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Correlation of core stabilization, respiratory functions and injury risk in football referees living in Bolu province, Turkey

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Abstract. The aim of this study was to investigate the correlation between core stabilization, respiratory functions and risk of injury of football referees working in Bolu province in Turkey. *Material and Method.* Active referees living in Bolu province were invited to participate in this study. Demographic data and physical characteristics of participants were gathered. International Physical Activity Questionnaire-Short Form was used. Respiratory functions, core stabilization, running performances, and risk of injury were evaluated by using spirometer, Pressure Biofeedback Unit, Playertek Global Positioning System and Functional Movement Screening, respectively. *Results.* Thirty four referees whose mean age was 21.1±3.8 years participated in this study. Significant relationships were found between core stabilization and respiratory functions ($0.348<r<0.587$, $p<0.05$), risk of injury ($0.344<r<0.696$, $p<0.05$), running performances ($0.348<r<0.548$, $p<0.05$). There was a relationship between running performances and respiratory functions ($0.356<r<0.511$, $p<0.05$) and risk of injury ($0.342<r<0.548$, $p<0.05$). As a result of regression analysis, the factors affecting the risk of injury was determined as left lateral flexion-repeat test ($p<0.05$). The factors affecting the running performances was determined as Functional Movement Screening score ($p=0.002$). *Conclusion.* Our findings showed that referees who had better core stabilization and higher respiratory functions performed increased running performance and reduced risk of injury. Therefore, informing referees about the factors affecting the risk of injury may have a positive effect on the field performance during football matches.
Keywords: *football referee, core stabilization, respiratory function, running performance, risk of injury, global positioning system.*

Introduction

Sport is the name given to individual and team actions that have been practiced within the framework of its own rules, existed in various forms throughout the history of humanity, and continued to develop by gaining a professional identity with the 20^{th} century (1). Football is the most popular sport all over the world. It maintains its attractiveness by keeping the level of excitement high, thanks to the fact that it is played on a wide field, with more players, and with positions that change frequently for ninety minutes (2). The developments in the football branch necessitated the existence of referees who would apply the rules of the game and provide justice. Just as the football players change their places during the match, the referees must follow the positions closely by showing physical performance and changing their places (3).

Referees with high responsibilities make an average of 2167 decisions in matches. This means 1.6 decisions per minute, 1 decision in 40 seconds. During the fast-paced match, the referees should be involved in the game physically and psychologically without losing their attention and authority (4, 5). Since 85% of the information about all movements in the field is obtained by seeing, referees must always take a position to see the rule violations and they have to use the diagonal by moving in the field in a way to get the game or the ball between them and his/her assistant referees (6, 7). In order to use the diagonal efficiently, the physical fitness, aerobic and anaerobic capacities of the referees must be sufficient. Today, despite the increasing speed of the game and the players, the referees have to run like an athlete in order not to miss any moment of the match, to be in the right position, to be at the right angle to make the right decision, and to dominate the field (8). It has been determined that the physical condition of the referees positively affects their match performance (9).

During the matches, running activities are carried out at varying tempos, distances and durations. It is seen that the referees move as walking, acceleration and fast running periods during the match (10). During a match, the referees cover 8-13 km and the assistant referees 5-5.5 km in runs at different tempos (11, 12).

In order to see all the positions in detail and to make the correct decisions regarding the position, referees must be in constant motion to reach every point of the field according to the speed of the ball and its location. These distances were found to be equivalent to the distances covered by the midfielder (13). When the referees' runs were divided into high-intensity (high-intensity, moderate-intensity runs) and low-intensity (jogging, walking, resting), it was observed that high-intensity activity was approximately twice as high. The referees, who have the chance to rest for only 3 seconds in every 2 minutes, perform a difficult task in terms of aerobic capacity. Only 2% of the distance they run is ball-related positions, and referees make an effort to create the diagonal for most of the match (14). The fact that the referees show these performances can enable them to be counted among the elite athletes (15).

Considering that referees must show vital capacity, muscular performance and endurance as in athletes, it should also be considered that they may be injured like athletes. More than 40% of referees reported disability, more than 60% of them had musculoskeletal problems at some point in their career (16). There are studies stating that a good stabilization of the core region can reduce the risk of injury in order to provide muscle balance in kinetic activities that require high effort (17-19).

In the light of this knowledge the aim of this study is to evaluate the physical parameters of referees such as running performance, muscular endurance, respiratory parameters, core stabilization and to examine their relationship with injury risk.

Material and Method

The permission of the Turkish Football Federation (TFF) was sought to carry out the study with referees. We have been informed that within the framework of the new rules of the federation, that we could only work with individuals who work as a referee on a provincial basis. For this reason, referees affiliated with the TFF from Bolu province and between the ages of 18-35 were invited to the study. The sample size of the study was found to be 34 as a result of the analysis performed with G*Power™ (20) when α was taken at $p<0.05$ and β at 80% power. Thirty eight referees working in Bolu province were interviewed; as 4 referees did not accept to participate in the research, 34 referees were included in the study.

Permission for the study was obtained from the Clinical Research Ethics Committee of Bolu Abant İzzet Baysal University with the decision dated 16/05/2018 and numbered 2017/207. Informed signed consent forms were obtained from the individuals included in the study.

Inclusion criteria. Being between the ages of 18-35, being an active football referee living in Bolu province of TFF, regularly participating in the weekly training programs determined by TFF. *Exclusion criteria.* Having any known respiratory system disease, not being able to take the positions required by clinical tests or not being able to understand and perform the tests, failing to perform the test in 8 attempts with the spirometer device during pulmonary function test.

After obtaining demographic information from the individuals participating in the study, they were asked to fill out the International Physical Activity Questionnaire-Short Form (IPAQ-SF). Then pulmonary function test (PFT) was performed. Clinical tests were applied to individuals who had adequate rest. Two-minute rest periods were applied between each clinical test. Functional movement screening (FMS) test battery was performed on a different day from these evaluations, and the running performances were evaluated with a Global Positioning System (GPS) device.

Demographic information. Data such as contact information, age, gender, height, weight, dominant side, educational status, whether they have any other occupation, past illnesses, operation and trauma history, daily sleep pattern, exercise frequency, weekly training time, weekly refereeing time, active total refereeing time were collected.

International Physical Activity Questionnaire-Short Form. The questionnaire consists of 7 questions. This test questions the frequency, severity and duration of physical activities performed in the last week. Sitting, walking, moderate and vigorous activities are calculated as MET (Metabolic Equivalent of Task). Individuals are classified as inactive, minimally active and very active in terms of physical activity by calculating MET-minute values according to the activities performed by the individuals. The Turkish validity and reliability study of the test was performed by Öztürk (21).

Pulmonary Function Test (PFT). Test was performed with the Cosmed Omnia microQuark 1.5 (*Cosmed, 2013, Italy*) spirometer device to determine lung volumes and capacities. Individuals who were informed about the measurement were asked not to smoke 24 hours before, not to drink alcohol 4 hours before, not to eat 2 hours before and not to exercise 30 minutes before the test. After recording the age, gender, height, weight and ethnicity information of the individuals, they were asked to take a sitting position. Their noses were closed with the help of clothespins and a cardboard mouthpiece was placed between their lips to prevent the passage of air from their mouths. A disposable mouthpiece was used for each individual. Test procedure was carried out with verbal stimuli for motivation. Individuals were asked to do the fastest and deepest inspiration possible after 3 normal breaths, and then to make a forced and rapid expiration for 6 seconds. The tests were repeated 3 times. FVC, FEV_1, PEF, FEF, and FVC/FEV_1 values were obtained (22).

Evaluation of deep lumbar muscle strength and endurance. Deep lumbar muscles were evaluated with Pressure Biofeedback Unit (PBU) (*Chattanooga Group, 2005, USA*). This device consists of a three-chamber air-filled pressure bag, a thin tube and a pressure gauge. When the movement or position changes, the indicator showing the 2 mmHg volume change in the pressure bag is monitored. This evaluation was done for the transversus abdominis and multifidus muscles. Individuals were first taught how to activate these muscles. The movement was perceived by making a corset analogy for the deep muscles. The perception of movement was reinforced in sitting, supine, and prone positions (23).

Core stabilization clinical tests. Static endurance of core muscles was measured with trunk flexion, trunk extension, plank, right and left lateral bridge tests, and dynamic endurance of core muscles was measured with right lateral flexion-repeat, left lateral flexion-repeat, sit-ups, push-ups tests. Measurements were recorded in seconds with a stopwatch (24-29).

Functional movement screening (FMS). It consists of 7 assessment tests: deep squat, step over obstacle, linear forward step, shoulder mobility, active straight leg raise, trunk stability push-up, and rotational stability. All movements were performed 3 times under the supervision of a physiotherapist. Each movement was scored between 0-3 and the FMS score was created. It was evaluated as 3 points if the movement was performed completely and correctly in the desired pattern, 2 points if it was performed with partial or compensatory movement, 1 point if it could not be completed, and 0 points if pain occurred at any moment. A FMS score of ≤ 14 means that the risk of injury is high (30).

Global Positioning System (GPS). In this research, Playertek GPS device, which was provided as part of the research project support of Bolu Abant Izzet Baysal University Scientific Research Project office, was used (Project No: 2018.14.01.1329). GPS systems have been shown to be valid and reliable devices for movement measurement in team sports (31). Playertek GPS device is an integrated GPS system with 3-axis 400 Hz accelerometer and 10 Hz magnetometer (32). Individuals wore a vest that was sold with the device, which did not prevent movement and breathing of the skin and was suitable for wearing the device. The device obtains the running parameters of the person via satellite connection. The data collection process of this device was planned to be done during the match. However, during the purchasing process of the device, FIFA (*Federation Internationale de Football Association*) announced its new rules and in parallel, TFF announced its new rules. In this context, referees and other field match officials are prohibited from wearing any equipment or jewelry, including cameras. Because of this rule, the running performances of the referees were evaluated not during the match, but during their weekly training. TFF collects 12-minute running performance data at the end and beginning of the seasons in order to monitor the physical conditions of the referees. For this reason, 12 minutes of running data were recorded during the training. The data was transferred to the Playertek Sync application on the internet and viewed on manufacturer's web site *www.go.playertek.com.*

Parameters such as sprint distance, top speed, power play, power score, work rate and load values that can be obtained from the GPS device were not included in the study since we could not obtain the real values of the referees running at different speeds and times during a match. Instead, we calculated the running time, distance and energy values of 40 meters in the 12 minute running.

Statistics Analysis. Individuals' data on demographic and physical variables were given as numbers and percentages for categorical variables, mean and standard deviation for continuous variables.

Relationships between continuous variables were calculated with Pearson's correlation analysis. Variables that were found to be statistically significant in the correlation analysis were used as independent variables in the regression analysis. SPSS 25.0 was used for data analysis and statistical tests were interpreted at $p<0.05$ and $p<0.01$ significance level. According to the results of the correlation analysis, when the r value is between 0.00-0.25, it is considered as a very weak relationship, between 0.26-0.49 as a weak relationship, between 0.50-0.69 as a medium relationship, between 0.70-0.89 as a high relationship, and between 0.90-1.00 as a very high relationship (33).

Results

All demographic data of 34 referees with a mean age of 21.1±3.8 years who participated in the study are summarized in Table I.

The mean values of our evaluation parameters are presented in Table IIa and Table IIb. No relationship was found between IPAQ-SF, which determines the level of physical activity, and any data (p>0.05). There was no relationship between pulmonary function tests and the risk of injury (p>0.05).

Table I. Demographic data of the sample

Variables		**Mean±SD** (n=34)
Age (year)		21.1±3.8
Height (cm)		175.6±6.2
Weight (kg)		68.9±9.4
Body mass index (kg/m^2)		22.3±2.4
Exercise frequency (days)		4.2±2.0
Sleep time (minutes)		441.2±71.4
Weekly training time (minutes)		502.9±364.2
Weekly refereeing time (minutes)		119.1±57.4
		n (%)
Gender	Male	30 (88.2)
	Female	4 (11.8)
Education	High school	15 (44.1)
	University	19 (55.9)
Occupation	Student	30 (88.2)
	Driver	1 (2.9)
	Teacher	1 (2.9)
	Officer	1 (2.9)
	Police officer	1 (2.9)
Dominant hand	Right	29 (85.3)
	Left	5 (14.7)
Trauma/operation	None	25 (73.5)
	Fracture	6 (17.6)
	Operation	3 (8.8)

SD: Standard deviation, n: number of participants, %: percentage

Table IIa. Mean values of outcome measurements

Variables	**Mean±SD**
IPAQ-SF (MET-min/week)	5713.59±3476.04
PBU multifidus pressure (mmHg)	12.47±3.75
PBU multifidus time (sec)	30.41±14.90
PBU transversus abdominis pressure (mmHg)	10.12±4.17
PBU transversus abdominis time (sec)	24.91±13.34
Trunk flexion test (sec)	71.65±32.48
Trunk extension (sec)	94.68±45.85
Right lateral bridge test (sec)	69.09±41.96
Left lateral bridge test (sec)	66.53±36.32
Plank test (sec)	116.91±47.45
Right lateral flexion-repeat test (number/minute)	47.18±18.42
Left lateral flexion-repeat test (number/minute)	47.09±18.25
Push-ups test (number/minute)	42.65±13.99
Sit-ups test (number/minute)	40.35±11.36

SD: Standard deviation, %: percentage, sec: seconds, mmHG: milimeters of mercury, IPAQ-SF: International physical activity questionnaire-short form, MET: metabolic equivalent of task, PBU: Pressure biofeedback unit.

Table II b. Mean values of outcome measurements

Variables	Mean±SD
FVC (L)	4.75±0.62
FEV_1 (L)	4.04±0.53
FEV_1/FVC (%)	85.30±7.72
PEF (L)	7.84±2.50
FEF (L)	4.45±1.01
Expected FVC (%)	94.97±8.82
Expected FEV_1 (%)	95.44±10.42
Expected FEV_1/FVC (%)	102.74±9.01
Expected PEF (%)	81.65±23,.3
Expected FEF (%)	90.56±1.63
FMS	18.24±1.63
Deep squat	2.68±0.58
Stepping over the obstacle	2.79±0.47
Linear step forward	2.71±0.46
Shoulder mobility	2.53±0.61
Active straight leg raise	2.62±0.49
Trunk stability push-up	2.79±0.41
Rotational stability	2.09±0.62
40 m running time (sec)	5.96±0.58
Distance (m)	2441.76±304.62
Energy (kcal)	374.11±491.33

SD: Standard deviation, %: percentage, sec: seconds, mmHG: milimeters of mercury, L: liter, m: meter, kcal: kilocalories, FMS: Functional movement screening.

Weak and moderate correlations were found between core stabilization values and respiratory parameters. A moderately positive and significant correlation was found between FVC and PBU multifidus pressure (r=0.587, p=0.001), left lateral bridge test (r=0.532, p=0.008), push-ups test (r=0.507, p=0.002). Between PBU multifidus time and FVC (r=0.401, p=0.035), PBU transversus abdominis pressure (r=0.375, p=0.043), right lateral bridge test (r=0.360, p=0.027), and sit-ups test (r= 0.425, p=0.025), a weakly positive and significant correlation was found. A weak positive and significant correlation was found between FEV1 and PBU multifidus pressure (r=0.385, p=0.024) and sit-ups test (r=0.370, p=0.031).

A weak negative and significant correlation was found between FEV1/FVC and PBU transversus abdominis pressure (r=-0.430, p=0.011) and PBU transversus abdominis time (r=-0.348, p=0.044). A weak positive and significant correlation was found between PEF and PBU multifidus pressure (r=0.392, p=0.022), push-ups test (r=0.407, p=0.017) and sit-ups test (r=0.476, p=0.004). A weak positive and significant correlation was found between expected PEF and sit-ups test (r=0.425, p=0.012). A weak negative and significant correlation was found between expected FEV1/FVC and PBU transversus abdominis pressure values (r=-0.394, p=0.021).

When the relationships between core stabilization and injury risk were examined, we found a moderately positive and significant correlation between FMS and PBU multifidus pressure (r=0.505, p=0.002), PBU transversus abdominis pressure (r=0.617, p=0.000), PBU transversus abdominis time (r=0.529, p=0.001), right lateral flexion-repeat (r=0.654, p=0.000) and left lateral flexion-repeat (r=0.696, p=0.000). There was a weak positive and significant correlation between FMS and PBU multifidus time (r=0.460, p=0.006), push-ups test (r=0.415, p=0.015) and sit-ups test (r=0.413, p=0.015).

When the relationships between core stabilization and running performance values were examined, a weak negative and significant correlation was found between 40 m running time and PBU multifidus pressure (r=-0.371, p=0.031), PBU transversus abdominis pressure (r=-0.348, p=0.044), right lateral flexion-repeat (r=-0.464, p=0.006) and left lateral flexion-repeat (r=-0.477, p=0.004). A moderately negative and significant correlation was found between 40 m running time and push-ups test (r=-0.541, p=0.01) and sit-ups test (r=-0.525, p=0.01). Between distance and PBU multifidus pressure (r=0.459, p=0.006), PBU multifidus time (r=0.485, p=0.004), PBU transversus abdominis pressure (r=0.462, p=0.006), PBU transversus abdominis time (r=0.420, p=0.013), right lateral flexion-repeat (r=0.446, p=0.008), left lateral flexion-repeat (r=0.453, p=0.007), and sit-ups test (r=0.348, p=0.044) were found to be weakly positive and significant. A weak positive and significant correlation was found between energy and trunk flexion test (r=0.374, p=0.029).

A moderately negative and significant correlation was found between 40 m running time and FEV1 (r=-0.511, p=0.002). A weak negative and significant correlation was found between 40 m running time and

FVC (r=-0.431, p=0.019) and PEF (r=-0.356, p=0.047). A weak negative and significant relationship was found between distance and FVC (r=-0.431, p=0.042).
When the injury risk and running parameters were examined, a weak negative and significant correlation was found between FMS score and 40 m running time (r=-0.342, p=0.012). A moderately positive and significant relationship was found between FMS score and distance (r=0.510, p=0.002). A moderately negative and significant relationship was found between linear forward stepping, one of the FMS sub-parameters, and 40 m running time (r=-0.548, p=0.001). A weak negative and significant correlation was found between the FMS sub-parameters, trunk stability push-ups and 40 m running time (r=-0.347, p=0.044). A weakly positive and significant relationship was found between trunk stability push-ups and distance, which is one of the FMS sub-parameters (r=0.400, p=0.019). A weak negative and significant correlation was found between rotation stability, another FMS sub-parameter, and 40 m running time (r=-0.372, p=0.030).
Examining Factors Affecting Injury Risk. Factors affecting the risk of injury were analyzed using a multivariate linear regression model. In this model, FMS was used as the dependent variable. In the correlation analysis, 40 m running time, distance, PBU multifidus pressure, PBU multifidus time, PBU transversus abdominis pressure, PBU transversus abdominis time, right lateral flexion-repeat test, left lateral flexion-repeat test, push-ups test and sit-ups test were found to be associated with FMS. These variables were also determined as independent variables in the regression analysis.
Since the number of data is less than the number of variables, significant ones among these independent variables were included in the model with the stepwise forward selection method, and the latest regression model parameters obtained to explain the injury risk are given in Table III.

Table III. Factors affecting injury risk (FMS test)

Independent variable	β	SH(β)	For β %95 CI	t	p^a
Left lateral flexion-repeat test	0,057	0,011	0,034-0,079	5,075	0,001

$^a H_0$: β=0 vs, H_a: for β≠0 t-test, Model R^2=0,519, β: Regression coefficient, Table values are given for 1 unit.

A statistically significant correlation was found between the risk of injury and left lateral flexion-repeat test. A mean increase of 10 points in the left lateral flexion-repeat score explains the 0.57 point decrease in the injury risk score (β=0.057, 95% CI: (0.034; 0.079), p=0.001).
Examining the Factors Affecting Running Performance. Factors affecting running performance were analyzed with a multivariate linear regression model. In this model, distance was used as the dependent variable. In the correlation analysis, the variables of FMS, trunk stabilization push-up, PBU multifidus pressure, PBU multifidus time, PBU transversus abdominis pressure, PBU transversus abdominis time, right lateral flexion-repeat, left lateral flexion-repeat, and sit-ups tests were also found to be associated with distance. They also were determined as independent variables in the regression analysis.
Since the number of data is less than the number of variables, significant ones from these independent variables were included in the model with the stepwise forward selection method, and the latest model obtained to explain running performance is given in Table IV.

Table IV. Factors affecting running performance (distance)

Independent variable	β	SH(β)	For β %95 CI	t	p^a
Functional Movement Screening (FMS)	95,17	28,34	34,45-152,89	3,358	0,002

$^a H_0$: β=0 vs, H_a: for β≠0 t-test, Model R^2=0,261, β: Regression coefficient, Table values were given for 1 unit.

A statistically significant relationship was found between running performance and injury risk (FMS). An average increase of 1 point in the FMS score explains the 95.17 meters of running distance (β=95.17, 95% CI: (34.45, 152.89), p=0.002).

Discussion

As a result of this study, it was found that referees with better core stabilization performed better respiratory functions. It was observed that high core stabilization endurance reduced the risk of injury. It was found that the data detected by the Playertek GPS device were affected by core stabilization.

Muscular and physiological endurance is required for adequate core stabilization. The contribution of the endurance values of the trunk muscles to the stabilization of the core is more valuable than the strength values of the muscle (34). Of the core muscles, the diaphragm is important because of its anatomical position. With the contraction of the diaphragm muscle, an increase in intra-abdominal pressure is observed, and the continuation of the contraction of the transversus abdominis and multifidus muscles ensures that this pressure increase is maintained. Thanks to this relationship, the amount of air taken in inspiration and the core stabilization function are affected by each other (34). The amount of air exchange that takes place in the lung is determined by the FVC values, which represent the amount of air exhaled. In our study, a correlation was found between FVC values and lateral bridge tests, transversus abdominis, multifidus, sit-ups and push-ups tests. We can say that with the diaphragm in the core region, the transversus abdominis on the side walls and the multifidus muscle on the back both support core stabilization and contribute to the respiratory system, thanks to the regulation of intra-abdominal pressure.

The sit-ups test requires the function of the core muscles, especially the abdominal region (35). An increase in the transdiaphragmatic pressure changes between 50-65% is observed in the abdominal region activity. For this reason, it has been said that some core stabilization exercises can be used to improve respiratory functions (36). A correlation was found between the observed PEF values and the expected percentage of PEF values in our study and the sit-ups test. As a result of the increase in the torque produced by the diaphragm, it may have increased the PEF value when the inhaled air becomes easier to get out.

PFT values are affected by many factors such as age, gender, height and weight (37). For this reason, "percentage of expected value" data was created by considering these factors. In our study, weak correlations were found between the expected percentage of FEV1/FVC and PEF values and core stabilization. FVC, FEV1, and FEF values were not correlated with expected percentage data. We think that this is due to the fact that the individuals included in our study have similar values in terms of weight, height, age and physical condition and that they train at similar levels.

In order to perform sports activities, stability in the sagittal, frontal and transversal planes is required. Especially in jogging sports, hip and trunk muscles should be strong and durable (38). Activation of the core and hip muscles affects the resistance of the quadriceps and hamstring muscle groups during jumping activity. Core stabilization must be maintained in athletic performances because of its effect on the biomechanical alignment of the lower extremity (39). In weak core stabilization, pathologies such as valgus in the knees, anterior cruciate ligament problems, patellofemoral pain syndrome, and iliotibial band tension can increase the risk of injury of the individual (38). In our study, a relationship was observed between the risk of injury and core stabilization. Transversus abdominis and multifidus muscle functions and lateral flexion-repeat tests, which are among the core stabilization parameters, affect FMS values. These muscle groups, which control the internal rotation and adduction movement of the femur, may have a role in reducing the risk of injury. In the study of Leetun et al., the effect of hip external rotation and abduction muscle strength on injuries was found in athletes (40). In the literature, it has been stated that core training programs reduce the risk of injury by regulating lower extremity functions (41-43). In our study, it was found that individuals with high core stabilization had a low risk of injury. Future studies can provide a better explanation of this relationship.

The physical fitness of the referees in our country is regularly tested by the TFF. These evaluations are in the form of determining the time run for 12 minutes and the time to run the distance of 40 meters. With these tests, it is tried to get an idea about the running performances of the referees in the matches. A high correlation has been shown between the total distance covered by the referees in the competitions, sprint distances and high-speed running values and the 40-meter duration (44). There are similarities between their 12-minute running distance and the distance they cover in matches (45). Therefore, these values were examined in our study. In the literature, no direct relationship has been observed between core stabilization and long-term running performance (46, 47). However, in the study conducted by Sato and Makho, it was observed that the 5000-meter running time decreased by 47 seconds in individuals who regularly performed core stabilization exercises for 6 weeks (48). In the study of Tong et al., it was stated that fatigue of the core muscles affects high intensity running (49).

In our study, weak correlations were found between the distance values measured by the Playertek GPS device, showing the distance run in 12 minutes, and the functions of the lateral flexion-repeat tests, sit-ups test, transversus abdominis and multifidus muscles. Apart from providing alignment of the lower extremity and creating resistance against physical loads during running, fatigue of the core region affects the performance of the individual. During running, the extremities are exposed to high levels of physical loads. Core stabilization may contribute to athletic performance by helping to optimize the energy generated against loading between the trunk and the extremities (18). Although the relationships between athletes who exhibit running performance and sedentary individuals were examined in the literature, no study was found that examined the relationship between pulmonary function tests and running distances or speeds. In our study, a relationship was found between distance data determined by Playertek GPS device and FVC, which is one of the respiratory functions, and between 40 meters running time and FVC, FEV_1, PEF values. Thanks to the improvement of the FVC value, the amount of physiological dead air remaining in the lungs is reduced (50). This allows higher volumes of air to be taken in with each breath, helping to breathe with a more efficient breathing pattern (51). Although the level of evidence for these relationships identified in our study is weak, it can be a reference for future studies.

Problems, especially lower extremity injuries, are frequently encountered in individuals performing running performance. Marti et al. 46% (52), Walter et al. 48% (53) and Adventure et al. (54) reported that 51% of athletes faced injuries. The FMS method, designed to determine the risk of injury, creates a score according to the movement quality of individuals. A score of 14 or less than 14 indicates that the individual is at risk of major injury (55). Individuals with a high FMS score have the mobility and stability skills required to establish and maintain balance (56). Although there are studies examining injuries in runners in the literature, there are no studies investigating the relationship between long distance running and injury risk. Estimating the risk of injury using orthopedic evaluations and background information did not yield successful results (57). However, there are studies examining short distance running performance with FMS (58, 59). Okada et al. (58) and Parchmann et al. (59) found no relationship between FMS score and sprint times in their studies. Lockie et al. found no relationship between 20 m running time and FMS total score and its sub-parameters (60). In our study, a relationship was found between 40 meters running time and FMS, linear step forward, trunk stability push-ups and rotation stability, and between distance value and FMS and trunk stability push-ups. Although the relationship between them is weak and moderate, it is recommended as an alternative method to measure with the Playertek GPS device, which does not require a separate time, effort and material for evaluation, instead of FMS, which is often used to determine the risk of injury.

The risk of injury in athletes is examined as intrinsic and extrinsic factors. Among the intrinsic factors, age, duration of sports and previous injuries increase the risk. Ankle and knee joint stability, joint laxity and functional stability factors are also effective in jogging sports such as football. Extrinsic factors such as lack of training, low training intensity and field floor problems make the athlete vulnerable to injury (61, 62). Reducing the injuries observed in sports can be possible by determining individual characteristics and developing preventive treatment programs. For this reason, in order to evaluate individual characteristics, the factors affecting injury should be determined and their relations with each other should be examined. Because there are many risk factors in sports injuries and their effects on each other cannot be considered separately (63).

Watson, who followed 102 athletes for 2 years, reported the relationship between previous injuries, posture, musculoskeletal system function, and running accelerations with injury (64). Taimela et al. examined 37 athletes and reported that previous injuries and reaction time affected the injury (65). Arnason et al., in their study of 306 athletes, stated that muscle tension, range of motion and previous injuries increased the risk of new injuries (66).

In our study, regression analysis was performed using FMS data as the dependent variable to determine the risk of injury. It was aimed to estimate the risk of injury by using core stabilization and running performance values, which were correlated in the correlation analysis. The 10-point increase observed in the left lateral flexion-repeat values of individuals explains the 0.57-point decrease in the risk of injury. The test method that measures the lateral core endurance of the individual includes lumbo-pelvic rotation and abduction movements. Rotation and abduction movement, which is also important for the mechanical alignment of the lower extremity in running sports, is an effective factor in the risk of injury. At the same time, in this test where the left side is down, the muscles on the right side above are expected to carry body weight, maintain endurance and maintain postural alignment. The fact that the majority of the individuals (n=29) participating in our study used their right side as dominant determined the result of the test. Since the endurance, strength and fatigue tolerance of the muscles of the individuals who are more successful in the tests will be better, their movement quality increases, which reduces the risk of injury.

In our study, the distance values determined by the Playertek GPS device were taken as the dependent variable, and the related data were used in the correlation analysis. As a result of the regression analysis, a relationship was found between the FMS method and distance. One point increase in the FMS score explains why individuals cover 95.17 meters more. The parameters used in the FMS method are similar to the movements we create during running. Factors such as step forward, shoulder mobility, harmonious cross movement of arms and legs, and trunk stabilization are of great importance in running quality. We think that the FMS score can provide information about running distance, as it tests the mobility. Parallel to our study, Chapmann et al. reported that a high FMS score increased the running performance of the athletes (67). On the other hand, there are studies in the literature reporting that there is no relationship between FMS and running performance. McGill et al. did not find a relationship between FMS score and performance in the athletes they followed for 2 years (68). Lockie et al. examined 22 athletes and reported that FMS score did not affect running performance (60).

Due to conflicting information in the literature, it is necessary to examine the relationship between FMS score and distance data. In future studies, it is recommended that groups with larger populations, using longer distance runs and determining the influencing factors by multivariate analysis method.

Limitations. The fact that the Turkish Football Federation allowed us to work only with provincial referees prevented us from reaching top-class referees who were refereeing for longer periods. Due to FIFA rules, we could not use the GPS device during the match and evaluate all the parameters. Measurements made during FMS were not recorded on camera.

Conclusion. As a result of this study, we found that individuals with good core stabilization have better FVC and PEF values and perform better respiratory functions. The high endurance of the core region, especially its lateral parts, reduces the risk of injury; the distance and energy data determined by the Playertek GPS device were affected by core stabilization. A relationship was found between pulmonary function tests and distance determined by Playertek GPS device and running time of 40 meters. A correlation was found between the FMS score, which examines the risk of injury, and the distance determined by the Playertek GPS device and the running time of 40 meters. As a result of regression analysis, parameters affecting the risk of injury were determined as lateral flexion-repeat test. The parameter affecting the running distance was found as the FMS score. The use of GPS devices, which can be called new to the literature, is recommended because of the relationships shown by its data. However, it is important to get the data during the match. Scientific studies are of great importance in the evaluation of the referees in the elite level athlete category and in raising awareness in the committees about the necessity of training programs based on scientific data. It can be ensured that physiotherapists and other health professionals work together on this issue.

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