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POTENTIAL RISKS OF OUTDOOR SPORTS IN A CHANGING CLIMATE

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Abstract: It is inevitable that each sector has a distinct vulnerability to climate change in divergent dimensions with different aspects. When health, social, cultural, and economic components are considered together, the vulnerability of the sports sector to climate change cannot be ignored in terms of its mass impact. Thus, it is estimated that professional or amateur athletes, trainers, and spectators, as well as managers, administrators, media workers, and sponsor companies interested in outdoor sports will be exposed to the potential direct and/or indirect impacts of climate change in the future. In this context, the potential impacts and risks of climate change on outdoor sports activities were comprehensively reviewed in terms of climate change indicators about the health of athletes and spectators, venues and calendars of competitions. Accordingly, the danger and risk thresholds were determined for the mentioned sports branches, and the conditions that cause the postponement or cancellation of the competitions are examined. Additionally, the extent to which these values and conditions may change in the short and long term with the increasing impacts of climate change has been considered. Moreover, the rules and regulations added to the sports and health policies of countries in order to minimize or prevent the adverse impacts caused by climate change have been examined, and additional precautions to be taken have been mentioned. The review indicates that these potential climate change-related disruptions may pose a serious risk for outdoor sports in terms of the health of athletes and spectators and sectoral incomes.

Key Words: Climate change, outdoor sports, thermal stress, weather events, health

DEĞİŞEN İKLİMDE AÇIK ALAN SPORLARINI BEKLEYEN RİSKLER

Öz: Her sektörün farklı boyut ve seviyelerde iklim değişikliğine karşı farklı etkilenebilirliğe sahip olması kaçınılmazdır. Sağlık, sosyal, kültürel ve ekonomik bileşenler bir arada düşünüldüğünde kitlesel etkisi bakımından spor sektörünün de iklim değişikliğinden etkilenebilirliği göz ardı edilemez. Bu nedenle, açık alan sporlarıyla ilgilenen profesyonel ya da amatör sporcular, antrenörler ve seyircilerin yanı sıra yöneticiler, idareciler, medya çalışanları, sponsor firmalar vb. grupların da gelecekte olası iklim değişikliğinin doğrudan ve/veya dolaylı etkilerine maruz kalacağı tahmin edilmektedir. Bu bağlamda, dış alanda gerçekleştirilen spor faaliyetlerinde, iklim değişikliğinin sporcu ve seyirci sağlığı, müsabakaların gerçekleşme yerleri ve takvimleri açısından iklim değişikliği göstergeleri özelinde beklenebilecek olası etki ve riskler kapsamlı bir şekilde değerlendirilmiştir. Bu amaçla, bahsi geçen spor dalları için belirlenmiş olan tehlike ve risk sınır değerleri, müsabakaların ertelenmesi ya da iptal edilmesine neden olan koşullar incelenmiştir. Ayrıca, iklim değişikliğinin etkilerinin artması ile kısa ve uzun vadede bu değer ve koşulların ne ölçüde değişebileceği ortaya koyulmuştur. Buna ek olarak, iklim değişikliğinin neden olduğu olumsuz etkileri en aza indirmek veya engellemek için mevcutta ülkelerin spor ve sağlık politikalarına eklenmiş olan ve hâlihazırda uygulanan kural ve yönetmelikler irdelenmiş ve ilaveten alınması gereken önlemlere değinilmiştir. Makale kapsamında yapılan inceleme, iklim değişikliğine bağlı bu olası aksamaların açık alan sporlarında gelecekte spor organizasyonları için sporcu ve seyirci sağlığı ile sektörel gelirler açısından ciddi bir risk oluşturabileceğine işaret etmektedir.

Anahtar Kelimeler: İklim değişikliği, açık alan sporları, termal stres, hava olayları, sağlık

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INTRODUCTION

Climate change is expected to have significant effects on the sports sector as well as in many areas such as agriculture, tourism, and industry. Especially in the next few decades, it is estimated that climate change will increase its impact and cause many changes in our daily lives. The most obvious indicators of climate change are increasing temperatures, changes in the precipitation regime, more frequent, more severe, and longer-lasting natural disasters, the expansion of their impact areas, and finally, sea-level rise for some regions. Heatwaves, prolonged dry periods, or sudden heavy precipitation are the common examples of these indicators (IPCC, 2021). These indicators, which have emerged as a result of climate change, adversely affect physical activities and sports activities, and the fact that such weather events and natural disasters are felt more intensely in some regions causes limited sports performance (Maloney and Forbes, 2011). It is expected that water sports such as sailing, rowing, most winter sports, and outdoor sports such as tennis and football will be seriously affected by this situation (Brocherie et al., 2015).

Especially high temperatures and heat strokes affect all participants of outdoor sports activities, including athletes, referees, technical teams, and spectators. In some cases, high temperatures can lead delays, postponements, or injuries in games. For example, in the 2014 Australian Open Tennis Tournament, more than a thousand spectators suffered heat stroke due to the air temperature above 41 °C for four consecutive days (BBC Sport, 2014a). Moreover, the water bottle of the famous tennis player Caroline Wozniacki and the shoes of another famous tennis player Wilfred Tsonga melted from the high temperature (BBC Sport, 2014a). In addition to increasing mean temperatures, other extreme weather events such as typhoons, hurricanes, and occasional heavy rainfalls pose a severe risk for sports competitions and tournaments. For instance, typhoons during the Japan Rugby World Cup in 2019 led to the postponement of the tournament and the cancellation of some matches (Lyons, 2019).

The impact of climate change on different outdoor sports is expected to continue with increasing intensity in the future (BBC Sport, n.d.; McGrath, 2020). In the future, it is predicted that the football fields of world-famous football teams such as Chelsea, West Ham, and Southampton may be affected by sudden heavy rainfalls (McGrath, 2020). Similarly, it is thought that high temperature and humidity values in the Tokyo Olympic Games, which will be held in Tokyo in 2021, will significantly affect the athletes who will compete in the Olympics (İklim Haber, 2021). On the other hand, in the short and medium-term, climate change is expected to cause an increase in winter temperatures in some regions and a shorter duration of winters (IPCC, 2013). It will undoubtedly affect the Nordic countries and Scandinavia, where winter sports are more common because a large amount of snow is needed for winter sports to be practiced. As a result of the short and hot winter months, the amount of snow remaining on the ground will start to decrease earlier, making it difficult to do these sports under suitable conditions. Although, in some cases, the organizers carry snow masses from the surrounding cities to cope with this situation, this practice is quite costly and laborious (Orr, 2020).

Currently very high or low temperatures can significantly affect the health of athletes and spectators. While evaluating the suitability of outdoor environments for sports activities, air temperature, and relative humidity in the summer season, on the other hand, air temperature and wind speed in the winter season are taken into consideration. In addition to these criteria, parameters such as vapor pressure, solar and thermal radiation, atmospheric pressure, and cloudiness should also be considered during performance measurements and health evaluation. The heat models developed with the advancing technology enable the calculation of the heat

exchange between the human body and its thermal environment with various algorithms and models. In addition, all kinds of meteorological data related to the calculation can be easily accessed, and this heat exchange can be determined with the Wet Bulb Globe Temperature (WBGT) or the Heat Index.

There is a risk for sports organizations and competitions due to sudden and significant weather changes caused by climate change. These changes, which are crucial for sports branches, each of which has become a big industry today, should not be ignored. For example, tennis is one of the sports branches that many people follow with great interest, and especially the four major tennis tournaments, the Australian Open, French Open (Roland Garros), Wimbledon, and US Open Tennis Tournaments, also known as the Grand Slam. These tournaments bring tennis lovers from all over the world together with professional tennis players. When tennis is considered in terms of active athletes, it is a widespread sport. According to the International Tennis Federation (ITF) 2019 Global Tennis Report, 55 countries globally have at least one male or female tennis player in the top 100 tennis player ranking, and according to the same report, there are 3,873 professional tennis players worldwide (ITF, 2019). Tennis, which has several athletes and spectators as a popular sport, is an outdoor sport. Because of the changing climate, it can be expected that the sector will be highly affected, and some risks will arise in terms of the health of athletes and spectators, with the increase in the number of examples experienced in 2014.

Football, which has expanded over time and has become a major industry, is one of the most followed sports worldwide and has a large number of active athletes. This sport, widely practiced especially in Europe and South America, has gained popularity in countries such as the USA and China in recent years. Of course, this development has also positively affected the football market. For example, the European football market increased by 2% in the 2018/2019 season compared to the previous year and generated total revenue of 28.9 billion dollars (Ajadi et al., 2020). In the same season, English professional football clubs, which have an important position in this sector, paid 2.3 billion dollars in taxes thanks to their income (Ajadi et al., 2020). As such, the place of the audience in this development of the football industry is undeniable. Viewers follow football matches and tournaments both on the screen and in the stands. Especially the World Cup, which is held every four years, attracts the attention of millions of spectators. For example, it is estimated that 3.2 billion people watched a total of 64 matches in the FIFA World Cup held in Brazil in 2014 (Sports Business Journal, 2015). However, an industry of this size also has some impacts on the environment. Air transport used for matches held in different regions or luxury accommodation for football players have a global effect on the environment. It is stated that 20 clubs in the English Premier League for the 2016/2017 season have a carbon footprint equivalent to 1134 tons of CO₂ (Bernard et al., 2021). The high and increasing carbon emissions in the atmosphere mean that all living things in nature may be damaged due to climate change. The fact that football has become an industry that attracts attention with a very high capacity, as a sport usually performed in the open field, draws attention in terms of the health of athletes and spectators. For example, since the 2022 FIFA World Cup will be held in Qatar, it has been decided to organize it in the winter months, whereas this tournament is typically held in the summer months (Bassam, 2018). Generally, the temperature in Doha is around 41 °C in June, and it can go up to 50 °C on extremely hot days (Miller, 2015). These temperatures, combined with high humidity, create hazardous conditions for the athletes in the region, and this is the reason why it has been decided to organize the tournament in winter. Football competitions may also face the risk of extreme precipitation and flooding. For example, in November 2011, the Italian city of Genoa was hit by heavy downpours and floods, and heavy rainfalls combined with strong winds brought life to a

standstill. Due to this situation, the world-famous football teams Inter and Juventus matches were postponed (Bandini, 2011).

Outdoor baseball is one of the most popular sports, especially in North America, and it has become a massive market. The American professional baseball organization Major League Baseball (MLB) generally starts in March and lasts until October. While the US National Baseball League earned 3.58 billion dollars in 2001, this revenue reached 10.37 billion dollars in 2019 (Gough, 2021a). The average revenue per club in baseball was \$345.3 million for 2019 (Gough, 2021b). For baseball, which has such a large market, it is crucial that athletes do not encounter health problems due to environmental conditions, sports competitions are not interrupted, and tournaments are held on time. However, unfortunately, high temperature and humidity values sometimes cause challenging conditions for athletes in baseball games. On June 30, 2018, the Minnesota Twins and Chicago Cubs came together for a match, and the athletes had a tough time in the competition due to the extreme temperatures (Bollinger, 2018). So that three athletes named Eddie Rosario, Bobby Wilson, and Max Kepler had to leave the game before they could complete the match due to the cramps and loss of performance they experienced during the competition (Bollinger, 2018). In addition to high temperatures and humidity, heavy rainfalls have also impacted baseball games at times. For example, the baseball game that was expected to be played on May 27, 2021, between the New York Yankees and the Toronto Blue Jays was postponed two hours before the start of the game because of heavy rainfalls and a possible hurricane (ESPN, 2021). Due to such situations, it is of great importance for both the athletes and the organizers what path a market with such a high volume of money flow will follow in the face of changing climate conditions and increasing environmental events.

Considering all these, climate change is an urgent and vital issue that needs to be taken into account in terms of both the health of athletes and spectators and the continuation of sports organizations in sustainable conditions. It is essential to compile academic studies in this field and contribute to the literature with new researches. Since there are few studies in this field in the literature, each study on the effects and risks is important in terms of raising awareness on the relevant groups and contributing to adaptation measures. This is a study that should be considered because it examines and exemplifies different sports branches with a holistic approach in terms of climate change. In addition, two short case studies were made for tennis and football in the study using pessimistic scenarios of global and regional climate models, and therefore the findings obtained in the literature review were compared with the results of the modeling case studies.

METHOD

Research Model

In addition to the fact that the conditions may cause loss of points or losses in the games or competitions held under extreme weather conditions, the health of the athletes, spectators and referees is significantly affected. In this study, a comprehensive literature review was conducted on the effects of climate change on the health of athletes and spectators, and the effects of extreme weather conditions on different sports branches, the factors related to the postponement or cancellation of sports organizations depending on certain threshold values were investigated. In the light of this information, the precautions to be taken have been determined and predictions have been made about what changes may occur in the organization of these sports in the short and long term.

The study also includes two short case studies that support the evaluation results based on the literature on the impact of climate change on both tennis and football. To that end, firstly, the future change of the maximum temperature averages between May 15 and June 15, the period when the tournament (French Open/Roland-Garros) is predominantly held, was examined for the city of Paris, which hosts one of the most important tournaments in tennis. With the combination of the MPI-ESM-LR (Giorgetta et al., 2013) global climate model developed by the Max Planck Institute in Germany and the REMO2015 (Jacob and Podzun, 1997; Jacob et al., 2012) regional climate model developed by the Climate Service Center Germany (GERICS), which is recommended as the most reliable climate model pair for the European continent (Altinsoy and Kurnaz, 2021), the high-resolution maximum temperature data were produced. For maximum temperature analysis, 1974-1999 was determined as the reference period, and 2025-2050 as the future period, taking into account the RCP8.5 scenario (Riahi et al., 2011), which depicts a world where the fight against climate change is not maintained, and greenhouse gas emissions are high. The comparison was made by considering these two periods.

As the second case study, Discomfort Index (DI) analysis was conducted for the province of Istanbul, which has the highest number of teams in the Turkish Super League. In this context, the combination of the MPI-ESM-MR (Giorgetta et al., 2013) global climate model developed by the Max Planck Institute in Germany and the RegCM4.4 (Giorgi et al., 2012) regional climate model of the Abdus Salam Centre for Theoretical Physics (ICTP) in Italy were utilized. DIs for August and September in Istanbul were calculated using 10-km horizontal resolution and 3-hour temporal resolution air temperature (T in $^{\circ}\text{C}$) and relative humidity (RH in %) outputs obtained from this model pair, which was previously applied for Turkey (Öztürk et al., 2011; Turp et al., 2014) and used to produce climate data. DI calculations were done under the RCP8.5 scenario for the reference period of 1974-1999 and the future period of 2025-2050, as in the tennis case study, and the values of these two periods were compared.

Research Category

While reviewing the literature, first of all, a general research was done about all sports branches performed indoors and outdoors. Afterward, review was carried out considering athletes and spectators who are more exposed to the effects of climate change in outdoor sports. Since the effect of climate change on outdoor sports in winter (e.g., skiing) has been investigated in various studies in the literature (e.g., Demiroglu et al., 2021; Göymen et al., 2017; Knowles et al., 2020; Scott et al., 2015, 2019; Steiger et al., 2019), this study focuses on sports such as tennis, football, baseball, and athleticism, which are also popular around the world and are performed with the participation of large audiences.

Data Collection Tools

The effects of threshold values, temperature and precipitation projections, some indicators such as humidity, lightning, and extreme weather events for the sports branches were examined. Measures to be taken by international sports federations depending on climate change parameters were researched. Different rules and regulations were included for each sport. All these factors were investigated and compiled in detail in the study.

In the case study parts of the research, the climate outputs obtained from the MPI-ESM-LR&REMO2015 and MPI-ESM-MR&RegCM4.4 climate model pairs were used.

Analysis of Data

In the research, a short case study was conducted for Paris, where the French Open (Roland Garros), one of the four major Grand Slam tournaments, takes place. Annual time series of maximum temperature anomaly was calculated using the data obtained from MPI-ESM-LR&REMO2015 climate model pair based on the RCP8.5 scenario for both the past (1974-1999) and the future (2025-2050) period, and then Paris was evaluated for possible risks in terms of upcoming tournaments by plotting an anomaly graph for the future period.

In another case study, the DIs in the evenings for the months of August and September, which coincide with the first weeks of the football season for Istanbul, were calculated and compared for the past (1974-1999) and the future (2025-2050). For this purpose, the trend of change in discomfort condition was shown by plotting the annual time series of the DIs calculated for both periods and months using the outputs obtained from the MPI-ESM-MR&RegCM4.4 model pair under the RCP8.5 scenario. The DI formula, which was developed by Thom (1959) and is still an effective way in showing the apparent temperature, is given in Equation 1 and Equation 2, and the risk criteria corresponding to the relevant index values are highlighted in Table 1.

$$DI = 0.4(T_d + T_w) + 4.8 \quad \text{Equation 1}$$

T_d : Dry-bulb temperature; T_w : Wet-bulb temperature

$$T_w = T \operatorname{atan}[0.151977(RH + 8.313659)^{1/2}] + \operatorname{atan}(T + RH) - \operatorname{atan}(RH - 1.676331) + 0.00391838(RH)^{3/2} \operatorname{atan}(0.023101RH) - 4.686035 \quad \text{Equation 2}$$

Table 1. Discomfort Index (DI in °C) classification (Thom, 1959)

DI Range (°C)	Discomfort Condition
DI < 21	Comfortable
21 ≤ DI < 24	Discomfort condition for less than 50% of the population
24 ≤ DI < 27	Discomfort condition for more than 50% of the population
27 ≤ DI < 29	Discomfort condition for most of the population
29 ≤ DI < 32	Severe stress condition for all of the population
DI ≥ 32	Medical emergency

FINDINGS

Possible Effects and Risks of High Temperatures Due to Climate Change on the Health of Athletes and Spectators

Bad weather conditions, which directly affect the performance of athletes in training and competitions, can lead to dangerous consequences if the necessary precautions are not taken. Athletes and spectators may be exposed to the possible effects of high temperature and humidity, especially in outdoor tennis competitions. For example, during the 2018 US Open Tennis Tournament, the athletes and spectators had a hard time due to the temperature and humidity levels rising to 35.5 °C and 47%, respectively, and the organizers gave male tennis players a 10-minute break between the 3rd and 4th sets for the first time with a new regulation. Famous tennis players who were overwhelmed by the heat used this break to cool off and renew themselves. In the same tournament, six male tennis players were withdrawn from the competition because of the extreme temperatures (Graham, 2018). To combat such conditions,

tennis players can change the way they play to adapt to weather conditions by prolonging the duration of the game and making less effort to minimize the harmful effects of high ambient temperatures in hot conditions (37 °C, 36% RH, 34 °C WBGT, and 0.5 m/s wind speed) and when rectal and thigh skin temperatures[†] rise to 39.4 and 39.5 °C, respectively (Périard et al., 2014). Similarly, a report in BBC News mentioned a possible effect of high temperature on athletes in tennis (BBC News, 2015). According to the news, high air pressure combined with the high temperature tends to slow the tennis ball in the air, and the drier ground due to the heat creates a harder surface that speeds up the game. More importantly, due to the harsh playing conditions, the tennis players' bodies pump more blood to perspire, increasing their heart rate (BBC News, 2015; Maughan & Shirreffs, 2004).

High temperature and humidity values can be challenging and dangerous for athletes and spectators during football matches. For example, during the match between the Netherlands and Mexico in the World Cup held in Brazil in 2014, the temperature in the stadium rose above 32 °C, and the players had a hard time (BBC Sport, 2014b). Some of the spectators affected by the heat went to the back of the stands to cool off. Due to these conditions, the practice of giving a 3-minute cooling break in football matches has started.

High temperature and humidity can cause excessive sweating in athletes, but it can also cause heat stroke and sudden death depending on the amount of exposure (Casa et al., 2012). Exertional heat stroke (EHS) can be seen in healthy and fit athletes due to increased body temperature and heart rate during activity (Armstrong et al., 2007). It can happen even in non-extremely hot environments. If the rectal temperature exceeds 40 °C, the central nervous system and organs can be significantly damaged (Armstrong et al., 2007). For example, American football players were at risk of fatal heat stroke when the air temperature was 26-30 °C, and the relative humidity was 50-80% (Armstrong et al., 2007).

It is possible to decide which activity to do where and when, thanks to the calculations made, and the athletes can get rid of these harmful effects with the precautions they take individually. As a matter of fact, climatic conditions are of great importance in sports played in the open field, and it is critical for the health and performance of the athletes to determine the most appropriate training time by following these conditions. A possible heat stroke or injury can be avoided, especially by looking at the temperature. Climatically safe threshold values should be known so that sports activities can be carried out and athletes can decide whether to continue training (Table 2). When the risky situations of sportive activities are examined according to the temperature thresholds, the critical WBGT level for the tournaments that have already started and/or continued is 27.9 °C. It has been observed that the risk of EHS increases in athletes when this level is reached and exceeded. However, the critical WBGT level is 30.1 °C for trainings and noncontinuous activities with specific break opportunities. In general, in conditions below 18.4 °C, sports activities can be done safely, except for personal situations.

[†] The temperature value taken rectally with a thermometer is considered as rectal body temperature, and the skin temperature value taken from the thigh region of the leg is considered as the thigh skin temperature (İlçe and Karabay, 2009; Özünlü Pekyavaş et al., 2017).

Table 2. Athlete activity status and temperature thresholds according to risk status (Armstrong et al., 2007)

WBGT Level	Continuous activity or competition	Training or noncontinuous activities	
		Nonacclimatized, Unfit, High-Risk Individuals	Acclimatized, Fit, Low-Risk Individuals
≤ 18.3	Generally safe Low EHS risk	Normal activity can be done.	Normal activity can be done.
18.4-22.2	Risk of EHS and other heat related illnesses begins to increase Especially high-risk individuals must be monitored or should not compete	Increase the number of breaks Pay attention to sufficient fluid intake	Normal activity can be done.
22.3-25.6	Risk for all individuals	Increase the number of breaks Decrease total duration of activity	Normal activity can be done. Sufficient fluid intake must be required.
25.7-27.8	High risk for unfit, nonacclimatized individuals	Increase the number of breaks Avoid doing long and intense activities	Normal activity can be done. Sufficient fluid intake must be required.
27.9-30.0	All activities and competitions must be cancelled because of high EHS risk	Give equal amount of time for breaks and non-breaks Avoid doing long and intense activities Monitor at-risk individuals	Plan intense or extended exercise with wisdom Monitor at-risk individuals
30.1-32.2	-	Cancel or stop exercise and competition	Avoid doing intense exercise and restrain total daily exposure to heat and humidity Pay attention to early signs and symptoms of heat stress
≥ 32.3	-	Cancel exercise	Cancel exercise because of high risk of heat stress for all individuals

Athletes have been adversely affected physically or even lost their lives due to the environmental conditions that stem from not taking timely precautions. For example, in a local match in Manisa in August 2006, a football player lost his consciousness because of extreme temperature (Aslan and Eyuboglu, 2017). In addition, a 22-year-old football player of one of the Spanish League teams had a heart attack and died due to extreme temperature (Aslan and Eyuboglu, 2017).

At this point, it is necessary to underline the risks that may occur depending on individuals since the body structures of the athletes also play a role in the level of exposure. For example, football or rugby players with a larger body and muscle mass can maintain average body temperatures by emitting higher metabolic heat production (Johnson et al., 2010). Compared to them, long-distance runners, who are weaker and have less muscle mass, have higher heat loss as a result of increased environmental temperature (Cheuvront and Haymes, 2001).

EHS can often occur in marathons or during high-effort outdoor training. When the Twin Cities, Chicago, and Marine Corps marathons between 2003 and 2005 are examined, it is seen that the risk of EHS occurs as one in 10,000 runners on average, and this number increases due to the rise in WBGT level (Roberts, 2007). In an 11.5 km marathon run in hotter and humid weather conditions (WBGT 21-27 °C), it was determined that 10 to 20 out of 10,000 runners were

exposed to heat stroke. When the same race is run in more suitable and cooler weather conditions, there is no case of EHS (Armstrong et al., 2007).

Along with temperature and humidity values, the wind is also one of the environmental factors affecting the health of athletes, depending on its severity. During the Pyeongchang Winter Olympic Games in South Korea in 2018, the wind caused great difficulties. The strong wind caused the air to get colder and ripped out tents and signposts. Some competitions in the slalom ski and snowboard genre were canceled due to the wind. Particularly, some of the athletes whose balance was disturbed due to the wind during the jump could not complete their jumps successfully, and some of them suffered injuries while completing their jumps (Branch, 2018). Another example of the effect of wind on sports competitions is what happened in the 2019 French Open Tennis Tournament. In Roland Garros, the only grand slam tournament played on clay court, during the Novak Djokovic and Dominic Thiem match at 2019 Roland Garros, the wind speed increased up to 90 kilometers per hour and caused the match to be postponed because of heavy rainfall (Clarey, 2019). In the final match between Roger Federer and Rafael Nadal, the strong wind lifted a lot of dust from the ground and caused difficult conditions for these two famous tennis players (Clarey, 2019).

Lightning strikes, which pose a risk to the health of athletes and spectators, and sports organizations, can be counted among environmental events with adverse effects. This natural phenomenon should also be considered for sports competitions. For example, a severe storm occurred during the 2019 Tour Championship, a golf organization, and the event was delayed in its third round. However, about half an hour after the delay, a tree was struck by lightning at the East Lake Golf Club, and some tree pieces fell on the six people who took shelter under the tree to protect themselves from the storm, causing injuries (Murray, 2019).

Evaluation of Possible Impacts and Risks of Climate Change in Terms of Sports Clubs, Federations, and Organizers

The sports industry undoubtedly has a very important place in the world economy. Sports branches with a large audience, organizations with high-budget commercial agreements, and the athletes and technical teams that generate their income from these sports are part of this industry. Climate change, which will affect many sectors, also has possible effects on the sports sector. As a result, this industry needs to maintain its current position and be freed from potential risks.

Threshold values have been determined by sports clubs and international committees regulating sports activities due to the increasing effects of climate change for sports played in the open field. There are also academic studies on high temperatures and other extreme weather events that affect the health of athletes (Armstrong, et al., 2007; Bernard et al., 2021; Casa, et al., 2015; Sherwood and Huber, 2010). With these studies and the threshold values determined by the federations, it is aimed to prevent the negative results that may occur on the athletes due to high temperature and humidity values. The extreme temperature condition as determined by the ITF and associated game modification is defined as WBGT equivalent to or exceeding 30.1 °C (ITF, 2021). If WBGT on the field is equivalent to or exceeds 32.2 °C, the game will be suspended. If WBGT cannot be measured, the heat index is also calculated using Table 3. In this case, the games are suspended if the temperature index is or exceeds 40.1 °C (ITF, 2021). However, the organizers may change and update these threshold values considering the annual average temperature and humidity values that increase over time. As a result of the high temperatures and humidity experienced in the Australian continent, the currently applied thresholds were insufficient, and a special temperature policy was developed for the Australian Open, which is

one of the four big tennis tournaments. With this, it is aimed to prevent disruptions and cancellations in competitions (The Guardian, 2018). Likewise, decisions are made by looking at the daily maximum WBGT estimates about which days to train for football or play matches. The same is true for postponements and cancellations (Houser et al., 2015). If the WBGT reaches or exceeds 27.78 °C, competitions or training may be postponed (Armstrong et al., 2007).

Table 3. Heat index dependent on relative humidity and air temperature (ITF, 2021)

		Relative Humidity				
		0%	20%	40%	60%	80%
		Heat Index				
Air Temperature	21.1 °C	17.8 °C	18.9 °C	20.0 °C	21.1 °C	21.7 °C
	23.9 °C	20.6 °C	22.2 °C	23.3 °C	24.4 °C	25.6 °C
	26.7 °C	22.8 °C	25.0 °C	26.1 °C	27.8 °C	30.0 °C
	29.4 °C	25.6 °C	27.8 °C	30.0 °C	32.2 °C	36.1 °C
	32.2 °C	28.3 °C	30.6 °C	33.9 °C	37.8 °C	45.0 °C
	35.0 °C	30.6 °C	33.9 °C	38.3 °C	45.6 °C	57.8 °C
	37.8 °C	32.8 °C	37.2 °C	43.3 °C	55.6 °C	
	40.6 °C	35.0 °C	40.6 °C	50.6 °C	65.0 °C	
	43.3 °C	37.2 °C	44.4 °C	58.3 °C		
	46.1 °C	39.4 °C	48.9 °C	66.1 °C		
	48.9 °C	41.7 °C	54.4 °C			

Increasing average temperature values are also a challenging factor for winter sports. The 2014 Sochi Winter Olympics went down in history as one of the warmest winter Olympics. In the winter Olympics held in Sochi, Russia, in February 2014, night temperatures were measured as 4 °C on average and daily average temperatures as 10 °C (Kennedy, 2014). Melting snow caused hard times for skiers and snowboarders, and some games were postponed to colder nights with the change made by the organizers (Walker, 2014). It is of great importance to bring the ambient temperature to optimum values for indoor sports branches. Ventilation and cooling systems must work adequately and correctly. However, in the 1st Game of 2014 NBA Finals, the ambient temperature increased to 32 °C as a result of the failure of these systems in the building where the competition was held (Young, 2014). It was observed that the players got very tired and tried to cool off by putting ice bags on their necks between games. Famous basketball player, LeBron James had to leave the game when he experienced cramps in his leg due to extreme heat in the last period, despite taking enough fluids and changing his clothes at halftime (Young, 2014).

In addition to the effects of high temperature and humidity on sports branches, extreme weather events such as lightning strikes can also cause interruptions in sports competitions. Especially for outdoor sports, federations, and organizers closely monitor the possibility of these weather events. For example, the ITF has made some regulations regarding the vulnerability of tennis events to such natural events. The Federation appoints a supervisor responsible for monitoring local weather conditions for possible events such as lightning. This person has the authority to suspend the game in the event of a potential severe storm. In the event of a lightning strike, if thunder occurs in 30 seconds or less, it is recommended that everyone take shelter in a place where they can protect themselves against the risk of a new lightning strike (ITF, 2021). The game should not be continued until the possibility of another lightning strike has passed. It should be waited until at least 30 minutes after the last lightning strike and the last thunder (ITF,

2021). Additional information on storms and lightning is in ITF Guide to Recommended Health Care Standards (ITF, 2021).

Inevitably, industrial football will be directly affected by the changing climatic conditions. In football, there are some precautions taken, especially for stadiums in this respect. For example, the stadium safety and security management team should create emergency plans in case of severe adverse weather conditions (e.g., lightning strikes, flash floods, strong winds, hurricanes) together with the relevant specialized institutions and organizations (FIFA, n.d.). In this context, detachable platforms such as temporary stands or structures, award ceremony platforms that may cause physical harm to athletes or spectators should be avoided as much as possible. The use of temporary stands should only be considered if there is no other option and local authorities have already inspected the structure in question and issued a safety certificate approving its use so that FIFA can then carry out its inspection (FIFA, n.d.). In this context, it is crucial to monitor adverse weather conditions, especially strong winds, regularly. For example, in the match played between the South African teams Orlando Pirates and Black Leopards in 2007, strong winds knocked down the billboards and injured an assistant referee and two football players, causing them to leave the game for a while (Hackett, 2010). In addition, high winds can give teams an advantage or disadvantage depending on the direction of the blow. While the team players attacking in the direction parallel to the wind direction can find their place more quickly, the players attacking in the opposite direction may have to exert more effort as they encounter resistance while passing and shooting. Similarly, depending on the direction of the wind, football players can benefit from the driving force of the wind while running, but if they move in the opposite direction, the wind can be a compelling factor for them (Kadioğlu & Acar, 2015).

Heavy rainfalls, floods, and storms are also among the factors affecting sports organizations. There is a relationship between climate change and increasing average temperature values and precipitation falling on the earth. The Clausius-Clapeyron equation tells us that an increase of 1 °C in surface temperature averages causes a rise of 7% in the amount of precipitation falling on the earth (Schroeer and Kirchengast, 2017; Trenberth et al., 2003). In this context, with the increasing warming, heavy rains and floods that occur during the baseball seasons, especially in the summer months, will strongly affect the baseball matches and tournaments and may lead to delays or cancellations (Orr, 2020). Similarly, football matches can be affected by heavy rainfalls and snowfall. 2008 Champions League final took place between two English teams, Manchester United and Chelsea, and the game took place under heavy rains. One of the most unfortunate incidents in the match occurred during Chelsea captain John Terry's penalty shootout. John Terry, who was going to take the penalty shot on the ground deteriorated by the rain, slipped during the shot and lost his balance, and could not benefit from the penalty shot. This event, which directly affected the result of the match, upset the player and the technical team (McNulty, 2008). Likewise, five minutes after the start of the match between France and Ukraine in the 2012 European Cup, it was postponed for a while due to heavy rain, storms, and lightning. Spectators were drenched with rain, and players had to return to the locker room (The Guardian, 2012). Another example where precipitation negatively affects sports organizations is the 2016 Wimbledon Tennis Tournament, which started under heavy rain. The court was not fully filled in the first two days of the tournament, and 155,845 spectators attended in the first four days. This record was the lowest compared to the previous nine years (Grierson, 2016).

Climate Change and Tennis: A Short Case for the French Open Tennis Tournament, Paris

Paris is significant for hosting the French Open Tennis Tournament (also known as Roland Garros), one of the four major Grand Slam tournaments. For this reason, predictions about the temperature values that can be experienced in the near and medium-term are critical. A short case study was conducted for this, and the average maximum temperature projections for the tournament period (15 May-15 June) for Paris between 2025 and 2050 were examined, and the changes in comparison to the 1974-1999 period were evaluated (Figure 1). As a result of this study, in which regional climate model outputs were used, it is predicted that there might be an increase of approximately up to 6 °C in the maximum temperature averages for Paris in 2025-2050. In the next few decades, when the maximum temperature averages reach higher values, a more risky environment for the athletes and spectators is likely to occur during the tournament. It is expected that the probability of heat stroke may increase, and the frequency of heat-related fatigue, thirst, and injuries in competitions may increase. In addition, it can be said that the difference between low and high-temperature values during the year tends to increase as a result of fluctuations in the temperature anomaly. If these extreme temperatures occur during the tournament and the organizers do not take the necessary precautions at the appropriate time, it may pose serious risks for the athletes and spectators.

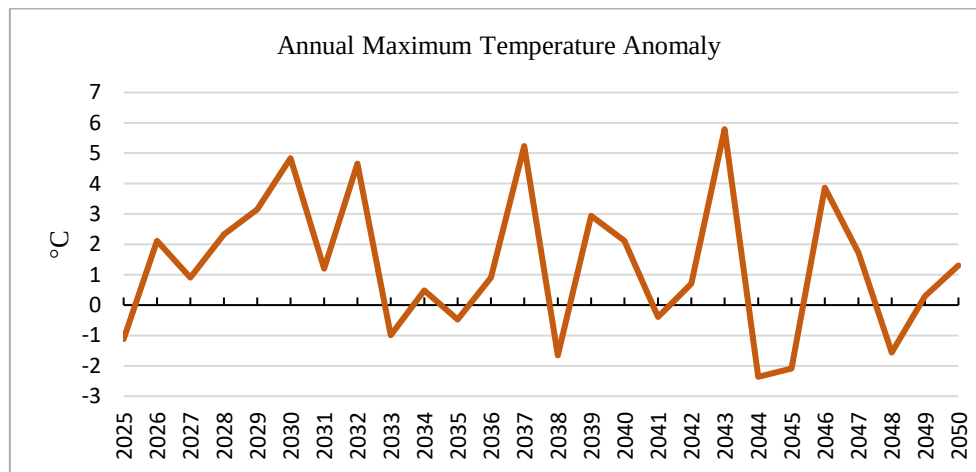


Figure 1. Maximum temperature anomaly for the tournament period of the city of Paris between 2025 and 2050 under the RCP8.5 scenario (Reference period is 1974-1999)

Climate Change and Football: A Short Case for Turkish Super League

The top national level organization of football in Turkey, which is followed by millions of people and is the most popular sport in the country, is known as the Super League. In the Super League, the season usually starts in August, which is one of the hottest months, and the matches played in the first weeks of the season are scheduled in the evenings considering the health of the players, referees, and spectators, and also short cooling breaks are given during the matches. In a changing climate, it can be thought that football matches played in hot months may also carry a risk in terms of human comfort. With this intention, the change in the DI for Istanbul, which currently has the highest number of teams (i.e., Beşiktaş, Fenerbahçe, Galatasaray, Kasımpaşa, Medipol Başakşehir, Vavacars Fatih Karagümrük) in the Super League, was examined.

When the DIs for August and September for the periods of 1974-1999 and 2025-2050 for Istanbul are compared, it is seen that there is an increasing trend in both months. As the matches are played in the evenings as a precautionary measure during this period, although there is an increase in the DI value, the DI seems to be at comfortable levels (on average, approximately

20.4 °C in August and 18.6 °C in September) in the reference period (Figure 2). It is seen that the increase in DI values may continue for both months in the future, but may exceed the comfortable level for August and reach a level (≈ 22 °C) where less than half of the population may experience discomfort condition (Figure 2).

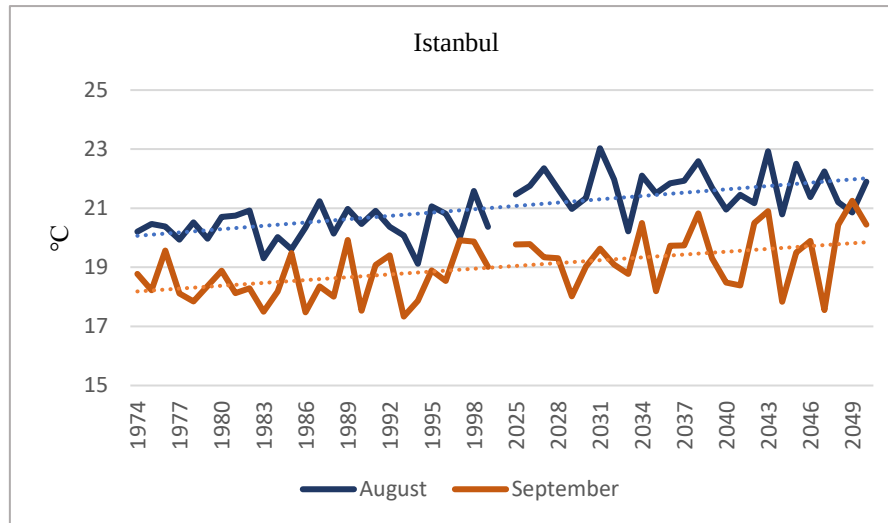


Figure 2. DI trend for Istanbul under the RCP8.5 scenario for the periods of 1974-1999 and 2025-2050

DISCUSSION AND CONCLUSION

In the study, the vulnerability of outdoor sports such as tennis, football, baseball, and athletics to environmental conditions brought by climate change was investigated and the conditions that caused the postponement or cancellation of competitions were examined with examples. With the increase in the effects of climate change, inferences have been made on what organizations and institutions can do in case such situations arise in the future.

A comprehensive literature review on climate change indicators affecting the health of athletes and spectators in sports activities has been made, and studies on the subject have been compiled around the world and in Turkey. In the light of this information, the measures that should be taken in addition to the rules and regulations currently in the health policies of the countries and applied in order to be affected by climate change to the least extent are listed. It is aimed to raise awareness of athletes and trainers against injuries that may arise from environmental reasons.

In addition to not delaying or canceling sports organizations, not taking measures to protect the health of athletes also creates ethical obligations. Large-scale organizations such as the Olympics and World Championships have the potential for additional income and advertising. Since such essential organizations will be affected by the possible risks posed by climate change, not delaying or canceling such organizations due to financial concerns may create damaging situations for athletes and spectators.

As can be seen from Figure 1, increasing temperature values may affect the French Open Tennis Tournament. Since a particular temperature policy has not been followed for this tournament yet, performance losses and injuries may be observed in athletes due to increased temperature values, and the spectators may be adversely affected by these temperature conditions. For this reason, it may be necessary to develop a separate regulation for this, as in the Australian Open and Wimbledon. In addition, some arrangements may be required to make the Roland Garros

Court, which hosts the tournament, less affected by environmental conditions. The retractable roof of the stadium can be used for this purpose. In addition, improvements to the stadium's infrastructure and cooling system can enable athletes and spectators to cope with this situation. If high temperatures and humidity levels become unbearable in the coming years, there may be a possibility that these tournaments will be moved to more suitable cities. However, the relocation of these tournaments, all of which have deep-rooted histories and left good memories for the audience, can have an emotional impact as well.

Similarly, high temperature and humidity values create dangerous conditions for football players. Federations can change the scheduling of the seasons by deciding to have fewer matches during the hot summer months. It can be ensured that match seasons start later and end earlier; however, this may result in teams having a more intense fixture. On the other hand, thanks to this measure, players can continue their competitions in cooler conditions. Reducing the number of teams in leagues can also reduce the intensity of fixtures. Matches currently played during the summer months start late in the evening. However, the increase in temperature values in the evening hours may lead to the inadequacy of this application. Although cooling breaks might be a solution initially, more practical and effective applications may be needed in the near future.

Heavy rainfalls, strong wind, and the risk of lightning strikes are also factors to be considered for stadiums. Against the possibility of such events, sports clubs and federations should make the necessary arrangements to improve the stadiums' infrastructures and make the arenas less affected by possible heavy rains and strong winds. Dissemination of retractable roof systems, improvement of the capacity of stadium arenas to absorb excess water and discharge it, development and dissemination of aerodynamic structures that can reduce the wind that players are exposed to during the competition can help minimize the possible effects of such weather events.

The effect of climatic factors may vary depending on the duration, the type, and the intensity of the activity, as well as the physical characteristics, performance, and clothes of an athlete. For example, the excessive insulation of the clothes worn plays a role in heat exchange (Johnson et al., 2010; Kulka and Kenney, 2002). Maintaining thermal balance in a hot environment is critical to reducing vital heat disturbances. Especially in athletics, this balance is also an essential criterion for maintaining performance efficiency. During exercise, clothing poses a threat to cellular balance by acting as a barrier against the body's cooling mechanisms (Davis and Bishop, 2013). When appropriate clothing is worn, the human body can become highly adaptable to the environment, even in extreme environmental conditions between -50 and 100 °C (Davis and Bishop, 2013). Choosing clothes designed to facilitate heat exchange between the athletes' bodies and the environment and absorb sweat and excess moisture are necessary adaptation measures to cope with these conditions.

In summary, the risks of outdoor sports organizations against climate change factors, which are expected to increase in the future, are obvious. It is necessary to determine the measures to take against these risks, predetermine the risky areas be exposed to possible natural disasters and extreme weather events, and postpone or cancel the organizations. These decisions are necessary adaptation actions to protect the health of all stakeholders, especially the athletes and spectators, and to reduce the possible socio-economic effects. Conducting scientific studies in this direction is of critical importance.

SUGGESTIONS

The balancing of the human body with varying environmental (atmospheric) and metabolic heat loads is controlled by an autonomous thermoregulatory system for healthy people. This is supported by behavioral adaptation (e.g., eating and drinking, activity and rest, clothing, exposure, shelter, relocation) driven by conscious feelings of thermal discomfort (Jendritzky et al., 2012). Considering all these effects, there are some precautions that can be taken to protect the health of athletes. Athletes should sleep for at least 7 hours in a cool environment before the activity, eat a balanced diet, and drink enough water before, during, and after exercise (Aslan and Eyuboglu, 2017). In fact, consuming liquids containing carbohydrates and electrolytes is more effective than plain drinking water, and drinking these liquids cold will also be more beneficial (Maughan et al., 2010.) In order to restore the mineral and vitamin balance of the body, which is especially disturbed by sweating, foods containing sodium and beverages should be consumed, and the nutrition program should be arranged accordingly (Casa et al., 2012). In addition to the athletes, the supervisors and organizers should be knowledgeable about heat stroke and dehydration and should monitor the athletes throughout the competition (Casa et al., 2012). They should notice the first signs of such a case and have immediate treatment information (Casa et al., 2012).

To maximize regeneration and recovery in athletes, individuals should be advised to rest in a cool environment during periods of inactivity (e.g., off days, between sessions on double exercise days) (Casa et al., 2015). Relaxation periods should include meal times, and athletes should be allowed between 2 and 3 hours to digest and absorb food, fluids, electrolytes (mainly sodium and chloride), and other nutrients before the next training or competition (Casa et al., 2015). If sports are to be done in areas where air pollution is intense or ozone density is high, early morning or late evening and time periods when traffic is not heavy should be preferred (Casa et al., 2015).

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