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Abstract

Purpose: To describe the effects of travel distance and bio-meteorological conditions on the 2020 multi-hosting UEFA European Championship's match outcomes and progress in competition. **Methods:** Teams' basecamps, distance from match venues, match outcomes (defeat, draw and win), bio-meteorological data (ambient air temperature, relative humidity and wet bulb globe temperature) and corresponding FIFA world ranking were extracted from the official UEFA and FIFA websites, respectively; and analyzed through Chi-squared test (impact of basecamp location on match outcomes), Kruskal-Wallis test (distribution of travel distances carried out according to match outcomes and competition phases), ordinal regressions (with match outcomes and competition phases as variables of interest and FIFA ranking and venue distance as explanatory variables) and principal component analysis with the bio-meteorological conditions and match outcomes for each match. **Results:** Teams with basecamp near match venue improved their match outcomes. However, neither Kruskal-Wallis test ($p > 0.05$) nor ordinal regressions (odds ratio (OR) > 0.96, $p > 0.403$) identified any significant effect of travel distance on match outcomes. Besides, FIFA ranking improved the likelihood of a favorable match outcome (OR = 0.87, $p = 0.001$) and progression in competition (OR = 0.97, $p = 0.003$). Further, despite some matches were played in more stressful bio-meteorological conditions, this was not associated with match outcomes (r = -0.07 to 0.19, $p > 0.188$). **Conclusions:** These findings cannot conclusively clarify on the effects of travel and bio-meteorological conditions on match outcomes and progress in the multi-hosting UEFA European championship, but suggest to carefully consider these variables for future multi-hosting competition to avoid any discrepancies between teams.

Keywords: soccer, home advantage, match location, match outcome, travel, heat.

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Introduction

For the first time in the UEFA European Football Championship competition's 60-year history, the edition 2020 – exceptionally delayed by one year due to the COVID-19 pandemic – was held across the continent with 11 host cities. The announcement of this new competition format by UEFA in 2012 was confirmed later on despite that it was postponed to adhere to local governments and health authorities. Herein, the consequence was the need to almost all participating countries to multiple short-haul air travels (*i.e.*, with minimal to no time zone disruption) and/or train and bus trips/transfer for either group stage and knockout matches. This raises the question of the optimal basecamp location in order to minimize any negative influence on the (successive) match outcomes.

Although the well-established home advantage phenomenon is consistently observed in the European domestic leagues[1] – even in the absence of crowd support during the COVID-19 pandemic[2] – its effect in international multi-hosting competition is less known. To our knowledge, this home advantage was however confirmed in the multi-hosting Rugby Six Nations tournament[3]. Among various influences (*e.g.*, crowd support, familiarity with local playing conditions, territoriality, referee bias)[1], two factors (*i.e.*, travel and bio-meteorological conditions), known as influential in the Brazilian football league[4], appear of interest in the particular context of this multi-hosting UEFA competition.

Major concerns associated with travel, regardless of transportation mode, are acute or cumulative fatigues[5], susceptible to impede performance[6] and increase injury risk[7]. This might be particularly relevant during a competition held on various venues over a short timeframe (*i.e.*, 4 weeks). Previous analyses from the 2018 FIFA World Cup have shown that travel distance and direction impacted on-match locomotor and technical activities and consequently end-of-tournament ranking[8]. In a competitive context where the smallest detail determines the

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final success or failure, dealing with geographical and bio-meteorological changes within the competition remains an important issue.

Adverse bio-meteorological conditions (*e.g.*, ambient air temperature [T_a], relative humidity [RH] and wet bulb globe temperature [WBGT]) may lead to hyperthermia and premature fatigue, thereby altering football match outcomes[9-13]. High T_a, RH and/or WBGT – that are integral factor of the home advantage[9] – were previously reported to affect football matches' outcomes (*e.g.*, decrease in total and high-intensity running distances covered toward match-end)[11] in a United Arab Emirates League's professional team[14], the Chinese Soccer League[15] and the 2014 FIFA World Cup[10 12]. With the growing incidence of heatwaves in Europe, such considerations seem relevant for the players' health safety and matches equities during multi-countries hosting competition susceptible to present variable climates.

This observational study therefore investigated whether there were any effects (1) of travel distance, and/or (2) of bio-meteorological conditions on the match outcomes and progress through groups and knock-out phases during the 2020 multi-hosting UEFA European Championship.

Methods

Study design and data collection

This non-interventional study was conducted in compliance with the Declaration of Helsinki and was approved by the institutional ethics committee. Data collection was compliant with the General Data Protection Regulations applied in the European Union.

The UEFA European championship participating teams' basecamps, match and bio-meteorological data and corresponding FIFA world ranking were extracted from the official UEFA (https://www.uefa.com/uefaeuro-2020/fixtures-results/) and FIFA websites (https://www.fifa.com/fifa-world-ranking/men?dateId=id13442), respectively.

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Variables and statistical analyses

For each team, travel distance was determined as the driving route (*e.g.*, from basecamp to the closest airport and/or from airport to match venue) and airline/flight route (*i.e.*, defined as the spherical distance between the two airports. Ambient air temperature and RH of the day for all matches (retrieved from the stadiums' meteorological stations reported on official UEFA match reports) were used to determine the WBGT calculated as follows[9]:

$$\text{WBGT (°C)} = 0.567T_a + 0.393[RH / 100 \times 6.105 \times \exp(17.27T_a / 237.7 + T_a)] + 3.94$$

In order to explain the impact of basecamp location on match outcomes, teams were categorized into basecamp near match venue (*i.e.*, inside hosting countries) or away (*i.e.*, outside hosting countries; in case of two opponents having both basecamps inside or outside hosting countries, data were not considered for calculation, with the exception of matches including participating hosting country teams), with dependency assessed with a Chi-squared test. In case of a significant test result, standardized residuals were compared to the quantiles of the normal distribution with thresholds of 0.01, 0.05 and 0.1, with residues exceeding the quantiles representing the derived dependencies. Further, Kruskal-Wallis test was performed to differentiate the distribution of travel distances carried out by each team according to the competition phases (*i.e.*, group stage [including first, second and third match], and knockout matches [round of 16, quarter-finals, semi-finals and final]) and match outcomes (*i.e.*, defeat, draw and win; final outcome considered during the knockout matches in case of overtime [n = 6 including 5 ending with penalty shot-outs]). Positive test was further examined through *post hoc* Wilcoxon tests with Bonferroni adjustment. Two ordinal regressions were also performed with match outcome and competition phases as variables of interest (model 1, $Y1$: defeat > draw > win; model 2, $Y2$: group stage > round of 16 > quarter-finales > semi-finales > final) and FIFA ranking ($X1$) and venue distance ($X2$) as explanatory variables. Odds ratios (OR

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[95% confidence intervals]) indicate the level of risk of the explanatory variable according to its level value (*i.e.*, increased risk to have a higher variable of interest with an increasing explanatory values).

A principal component analysis was performed with the bio-meteorological conditions (*i.e.*, T_a, RH and WGBT) as well as match outcomes derived variables (*i.e.*, total goals and goals difference) with each individual match. A correlation matrix, comprising the correlation coefficients and Pearson's tests, was used to determine the relationships between each variable of interest.

All statistical analyses were completed using the R statistical package (v 3.5; R Core Team, http://www.r-project.org) with significance level set at $p < 0.05$.

Results

Table 1 presents the descriptive characteristics of the participating teams.

Figure 1 illustrates that teams with basecamp near match venue (*i.e.*, located in hosting countries) improved their match outcomes (*i.e.*, residuals = -0.88, -0.17 and 1.02 for defeats, draw and win, respectively) and inversely, teams with away basecamp (*i.e.*, resembling visiting teams) decreased their likelihood of favorable match outcomes (residuals = 0.56, 0.11, -0.65 for defeats, draw and win, respectively). However, Kruskal-Wallis test did not reveal any significant difference between travel distance and match outcomes ($p > 0.05$). Likewise, ordinal regressions did not identify any significant effect of travel distance on match outcomes (OR = 1.03 [0.48; 2.29], p = 0.403) or competition phases (OR = 0.96 [0.87; 1.05], p = 0.934).

Noteworthy, FIFA ranking significantly impacted both match outcomes (OR = 0.87 [0.79; 0.94], p = 0.001) and competition phases (OR = 0.97 [0.95; 0.98], p = 0.003). This indicates

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that, for each 1-unit stronger FIFA ranked team (*i.e.*, lower FIFA rank), the likelihood of a favorable match outcome (by 15%) and to progress in competition phases (by 3%) improved. Figure 2 describes the repartition of matches played in reference to T_a, RH and WBGT. While no matches were played in very hot (*i.e.*, WBGT > 28°C) or extreme heat (*i.e.*, WBGT > 30°C), synonym of danger or extreme danger, 12 matches were performed with WBGT > 24°C with some corresponding to T_a > 30°C or RH > 80%, requesting extreme caution. No significant relationships (r ranging -0.07 to 0.19, all $p > 0.188$) were observed between the bio-meteorological conditions and the match outcomes (*i.e.*, total goals and goals difference).

Discussion

In an attempt to investigate whether there was any effects of travel distance, and/or bio-meteorological conditions on the match outcomes during the multi-hosting UEFA European Championship, the main findings are: (1) teams with basecamps near match venue improved their match outcomes, likely indicative of a "home advantage"; but (2) no significant effect of travel distance on match outcomes was identified; while (3) there was an accompanying FIFA ranking effect that improved the likelihood of a favorable match outcome and to progress in competition; and (4) despite some matches were played in more severe bio-meteorological conditions, no significant effect was observed on match outcomes.

Although not easy to isolate, travel distance is one of the various factors purported to underlie the well-described home advantage. In the particular context of the 2020 multi-hosting UEFA competition, the home advantage can be slightly observed (especially observable for hosting participants such as Italy, Netherland and England), but without any noticeable effect of travel distance on match outcomes. This aligns with previous studies that have reported a negligible effect of short-haul air travel on football codes match outcomes[6 16] with evidence supporting the home advantage phenomenon[16]. As observed here, other variables such as the FIFA

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ranking of the teams played a role in the likelihood of a favorable match outcome and to progress in competition. One of the main consequences of such multi-hosting competition is the additional cumulative fatigue due to repetitive travel regardless of the mode of transport (plane, train, bus)[5], travel distance and direction[8] and/or disruption of routines (*e.g.*, first-night effect on an unfamiliar environment)[17]. In order to avoid such inconveniences, we believe that the selection of basecamp location should be considered in light of many variables – including travel distance, but not exclusively – that may positively or negatively influence the match preparation and post-match recovery process in such multi-hosting competition setting. This also raises specific consideration from UEFA and FIFA stakeholders to avoid any biased organizational implications, the 2026 FIFA World Cup programmed in USA, Canada and Mexico – mixing long-haul travels, jet lag, bio-meteorological and altitude differences within the hosting cities – being a clear example.

Regarding the impact of bio-meteorological conditions during the multi-hosting UEFA competition, no effect was observable presumably due to the few matches played in challenging conditions. However, given the patterns of heat-induced fatigue during football matches[10-12 15 18] and the importance of heat acclimatization/acclimation on home advantage when competitions are held in hot and humid environments[4 9], this might be a fairness issue by not playing in similar environmental conditions during a multi-hosting competition, in case of heatwaves in Europe. Similar observation is also relevant regarding the detrimental effect of altitude on football performance during the 2010 FIFA World Cup[19 20] and highlights the search for optimal basecamp location for preparation and competition. When several home advantage and on-match related factors interact, as it will be the case for the 2026 FIFA World Cup, any minimal advantage over the concurrence may have an effect on end-of-tournament ranking.

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To conclude, bearing in mind some potential limitations such as the small number of matches analyzed and other home advantage-related variables (*e.g.*, COVID-19 restriction crowd support) or new regulation (*i.e.*, 5 substitution changes) not considered, this observational study cannot conclusively clarify on the effect of travel and bio-meteorological conditions on match outcomes and progress in the 2020 multi-hosting UEFA European championship, but suggests to carefully consider these variables (among other) for any (future?) multi-hosting competition to circumvent any discrepancies between participating teams.

Disclosure of interest

The authors report no conflict of interest.

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Figures legend

Figure 1. Chi-squared test residuals between basecamp location (near match venue or away) and multi-hosting UEFA European Championship's match outcomes.

Figure 2. Principal component analysis biplot of the multi-hosting UEFA European Championship's matches (dots and texts) on the variables (arrows) of ambient air temperature (T_a), relative humidity (RH) and wet bulb globe temperature (WBGT) as well as total goals and goals difference. The first two axes accounted for 72.5% and 27.3% of variance for dimension 1 and 2, respectively.

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Table 1. Summary of the multi-hosting UEFA European Football Championship dataset.

Team	FIFA ranking**	Group	Basecamp	Group standing	Final standing	Nb of matches played	Travel distance group (km)	16	QF	SF	F	Travel distance knockout (km)	Total travel distance (km)
Italy*	7	A	Coverciano, Florence (Italy)	1	F	7	1428.1	2418.1	970.5	2418.1	2418.1	8224.8	9652.9
Wales	17	A	Baku (Azerbaijan)	2	16	4	7747.7	7262.3				7262.3	15010.0
Switzerland	13	A	Rome (Italy)	3	QF	5	15496.3	2273.5	4691.6			6965.1	22461.4
Turkey	29	A	Baku (Azerbaijan)	4	GS	3	7747.7						7747.7
Belgium	1	B	Tubize (Belgium)	1	QF	5	10520.0	3410.0	1203.9			4613.9	15133.9
Denmark*	10	B	Helsingor (Denmark)	2	SF	6	270.0	1241.6	6398.3	1916.2		9556.1	9826.1
Finland	54	B	Repino, St Petersburg (Russia)	3	GS	3	3508.4						3508.4
Russia*	38	B	Novogorsk, Moscow (Russia)	4	GS	3	5632.1						5632.1
Netherland*	16	C	Zeist (Netherland)	1	16	4	342.0	2292.0				2292.0	2634.0
Austria	23	C	Seefeld (Austria)	2	16	4	6190.3	1918.2				1918.2	8108.5
Ukraine	24	C	Bucharest (Romania)	3	QF	5	3575.7	4958.5	2273.5			7232.0	10807.7
North Macedonia	62	C	Bucharest (Romania)	4	GS	3	3575.7						3576.7
England*	4	D	Burton-upon-Trent (England)	1	F	7	1380.5	460.0	2873.8	460.0	460.0	4253.8	5634.3
Croatia	14	D	Rovinj (Croatia)	2	16	4	12836.2	2345.6				2345.6	15181.8
Czech Republic	40	D	Prague (Czech Republic)	3	QF	5	7666.0	888.4	5891.6			6780.0	14446.0
Scotland*	44	D	Middlesbrough	4	GS	3	1584.6						1584.6

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			(England)									
Sweden	18	E	Gothenburg (Sweden)	1	16	4	9548.2	2012.5			2012.5	11560.7
Spain*	6	E	Madrid (Spain)	2	SF	6	2339.9	4146.0	6379.9	2524.0	13049.9	15389.8
Slovakia	36	E	St Petersburg (Russia)	3	GS	3	7158.1					7158.1
Poland	21	E	Sopot (Hungary)	4	GS	3	9058.3					9058.3
France	2	F	Clairefontaine (France)	1	16	4	6344.0	3740.7			3740.7	10084.7
Germany*	12	F	Herzogenaurach (Germany)	2	16	4	1164.3	1654.2			1654.2	2818.5
Portugal	5	F	Budapest (Hungary)	3	16	4	1124.3	4652.4			4652.4	5776.7
Hungary*	37	F	Telki (Hungary)	4	GS	3	1124.3					1124.3

* Participating hosting countries: Denmark (Copenhagen), England (London), Germany (Munich), Hungary (Budapest), Italy (Rome), Netherland (Amsterdam), Russia (St Petersburg), Scotland (Glasgow), Spain (Seville); Azerbaijan (Baku) and Romania (Bucharest) were non-participating hosting countries.
** calculated on 27 May 2021.
GS: group stage; 16: round of 16; QF: Quarter-finals; SF: semi-finals; F: final.

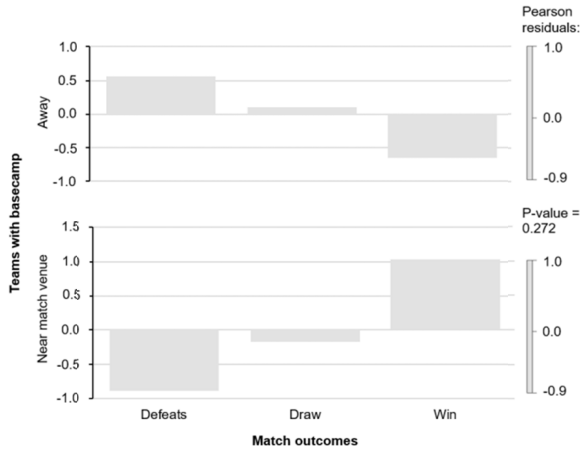

Fig1

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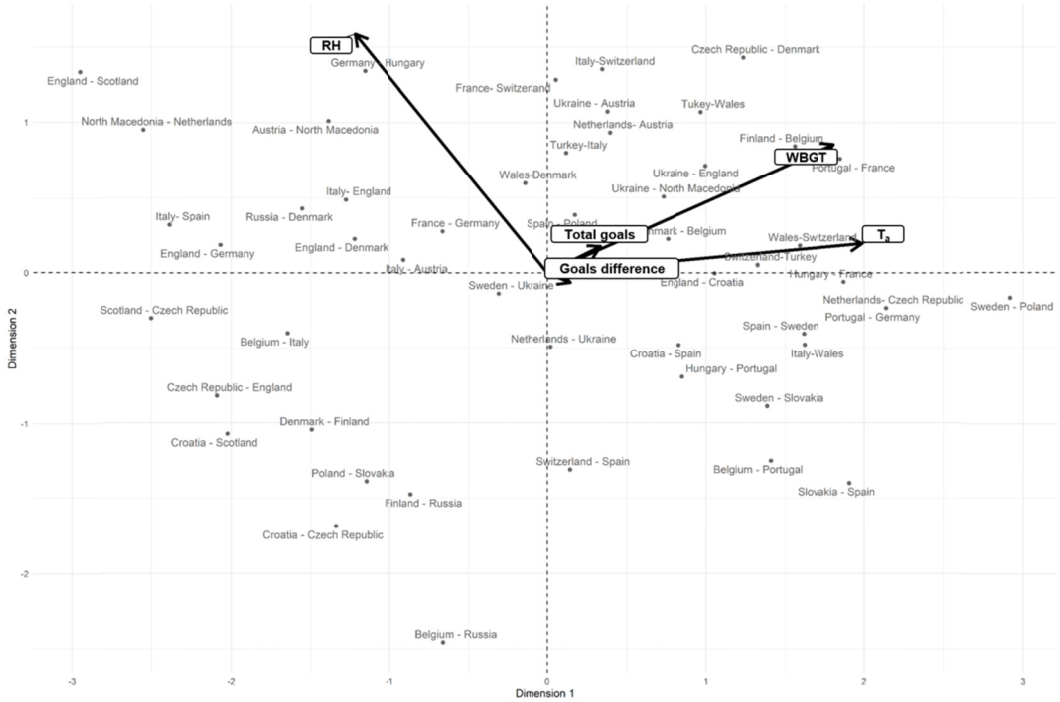

Fig 2

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