aerobik sering kali mempengaruhi performa teknis pemain, yang dapat berujung pada peningkatan risiko cedera. Penelitian ini bertujuan untuk menganalisis pengaruh kelelahan aerobik terhadap kinematika gerakan *landing* pada atlet Sepak bola. Metode yang digunakan dalam penelitian ini adalah kuantitatif dengan pendekatan deskriptif, melibatkan 12 atlet laki-laki dari Unit Kegiatan Mahasiswa (UKM) Sepak bola Universitas Pendidikan Indonesia. Instumen pada penelitian ini yaitu alat pengukur kadar asam laktat, *treadmill* (*bruce test*) tes *landing*, kamera, perangkat lunak Kinovea versi 0.9.4 dan SPSS versi 26.0. Parameter yang diamati pada penelitian ini mencakup sudut *knee* kanan dan kiri, sudut *plantar* kanan dan kiri. Hasil test menunjukan terdapat perbedaan yang signifikan sebelum dan sesudah kelelahan pada beberapa parameter yang di ukur: kadar asam laktat sig 0,000 > 0,005; sudut *knee* kanan 0,000 > 0,05; sudut *knee* kiri 0,000> 0,05; *plantar* kanan 0,000 > 0,05; sudut plantar kiri 0,000 > 0,05. Berdasarkan analisis data dan teori pembahasan, dapat disimpulkan dalam sudut-sudut sendi, seperti lutut dan pergelangan kaki, sebelum dan sesudah kelelahan aerobik. Hasil ini mengindikasikan bahwa kelelahan aerobik dapat mempengaruhi teknik *landing*, yang berpotensi meningkatkan resiko cedera.

Kata Kunci: kelelahan aerobik; kinematika; *landing;* Sepak bola

ABSTRACT

Soccer is one of the most popular sports today and is a place for both regional and international competitions in the world. Aerobic fatigue often affects the technical performance of players, which can lead to an increased risk of injury. This study aims to analyze the effect of aerobic fatigue on the kinematics of landing movements in soccer athletes. The method used in this study is quantitative with a descriptive approach, involving 12 male athletes from the Student Activity Unit (UKM) Soccer, Universitas Pendidikan Indonesia. The instruments in this

Diterima : 02 Agustus 2024
Disetujui : 15 Agustus 2024
Tersedia Secara *Online* 15 Agustus 2024

study were a lactic acid meter, treadmill (bruce test) landing test, camera, Kinovea software version 0.9.4 and SPSS version 26.0. The parameters observed in this study included the right and left knee angles, right and left plantar angles. The test results showed significant differences before and after fatigue in several parameters measured: lactic acid levels sig 0.000> 0.005; right knee angle 0.000> 0.05; left knee angle 0.000> 0.05; right plantar 0.000> 0.05; left plantar angle 0.000> 0.05. Based on data analysis and discussion theory, it can be concluded in the angles of joints, such as the knee and ankle, before and after aerobic fatigue. These results indicate that aerobic fatigue can affect landing technique, which has the potential to increase the risk of injury.

Keywords: *aerobic fatigue; kinematics; landing; Soccer*

Introduction

Soccer is one of the most popular sports today and is a place for regional and international competitions in the descriptive world (Hidayat et al., 2019). In addition, soccer also requires high physical, technical, and tactical skills (Qader et al., 2017)**.** In soccer matches, players often make various movements such as high-intensity acceleration, deceleration, sudden changes in direction, jumps, and other movements related to soccer (Mappaompo, 2024). n addition, players also often experience injuries when using one leg to stop and make cutting movements while running, while the other leg is used to kick or tackle the ball (Sofyan et al., 2023).

Injuries in soccer can also occur due to sudden changes in speed without impact, unexpected rapid movements, and exposure to high loads when maintaining knee joint stability in sudden movements (Hewett et al., 2005). One of the injuries in soccer is the ACL. This injury generally occurs in sports that involve zigzag movements, changes in direction of movement, and sudden changes in speed (acceleration-deceleration) (Ikhwan Zein, 2015). The incidence rate of ACL injuries per year is 68.6 per 100,000 people (Sanders et al., 2016). In addition to ACL injuries, there are cases of injuries during the game, namely lower extremity injuries, one of which is the ankle (Yuliza et al., 2022). Ankle injuries are injuries to the ankle that occur due to ligament ties, namely the tendons that bind the bones experiencing excessive stretching or tearing (Presdenta, 2022) Cases of ankle injuries are 75 percent ankle sprains. Ankle sprains often occur due to overstretching of the lateral ankle ligament complex as a result of sudden inversion and plantarflexion movements of the ankle due to the position of the foot not supporting or stepping perfectly on an uneven floor surface according to (Kisner dan Colby, 2012) in (Saputro et al., 2022). Ankle sprains can occur in athletes when they are training, competing, or after competing according to (O'Connor et al., 2004; Faruhasa, 2020).

Aerobics is a form of physical exercise that requires oxygen in its production process to produce the energy needed by the body. Aerobic exercise involves moderate to high intensity activities carried out over a long period of time. The goal of aerobic exercise is to increase the efficiency of the cardiovascular and respiratory systems, strengthen muscles, and increase endurance (Modric et al., 2021). One of the aerobic tests is using the Bruce test which is carried out on a treadmill to cause aerobic fatigue in soccer players Because soccer is a type of sport that requires speed and muscle strength, especially leg muscles. The movements in this game

often change every 5-6 seconds and can involve up to 40-60 times the change in running speed. As a result, many athletes in Indonesia often experience fatigue during matches (Hasanah, 2015). Fatigue in soccer can be categorized into two types. Physical fatigue is related to neuromuscular and metabolic aspects, such as muscle fatigue caused by intense physical activity, which is often experienced by players during matches and training sessions. Then mental fatigue is also very important in soccer because of the high cognitive demands. Players must be able to stay focused, make decisions quickly, and maintain attention levels. Mental fatigue can have an impact on a player's decision-making ability, concentration, and overall performance (Haryanto et al., 2021; Pulungan et al., 2023).

One method to identify efficient and safe techniques is through the analysis of motion mechanics to determine the landing pattern technique. In research in the field of biomechanics, good mastery of movement skills can be achieved and function as a supporting factor in related sports. Motion mechanics analysis involves an in-depth study of how the body moves and functions during physical activity. Biomechanical research helps identify optimal movement patterns, reduce the risk of injury, and improve athlete performance. By understanding movement dynamics, researchers and coaches can develop more effective and safe training techniques, so that athletes can reach their peak abilities. Good mastery of movement skills also contributes to improving overall performance in the sport, ensuring that the techniques used are not only efficient but also protect athletes from long-term injuries (Nugroho & Doewes, 2023). Sports biomechanics is a field of study that examines sports performance quantitatively, and sometimes qualitatively, especially in relation to the kinematics and kinetics of sports movements (Taborri et al., 2020). n conclusion, good mastery of movement skills is a crucial factor in improving overall athlete performance and preventing long-term injuries. The field of sports biomechanics supports this by analyzing sports movements in detail, both in terms of kinematics and kinetics, to ensure that the techniques used are not only efficient but also safe for the athlete. Through this scientific approach, sports biomechanics helps in optimizing athlete performance by minimizing the risk of injury and increasing the effectiveness of movement techniques.

Thus, this study aims to identify the effect of aerobic fatigue on landing movements through a kinematic approach. The purpose of this study is to determine whether aerobic fatigue affects the landing movement of soccer players, as measured using Kinovea software and skill spector. This study will involve evaluating the landing movements of soccer players before and after they experience aerobic fatigue.

Method

This study uses a quantitative method with an approach. The subjects of this study were athletes from the Student Activity Unit (UKM) Soccer, Universitas Pendidikan Indonesia. Sampling was carried out using the purposive sampling method, which means that the sample was selected based on certain considerations in accordance with the objectives of the study. This study was conducted at the Universitas Pendidikan Indonesia Laboratory involving 12 male

athletes as samples. The subjects were tested by conducting aerobic endurance tests and landing tests on soccer players, both before and after experiencing fatigue. The purpose of this test is to analyze the biomechanics of landing movement techniques. Video data collection was carried out using three cameras to analyze movement. The software used in this study is Kinovea version 0.9.4 and skill spector, the Kinovea application can help analyze variations in two-dimensional movements, then skill spector can help create animations and movement trajectories by reconstructing 3D coordinates from 2D videos. Kinovea and skill spector software are suitable for use in this study because they are able to support the implementation of biomechanical analysis of landing movements before and after fatigue.

Table 1. Anthropometric Data

No	Body Weight/kg	Height/cm	Fat(%)	BMI(kg/m2)
1	63,2	165	18,6	23,2
2	60,8	171	15,6	20,8
3	59,5	169	13,9	20,8
4	65	178	11,6	20,5
5	63,5	168	18,8	22,5
6	63,3	167	21,5	22,7
7	56,7	169	23	19,9
8	55,9	169	12,8	19,6
9	67	165	22	24,7
10	73,2	165	20,2	26,9
11	61	174	12,7	20,1
12	59,1	168	20,3	20,8

The data collection procedure begins with; (1) Carrying out anthropometric measurements on samples consisting of height, weight, fat content and BMI, (2) Then checking the lactic acid levels (mmol) in the blood before testing, the method used is by taking samples through the sample's fingertips, (3) then the athlete warms up, (4) After that the athlete calibrates, (5) Then the athlete does an initial landing test before being given the Bruce test treatment, (6) After doing the initial test, the athlete does the Bruce test treatment (treadmill), (7) then the athlete checks the blood lactic acid levels after being given the Bruce test treatment, (8) After that, the athlete takes the landing data again. To test normality and hypothesis, then to compare the results of the data to be processed, namely using SPSS version 26.0. Then the comparison test uses the Paired T Test to determine the differences related to fatigue parameters. Data on fatigue is obtained through the Bruce test (treadmill) to measure aerobic capacity, and lactic acid measurements are carried out as part of the data collection.

Results

Based on the data depicted in the table, it shows that there is a difference in lactic acid levels before and after fatigue with a sig value of 0.00 <0.05.

Table 2. Lactic Acid Table Before Fatigue and After Fatigue

Variable	Average Before± SD	Average After ± SD	Significance (Difference)
Lactic Acid (mmol/L)	1,5 ± 0,5	11,7 ± 2,5	0,000*

It can be seen from the table, the results of the data show that there is no difference in the right hip angle before fatigue and after fatigue, with degrees in the hip joint angle with a sig value of 0.400 > 0.05. In the right knee phase, there is a difference in the degree of the knee joint angle before fatigue and after fatigue, with a sig value of 0.000 < 0.05. The last phase, right plantar, there is a difference in the degree of the ankle joint angle, with a sig value of 0.000 < 0.05.

Table 3. Right Angle Data Before and After Test

Variabels	Avarage Before ± SD	Avarage After ± SD	Significance (Difference)
Right hip (Degree/º)	64,2 ± 8,1	62,0 ± 9,5	0,400
Right knee (Degree/º)	125,4 ± 6,7	109.9 ± 6,2	0,000*
Right plantar (Degree/º)	87,5 ± 7	81.3 ± 1,4	0,000*

From the data results in the table, it shows that there is no difference in the left hip angle before fatigue and after fatigue at the hip joint angle with a sig value of 0. > 0.05. Then in the left knee phase before fatigue and after fatigue there is a difference in the degree of the knee joint angle with a sig value of 0.000 <0.05, and in the left foot plantar phase before fatigue and after fatigue there is a difference in the sig value of 0.000 <0.05.

Table 4. Left Corner Data Before and After Test

Variabels	Avarage Before ± SD	Avarage After ± SD	Significance (Difference)
Right hip (Degree/º)	109,9 ± 18,1	122.2 ± 16,1	0,082
Right knee (Degree/º)	122,3 ± 10,8	110,2 ± 5,2	0,000*
Right plantar (Degree/º)	84,2 ± 2.0	77,5 ± 18,2	0,000*

From the data results in the table, it shows that there is no difference in the right front knee angle before fatigue and after fatigue with a significance value of 0.338 > 0.005. Then in the left front knee angle there is no difference in the corner point, with a significance value of 0.220 > 0.005.

Tabel 5. Data Kedua Kaki *Landing* Depan

Variabels	Avarage Before ± SD	Avarage After ± SD	Significance (Difference)
Right hip (Degree/º)	-0,13 ± 0.13	-0,22 ± 0,17	0,338
Right knee (Degree/º)	0,24 ± 0,08	0,17 ± 0,21	0,220

Discussion

The results of this study indicate differences in landing movement techniques before and after experiencing aerobic fatigue. Kinematic parameters, there are four parameters analyzed: the right knee angle when landing, the left lat angle when landing, the right and left plantar when landing, there are differences in the knee angle and ankle angle.

During the landing phase of the right leg, there is a decrease in the angle. Before fatigue, the average right knee angle was 125.4 degrees, while after fatigue, the average angle dropped to 109.9 degrees. The left knee also experienced a decrease in degrees, with an average of 122.3 degrees before fatigue. After fatigue, the average angle dropped to 110.2 degrees. While in the front landing knee angle phase using two legs simultaneously there was no significant decrease in the degree angle. Fatigue increases susceptibility to non-contact ACL injuries by reducing the body's ability to maintain control and stability during physical activity (Tamura et al., 2016). Muscle fatigue can also negatively impact physical performance and safety, especially in joints such as the knee that rely heavily on muscle strength and coordination for stability and proper function.

Cardiovascular fatigue can result in decreased muscle strength. When the body experiences fatigue due to intense aerobic activity, the muscles may not be able to contract with maximum force, which can affect performance in physical activities that require strength (Colosio et al., 2020). Then in the landing movement phase in the right plantar angle, there was a decrease in the angle before fatigue, with an average angle of 87.5 degrees. Then when experiencing fatigue, the average angle dropped to 81.3 degrees. In the left plantar angle, there was also a decrease in the average angle before fatigue of 84.2 degrees. In the left plantar phase after fatigue, there was a decrease in the angle of 77.5 degrees. This decrease occurs at the center of gravity in the middle of the foot when the athlete sprints. With a lower and more stable center of gravity, pressure on the joints and muscles is reduced, so the risk of injury is also reduced. The knee and ankle, which are prone to injury during sprinting, receive better support from the surrounding muscles and structures (Hawrylak et al., 2021). The impact of plantar fatigue occurs when athletes sprint, resulting in ankle adduction, which refers to the movement of a body part toward the midline of the body, and plantar flexion, which means the ankle bends downward so that the sole of the foot points toward the ground. These movements are important in various physical activities, including sports, because they affect the stability and efficiency of the athlete's movements.

Conclusion

The results of this study indicate that aerobic fatigue has a significant impact on the kinematics of landing movements in soccer athletes, with significant changes in the knee and ankle joint angles before and after fatigue. Through biomechanical analysis, optimal movement patterns are identified to reduce the risk of injury and improve athlete performance. Thus, the results of this study provide insight for coaches and athletes to develop more effective strategies in managing fatigue and maintaining the quality of landing movements. This study provides an

important contribution to understanding the relationship between aerobic fatigue and technical performance in soccer, as well as a basis for developing better training programs.

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