DIFFERENCES IN HOME ADVANTAGE BETWEEN SPORTS

Marshall B. Jones

The Pennsylvania State University
Differences in Home Advantage between Sports

Existing theories of home advantage attempt to explain home advantage wherever it exists; that is, they attempt to explain home advantage as a phenomenon. They do not attempt to explain the differences in home advantage between sports. There are only two studies in the literature that attempt to do so, and one of them is limited to contrasting baseball with other sports (Gómez, Pollard, & Luis-Pascal, 2011; Jones, 2015).

Figure 1 presents home advantage from 2006-07 to 2015-16 by year for the five major professional sports for men in North America: soccer, basketball, baseball, American football, and ice hockey. The present paper asks the question “To what extent, if any, does the distance typically covered by an entire team in the course of a game associate with home advantage as depicted in Figure 1?” Such an association does not, of course, necessarily explain home advantage. Nevertheless, if it exists, then the association itself requires explanation.

The five sports in Figure 1 are represented by the élite leagues in each sport: soccer (English Premier League-EPL), basketball (National Basketball Association-NBA), baseball (Major League Baseball-MLB), American football (National Football League-NFL), and ice hockey (National Hockey League-NHL). The data are taken from the statistics pages of the league websites. Home advantage is taken as the percentage of home wins minus 50%. Ties are ignored; only decided games are considered. This way of calculating home advantage is the most commonly used. It is also unbiased. In basketball, baseball, football, and hockey all games are decided one way or the other in regular season play, but in soccer, ties are common, accounting for roughly a quarter of all games in the EPL. Any way of calculating home advantage that awards a positive value to ties inevitably reduces home advantage and would therefore constitute a bias against soccer vis-à-vis the other four sports.
The effect size of the difference between the proportions of all decided games won by the home team in soccer and baseball, .62 versus .54, is .16, as indicated by Cohen’s $h$ (Cohen, 1977, pp.180-85). A value of $h$ this size is accounted as “small” by Cohen’s rule of thumb; and the difference between soccer and baseball is the largest of the ten differences. Therefore, all of the differences would be described as small by Cohen’s rule, or smaller or smaller yet. Effect size, however, is not the most telling feature of Figure 1 but, rather, the curves’ robustness over time. Each curve consists of ten independent tests or demonstrations of home advantage. All the tests in a given curve indicate home advantage and almost all of the differences between two given curves are in the same direction. The sample sizes each year are large for baseball, basketball, and hockey and moderate for soccer and football. Most of the tests are statistically reliable, many at the .001 level; and the curves in Figure 1 are abbreviated. All five go back as far as the Second World War and two of them, baseball and soccer, go back more than a century (Pollard & Pollard, 2005). Home advantages are small in effect size but very robust with respect to time, at least at élite levels of play. Even differences in home advantage do not change often and, when they do, change slowly, requiring at least a decade to take place.

**Background**

**Individual sports**

The literature on home advantage has always focused on team sports. The pioneer paper by Schwartz and Barsky (1977) presented data on American football, basketball, baseball, and ice hockey but not a word on any individual sport. Nevertheless, a few papers on individual sports did appear, but not quickly: high school cross country (McCutcheon, 1984), high school wrestling (McAndrew, 1992), and Alpine skiing (Bray & Carron, 1993). In all of these studies the advantage was small, 3-4%; all three were also isolated studies. In the rest of the 1990s and the
first decade of the 21st century studies were published on tennis, golf, boxing, and the Olympics. Most of these studies were carried out in sizeable samples and some were statistically significant.

In 2013 Jones carried out a systematic review of all publications on home advantage in individual sports to date. It concluded (p.397) that “Except for subjectively evaluated sports [such as diving, gymnastics, or figure skating], home advantage is not a major factor in individual sports, much less does it play a role in individual sports comparable to its role in team sports.”

This last point was drawn out further by Jones (2015). In the major team sports home advantage can be shown to hold not just at present or in a selected sequence of years but repeatedly back over time. As pointed out earlier, the advantage in baseball can be shown to be significant year by year for more than a century. It holds not just in the major leagues but in minor leagues and college baseball also. Home advantage has been demonstrated in soccer not just in the EPL but in every level of English soccer (Pollard & Pollard, 2005). Soccer is played all over the world, and Pollard and Gomez (2014) have shown that home advantage exists everywhere. The advantage in basketball exists in the college game as well as the NBA. It exists in women’s basketball, as it does in women’s soccer or women’s hockey (Jones, 2015, p.795). In short, home advantage is characteristic of major team sports, but only in team sports. No such showing has been made for any individual sport.

The most compelling evidence that the home effect is minor or nonexistent in individual sports is embedded, oddly enough, in team sports. Many team sports include passages that can be described as “individual efforts.” Free throws in basketball are a good example. When a player attempts a free throw, he or she plays as an individual; teammates and opposing players are sidelined or otherwise idled. In samples from the NBA numbering 95,494 (home) and 90,875 (away) Jones (2013) reported a difference in conversion rates of 0.2%, 75.2% (home) to
75.0% (away), not significant at the .05 level (critical ratio = 0.71, \( p > .4 \)), despite the enormous sample sizes and despite, too, the efforts of hometown fans behind the backboard to distract the away shooters.

Shootouts in NHL ice hockey are used to decide games in the regular season that end in ties after regulation time and one 5-minute overtime period. A shootout consists of a sequence of contests each one pitting a shooter from one team against the goaltender from the other. Here again we have an individual effort embedded in what is otherwise a team sport; and again the result is no difference between conversion rates for the home and away shooters (Jones, 2013; McEwan et al., 2012). In fact, both of the reports just cited found a small but nonsignificant difference in favor of the away shooters.

Penalty kicks in soccer are a third example. Dohmen (2008) collected all penalty kicks in the German Bundesliga from its foundation in 1963 until the end of the 2003/2004 season, a total of 3619 kicks. The result was the same as in hockey shootouts. Out of 2560 kicks the home kickers converted 1884 or 73.6%; out of 1059 kicks the away kickers converted 803 or 75.8%. The difference is not significant (\( z = 1.39; p > .05 \)) and in the wrong direction; the away kickers did better than the home kickers, albeit not reliably better.

These observations could hardly be clearer. In all three cases the individual efforts are embedded in a team sport. The individual players are also teammates in the team sport. The court, rink, or pitch is the same. The same crowd, the same officials, the same games, all are the same; and all three sports show hefty home advantages as teams. Yet when the same players compete as individuals, the home effect goes away.

**Away disadvantage**
The teamwork theory (see below) contends that the home effect is better understood as an away disadvantage than as a home advantage. Of course, as far as the numerical result is concerned, home advantage and away disadvantage come to the same thing,

\[
\frac{\text{Home Wins}}{\text{Home Wins} + \text{Away Wins}} = .5 - \frac{\text{Away Wins}}{\text{Home Wins} + \text{Away Wins}}
\]

The two formulations do differ, however, in suggested locus of action. Home advantage suggests that the cause or causes of the effect act primarily on the home team and away disadvantage that they act primarily on the away team. This difference in which team is primarily affected may be helpful in separating the two formulations. If a cause could be found which counters or nullifies the home (away) effect, then, perhaps because of where it acts or what it is, it might be possible to infer which formulation is the more correct. The teamwork theory contends that playing away puts a team on the defensive. The away players realize that they are not in familiar circumstances, that the crowd is against them and, they suspect, so are the officials. They feel on the defensive, even intimidated or threatened. If it could be shown that other causes known or suspected of putting a team on the defensive also affect the home (away) effect and do so conformably to theoretical expectations, it would constitute evidence in favor of the teamwork theory. Concussions and other injuries in football or fighting in ice hockey may be cases in point (Jones, 2016).

**The teamwork theory**

There are three principal theories currently advanced to explain the home advantage in team sports. All three agree that in one way or another where the game is played (at home or away) and the attitudes of the crowd and officials are critical. They disagree about how these circumstances are mediated and what they affect. The popular theory has it that the home players are
encouraged as individuals by the support they receive from the hometown crowd and play better as a consequence, while the away players are discouraged. The second theory claims that it is the officials, not the players, who are affected by the manifest, often noisy support of the hometown crowd (Balmer et al., 2001, 2003; Nevill et al., 2002). They can’t help but be affected, even if unconsciously, by how the crowd responds to their decisions for or against the home team. The teamwork theory agrees with the popular theory that the home effect is mediated by the players but disagrees that it is their play as individuals that is affected.¹

The main tenet of the teamwork theory is that the away effect depends on how well the players on a team work together to achieve their common purpose of winning the game. It begins, however, with the away players feeling on the defensive. This feeling affects both their behavioral and perceptual dispositions. One of the earliest and best-established results of stress research is that the attention of people who feel threatened narrows on whatever it is that they perceive as threatening them (Combs & Taylor, 1952; Easterbrook, 1959). In the case of team sports, away players tend to focus on their opponents rather than their teammates.

It was not until after the Second World War that the narrowing effects of stress on the perceptual field and stress in general moved to center stage in psychology. The spearhead of this surge was Hans Selye’s “general adaptation syndrome.” Very quickly, specific features of this syndrome began to emerge. As early as 1952 Combs and Taylor asserted that “The perceptual field of the threatened individual becomes restricted to the area of the threat he perceives.” Combs

¹ These three theories all specify a mechanism whereby playing at home or away affects the outcome of the game. Studies which report a “factor” several steps removed from the away (home) effect, the play of the game, or even the playing field have not been included.
and Taylor themselves used sentences as stimuli, such as “The silly worms crawled over my neck” or “His brain was crushed to a mushy pulp.” In the next few years a rush of papers pursued the same theme, using a variety of stressors. All were to some extent aversive such as oppressive heat, a bucket of ice water, or loud and unwelcome noises. Some were potentially threatening such as insults, angry or hostile faces, or sentences like those used by Combs and Taylor. At the end of the decade Easterbrook (1959) reviewed this literature and advanced a proposal.

Attentional narrowing was also called restricting, focusing, concentrating, or funneling the field of view, perception, or awareness. Perhaps the least misleading, because it carried the least irrelevant baggage, was what Easterbrook called it, “a reduction in cue utilization.” Easterbrook’s proposal was that “emotional arousal acts consistently to reduce the range of cues that an organism uses; and that the reduction in range of cue utilization influences action in ways that are either organizing or disorganizing, depending on the behavior concerned.” Research since the 1950s has been directed mainly at detailing this proposal, especially its latter half.

The research reviewed by Easterbrook related only to unpleasant situations, what came to be called “negative” stressors. What about “positive” stimulation, for example, pictures of appetizing food or erotic nudes? Some recent studies indicate that positive stimulation broadens attentional focus (Frederickson & Branigan, 2005; Hicks & King, 2007). Others present evidence that positive stimulation broadens attentional focus only if it is low-intensity; if it is high-intensity it narrows attentional focus (Gable & Harmon-Jones, 2008, 2009). However, on the central issue for present purposes there is no disagreement. Negative (threatening or potentially threatening) situations narrow and focus one’s attention on whatever is perceived to be the source of the threat (Steenbergen, Band, & Hommel, 2011).
Consider, then, the situation of a team playing away in a major sport. The situation is enclosed. The stadium or arena blocks the horizon on all sides; and it is filled with people, most of whom are vociferously rooting for the away team’s defeat. Chants and fight songs fill the air, while cheer leaders work the crowd. Sometimes a sequential wave sweeps the crowd, massed fists punch the air in unison, or large numbers of outstretched stiffened arms snap shut to indicate to opponents of the Florida Gators what’s in store for them. However, it is the opposing (home) players who will actually deliver these threats. The crowd may sound and show its support but it is the home players who will defeat the away team, and it is on them that the away players tend to focus.

Teamwork, however, requires players on the same side to pay attention to one another; and a tendency to focus on the opposing players contravenes that requirement. It’s not just a varying distraction; an attentional focus on the opposition specifically excludes attending to one’s teammates. The result is to impair concerted action. If one player hangs back because he is feeling on the defensive or because he is unaware of his teammates’ intentions and expectations (or the two together), then any action involving him is compromised and likely to fail, not all the time or always to the same degree but enough so to produce the away effect, which is not after all a large effect (at most ~62% as opposed to 50%).

A tendency to focus on the home players, especially those nearest to him physically and most likely to interfere with what he attempts to do, may prompt a concern in the away player for his own performance or safety. Such concerns, while they may impair performance in other ways, also systematically divert an away player’s attention from his teammates.
Applications of teamwork theory

So far the teamwork theory has successfully explained two major puzzles of the away effect. The first is that individual sports show little or no home advantage and, when they do, it is not characteristic of the sport. The teamwork theory asserts that the away (home) effect is mediated by interaction among players on the same side, that is, among teammates. Therefore, since individual sports are played by only one person on a side, the effect cannot exist in individual sports. If on an isolated occasion an effect is found, it is the result of minor causes happening to come together on that occasion.

The second puzzle to the teamwork theory’s credit is an explanation of why baseball has the smallest home advantage of any major sport in America. It is not the only explanation. In fact, this paper will advance a second, overlapping account of the same result. The gist of the earlier already-presented account is that, while unquestionably a team sport, perhaps half of the plays in a typical baseball game involve only one person on one team or the other.

When a player comes to the plate, more often than not he is the only player on his team on the playing field. The figures for 2016 (both leagues) were that in 104,864 out of 184,580 appearances at the plate or 57.1% of the time, there was no teammate already on base; and this result is repeated year after year. In baseball the team at bat is represented by a single player more than half the time. It is one man against nine players in the field.

For the team in the field it is much the same. The playing field in defense is divided into areas; and a player is responsible only for balls that are hit or thrown into his area. In the years from 2002-16, 56% of all batted balls in play were fly balls or line drives, and 44% were ground balls. Fly balls or line drives are caught 62% of the time. Therefore, at least 35% of all batted balls in play are fielded by just one player (Sawchik et al., 2017). Occasionally a blooper hit weakly
over the infield draws a crowd and interaction (communication) among the players is required to avoid the ball’s dropping for a hit. These cases are more than balanced by ground balls hit down the first base line where the first baseman fields it and steps on first base.

In all of these cases a single player performs by himself within a team sport, just as a basketball player performs free throws by himself or a soccer player penalty kicks (or a hockey player penalty shots). In basketball, soccer, and hockey these individual actions are known to be performed as well away as they are at home. If this generality holds in baseball, it explains why the home advantage in baseball is so small, although there may be other explanations to the same effect.

The away disadvantage in baseball, though small, unquestionably exists; and so do obvious examples of teamwork. The interaction between pitcher and catcher is involved in every play. Double plays around second base are combination play at its best and occur frequently. Plays in the infield routinely involve the first baseman as well as another infielder. Nevertheless, the away disadvantage remains low, in part, because almost half of all plays involve an individual acting by himself.

**Hypothesis**

The importance of teamwork in a sport varies and many differences between sports may affect it. The present paper focuses on the total distance covered by a team’s players in the course of a game. The away disadvantages are known (Figure 1). The hypothesis under test is that the more players a team has and the more they move the greater the disadvantage to the team playing away, despite the many other ways in which these sports differ one from the other.

The thinking behind this hypothesis begins with the observation that if a team relies solely on individual abilities (little or no teamwork), the more ground a team covers the more disorganized
it becomes. The hypothesis then follows from two propositions. First, the more players, the more moving parts, a team has and the more they move the more important teamwork is (to prevent the team from becoming disorganized). Second, the more important teamwork is the greater the disadvantage to the team playing away (by the teamwork theory).

**Methods**

The present study reports two characteristics of a sport: the number of moving parts a representative team in the sport has and the total distance covered by the members of the team in a representative game. In soccer, basketball, and baseball the number of parts equals the maximum number of players on the pitch, court, or field at the same time, that is, 11, 5, and 9 respectively. In all three sports each player is a “moving part.” He plays a “position,” distinguished by the role he is assigned, the skills needed to play well, and often a preferred physical type.

Substitutions in soccer, basketball, and baseball do not present a problem. In general, they are small in number and made one at a time. In soccer the number is limited by rule to three. In basketball and baseball it may be more than that but generally it is not. In other sports, however, substitutions have utterly transformed a sport. American football is a case in point. Before the Second World War the same 11 men played “both ways,” that is, they played when their team had the ball and when the other team had it, with occasional individual substitutions. After the war the game began to change as coaches made increasing use of free substitution and players

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3 It should be noted that all three sports are sometimes represented by less than these numbers of players. The major exception is baseball. The team at bat may have as few as one player on the field at a given time. In the field, of course, it is always represented by nine players. Other exceptions are red cards in soccer, power plays in hockey, and free throws in basketball.
tended increasingly to specialize in offense or defense. By 1964 the “two platoon” system was established. In effect, the number of positions had doubled, with eleven on the offensive platoon and eleven on the defensive platoon.

A platoon, it should be noted, is not just another group of positions. Players on the same platoon enter and leave the game together; they play as a unit. The substitution of one player for another is not platooning, in part, because an individual is not a team; he or she has no interpersonal character. In addition, platoons often have their own coaches and to a large extent train separately. When one player substitutes for another, both players are trained for the same position, have the same coaches, and the same or similar skill sets. One may be more proficient than the other but there is no change in the architecture of the sport.

Platooning is more complicated in ice hockey but fully as extensive. In current practice a team uses three (sometimes four) “lines” of forwards. Each line consists of three skaters and they are moved in and out of the game en bloc in what are called “shifts,” lasting as a rule about 45 seconds. The defensemen, two pairs, also play shifts, though the shifts usually last somewhat longer. The differentiation between one platoon and another is less dramatic in hockey than in American football, but still clearly present. The first line is usually called the “scoring” line and the third the “checking” or “defensive” line, while the second line is often designed to provide a balance of offensive and defensive capabilities. Thus a hockey team’s complement usually consists of three lines of forwards, two pairs of defensemen, and the goaltender, who typically plays the entire game, a total of 14 positions.

There are, then, two ways of counting the number of players (positions) on a team. The first (Positions 1) refers to the maximum number of positions (players) on the same team at the same time. The second (Positions 2) refers to the maximum number of positions on the same team in
the course of a game. In sports which do not practice platooning (soccer, basketball, and baseball) Positions 1 and 2 are the same.

The information currently available from which it is possible to estimate distance covered varies greatly in how it is collected and the quality of the estimate it allows. By far the best is player tracking, by the use of cameras and computers or by attaching devices to the players. Player tracking is currently emplaced for soccer and basketball, and distance covered has been aggregated over games for individuals or teams. The results are available online and are used in this study for these two sports.

Player tracking is also emplaced for major league baseball but individual or team data aggregated over games are not available. Baseball, however, is a discontinuous sport with games broken into innings, plays, and pitches. With the possible exception of soccer, it is also the oldest of the five major sports; and from the beginning its episodic nature has lent itself to the collection of statistics. Baseball statistics today are wonderfully detailed, comprehensive, and available. As a result it is possible to estimate the distance typically covered by a team in the course of a game from conventional statistics and is so estimated in this study.

Football is like baseball in that player tracking is emplaced but so far distance covered aggregated over games has not been made available, at least not for the NFL. A recent study by Wellman et al. (2016) has, however, used the Global Positioning System (GPS) to assess distance covered in college football. The subjects were football players from NCAA Division 1 schools (Football Bowl Subdivision). Division 1 schools are the primary recruiting ground for the NFL; and the rules of play at the college level, while differing in a few particulars, are essentially the same as in the NFL. An estimate calculated from information in the Wellman et al. report, while not ideal, is the best (in fact, the only) available option.
Rumors that the NHL is about to adopt a player tracking system have circulated for years but so far nothing definitive has happened. The present study uses a poorly documented but highly authoritative assessment of distance covered by “an average player” in the course of a game. Applying this assessment to the typical complement of an NHL team yields an estimate of distance covered by the entire team.

The estimates for soccer, basketball, and baseball can be safely regarded as benchmark results. The estimates, however, for hockey and football are better regarded as hypotheses to be tested when aggregated tracking statistics become available for all five sports.

Results

Soccer

SportVu is a tracking system produced in Israel that uses cameras above the playing field to track the players (Conover, 2017). SportVu is nonintrusive. It does not use chips or sensors or anything of the sort to identify the players. Instead, it relies on “computer vision” to recognize colors, shapes, or other marks. The NBA adopted SportVu in 2013. In the same year the EPL adopted TRACAB, a similar camera-based system produced by an American/Swedish company. However, FIFA, the international governing body for soccer, chose SportVu for the 2014 World Cup; and it is the World Cup data that are used in this paper to estimate distance covered in soccer.

The first stage in the World Cup is a group stage. The 32 qualified countries are grouped into eight groups of four each. Each country (team) plays every other country in its group, a total of six games a group, hence 48 games. The information on the FIFA website (FIFA World Cup,
2017) includes distance covered for each individual player on both teams in the 48 games. The mean distance covered by one team in a game (N = 96) was 107.0 kilometers.  

Basketball
As noted above, the NBA also uses SportVu and, beginning in 2013-14, has posted the results on its website. A user may choose which games he or she wants to see, which years, regular season or playoffs and, in the latter case, which rounds. A user may also choose how the results are to be presented, for example, by players or teams or by totals or averages per game. The following results are for the 2014-15 playoffs, all rounds, averages per game (NBA, 2017).

The playoffs involve eight teams in each of the two conferences. It takes three rounds to determine a conference winner and then a final round to determine the NBA champion. Each round is a best-of-seven series. Thus the 16 teams in the playoffs may play as few as 4 or as many as 28 games. Each team, however, covers an average distance per game regardless of how many games it plays. The average of these 16 averages came to 16.7 miles or, converting to kilometers, 26.9 km.

Baseball
Table 1 presents the relevant statistics for calculating distance covered by the team at bat in Major League Baseball in 2013. The data for this section are taken from Baseball Reference (2017).

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4 The group stage results were chosen to illustrate soccer because the knockout rounds are not representative of the sport as usually played, that is, in the regular season. In the knockout rounds every game must be decided. As a result, the games last much longer and the players cover much longer distances than in the regular season or group stage.
The first line concerns distance covered by the batter when he is “credited” with an out, that is, when he grounds out, flys out, or a teammate is forced or tagged out. Note first that strikeouts are not included. Typically, when a batter strikes out, he does not take off for first base but just walks back to his team’s dugout. Foul ball outs, that is, pop-up fouls that are caught by an opposing player, are also not included, because typically the batter remains in the batter’s box and just watches to see if the ball is caught or not.

Sacrifice bunts or flys (Line 2) are considered to be appearances at plate but not times at bat. Hence, the running the batters do to beat out a bunt or to run out a fly ball (even though it appears likely to be caught) are additional.

These first two lines are concerned with the distance covered by batters who are put out. The movements of players already on base, for example, a runner who is forced out at second when the batter hits a ground ball to the shortstop, are not considered in the first two lines of Table 1.

If a player gets on base by whatever means (a hit, walk, hit by a pitch, fielding error, or fielder’s choice), then he eventually scores or is left on base or is not left on base because he is put out before the third out ends the inning. The remainder of the table deals with each of these three possibilities.

If a player scores a run, he must have completed a circuit of the bases, that is, four times the distance from one base to the next (90 ft).

Distance covered by players left on base is broken into two components. The first (Left on Base 1) is the distance the runners must have covered to reach the bases they occupied before the inning-ending batter came to the plate. In a separate calculation the numbers of runners left on 1st, 2nd, and 3rd base were summed and divided by the total number left on base. The average was 1.74, that is, just about three quarters of the way from 1st to 2nd.
The second component (Left on Base 2) is the distance covered by the runners after the inning-ending batter came to the plate. With two outs already made, the runners typically break for the next base as soon as the ball is hit and run most or all the way to it.

 Forced Outs refers to plays in which a runner, typically but not necessarily on first base, is forced out at the next base, typically second. Double plays, in which a runner is also forced out, are not included. It is distance covered by the runner which is considered here, and that depends on where the runner is forced out. If the runner is forced out at second, he has covered two bases, third three bases, and home four. The average number of bases run is 2.07. Outs at bat takes account of the batter’s run to first base.

 In a typical Double Play a runner on base is forced out at second, third, or home and the batter at first. The batter is already accounted for under Outs at Bat. It is the runner already on base who requires accounting. As in forced outs, the runner in double plays is usually thrown out at second. It is much less common for a base runner in a double play, as in forced outs, to be thrown out at third or home. Hence, the average number of bases run in Double Plays has also been estimated as 2.07.

 Runners caught stealing are also most often put out at second but some, not many, at third or home. Hence, the average number of bases covered in Caught Stealing has also been put at 2.07.

 Other Outs on Base includes runners who are put out trying to advance on a fly ball or reach an extra base on a hit; it also includes runners who are caught off base after a hit to the outfield or put out attempting to advance on a wild pitch or passed ball. In general, Other Outs on Base includes all plays in which a base runner is retired but not accounted for in lines 6-9.

 Altogether, players on the team at bat average 1.6 kilometers covered per game. The movements of players in the field are not packaged into such neat quantitative categories as players on
the team at bat. On a strictly observational basis, however, it does seem safe to say that players in the field do not cover more ground than players at bat. Therefore, 3.2 kilometers per game is an upper bound to the distance covered per team per game in Major League Baseball.

**American football**

Each of the 33 player-subjects in the study by Wellman et al., mentioned earlier, was outfitted with a GPS receiver. The receivers were placed in a custom-designed pocket attached to a player’s shoulder pads before the game began. They remained there until the game was over, when they were downloaded to a computer for analysis. Twelve specific games in the 2014 regular season (September through November) were selected for study, and each one of the 33 subjects contributed one acceptable dataset.

To be “acceptable” the dataset had to include at least 75% of the total offensive or defensive plays in the game at issue. The paper did not indicate what the percentage of all offensive or defensive plays a dataset included. Hence, the figures used in this study, since they are taken from Wellman et al., are underestimates of total distance covered. On the other hand, the receivers ran continuously from before the game until after it and must have included ground the player covered when the clock was not running, for example, when a player carried the ball out of bounds, after an incomplete pass, on a penalty, or when a player was injured. These two sources of error tend to counteract each other and may have resulted in a figure not greatly different from what it would have been if only movements made while the clock was running were counted.\(^5\)

\(^5\) As is the case in soccer, basketball, and hockey.
Wellman et al. grouped the data sets according to positions played, five groups for offense and four for defense. For offense the groups were wide receivers, quarterbacks, running backs, tight ends, and offensive linemen. For defense the groups were: defensive backs (cornerbacks and safeties), linebackers, defensive ends, and defensive tackles. The average distance covered by the players in each group was then multiplied by the number of positions in the group and summed:

Offense,

<table>
<thead>
<tr>
<th>Position</th>
<th>Average Distance (m)</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>wide receivers</td>
<td>5,530.6</td>
<td>2</td>
</tr>
<tr>
<td>running back</td>
<td>3,140.6</td>
<td>1</td>
</tr>
<tr>
<td>quarterback</td>
<td>3,751.9</td>
<td>1</td>
</tr>
<tr>
<td>tight ends</td>
<td>3,574.2</td>
<td>2</td>
</tr>
<tr>
<td>offensive linemen</td>
<td>3,652.4</td>
<td>5</td>
</tr>
</tbody>
</table>

Total = 43,364.1 meters

Defense,

<table>
<thead>
<tr>
<th>Position</th>
<th>Average Distance (m)</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>backs</td>
<td>4,696.2</td>
<td>3</td>
</tr>
<tr>
<td>tackles</td>
<td>3,013.0</td>
<td>3</td>
</tr>
<tr>
<td>ends</td>
<td>3,276.6</td>
<td>2</td>
</tr>
<tr>
<td>linebackers</td>
<td>4,145.4</td>
<td>3</td>
</tr>
</tbody>
</table>

Total = 42,117.0 meters

The total distance covered by the team as a whole then equaled 85.5 kilometers.

---

6 In the NFL special teams may constitute an additional platoon or platoons.

7 The figure for tackles is taken to apply to the three interior defensive linemen.
Hockey

The National Hockey League (NHL) has not yet adopted a player-and-puck tracking system, although it has been working with a company called Sportvision for seven years to develop such a system. Reports have it that the system may be introduced in the 2017-18 season, but so far nothing definite.

Otherwise, all we have is an article in Popular Mechanics published in 1968. The article was written by a journalist named William Barry Furlong on the basis of an interview with Lloyd Percival, at the time director of the Toronto Sports College. The article is loaded with statistics obviously provided by Percival. One of the statistics is an estimate of distance covered in hockey. The estimate reads “Distance an average player skates in a game: 2.3 miles.”

It is clear from the context that this estimate refers to individual players, not positions. Just about everything else, however, is not clear. The text of the article does not indicate how this figure was obtained (human observation, video, radar gun)? It does not say who “an average player” includes. How many lines of skaters? Two pairs of defensemen? It is, however, safe to assume that the estimate applies to the NHL.

The one thing in the estimate’s favor is its author, Lloyd Percival. Percival’s biographer Gary Mossman called Percival “Canada’s greatest athletics coach and first sports scientist.” Foremost among Mossman’s reasons was a book Percival wrote in 1951 entitled The Hockey Handbook. This book is still a classic, touted by many as the best book ever written about how to play hockey. It was adopted by Soviet hockey and became its “bible” in the years from 1954 to 1991 when the Russians dominated the hockey world. Percival was also an early believer in scientific measurement and the importance of carefully collected numerical indices of hockey performance.
If we assume Percival included under “average” three lines of forwards and two pairs of defensemen, then average distance covered by the team in the course of a game would equal, converting to kilometers,

\[2.3 \times 13 \times 1.609 = 48.1 \text{ km}.
\]

The goaltender, it is assumed, remains huddled in the nets and moves little.

**Summary**

Table 2 summarizes the results. For each of the five sports it presents home advantage, Positions 1, Positions 2, Distance Covered, Distance Covered/Position 1, and Distance Covered/Position 2. The hypothesis for this study claimed in part that home advantage was positively associated with the number of players (positions) a team has. As we have seen, this number turned out to be two numbers, Positions 1 and 2. The product-moment associations (correlations) between home advantage and Positions 1 and 2 are .24 and -.21 respectively. Clearly this part of the hypothesis is not supported by the present data. The two associations differ in sign and are both small.

It remains to consider the phrase “and the more they move,” which makes up the rest of the hypothesis. The relevant results here are the associations between home advantage and the last three columns in Table 2. The associations are:

- distance covered, .65
- distance covered per position 1, .58
- distance covered per position 2, .94.

The average of the three correlations is .72. Thus, as far as the present data go, this part of the hypothesis seems to be supported. For home advantage as a function of distance covered per position 2, see Figure 2.

**Discussion**
On the other hand, one of the two parts that made up the hypothesis has been contradicted. Home advantage associates strongly with distance covered, whether by itself or per position 1 or 2, but it doesn’t seem to matter how many players there are on the field. This contradiction creates a stumbling block for the teamwork theory. At the least it requires a reexamination.

The teamwork theory holds that the away players feel on the defensive and because they do and because of the attentional narrowing that being on the defensive entails, they play more cautiously, less aggressively, even less correctly than the home team; further, this kind of defensive play specifically impairs teamwork.\(^8\)

In American football almost everything that a player does, whether on offense or defense, is done in relation to teammates. Running backs and blockers in the open field have to coordinate with each other; corner backs and safeties have to cover for each other; interior linemen positioned next to each other need to work in combination, whether on offense or defense. These examples also involve opponents, of course; but the problem with players who feel on the defensive, that is, the away players, is that they tend not to notice their teammates; in general, they pay too much attention to their opponents.

There is a need in football as in all team sports for strategy, for a plan or plans that apply to the whole team. In football this need is met in part by the “playbook,” a list of all the plays in the team’s repertory. This book, however, is not written by the players but by the coaches. The

\(^8\) The evidence that the away team plays more defensively is extensive in soccer (Sasaki et al., 1999; Carmichael & Thomas, 2005; Tucker et al., 2005; Taylor et al., 2008; Seckin & Pollard, 2008). Note, however, that this defensiveness is not necessarily passive or good-natured. Fouls and yellow or red cards are also more characteristic of the away players.
coaches design the plays; usually they call the plays as well. The players’ role is to implement the plays, and to do that each player has “to do his job.” These jobs are the pieces of a play, each one assigned to a particular player (position). In a typical job one player serves as subject or frame of reference, together with instructions as to what he should do, and usually with which teammate or two he should do it. Note the numbers, one or two. The design of a play is, of course, key and every player has to know what it is and how he fits into it; but the teamwork necessary to making it work is carried out in small groups.

Consider, for example, a quarterback going through his progressions. Let the quarterback serve as subject or frame of reference. He looks at the first receiver in his progression and the opposing player defending him. If the receiver is covered, he moves to the second receiver and his defender. He may continue in this manner for as many as five receivers. The entire sequence involves 10 players other than the quarterback, five receivers and five defenders, but only two at a time.

In other examples there might be the man on the ball in soccer and two teammates or perhaps only one, as in a basketball player throwing an alley-oop. If “teamwork” is understood in this manner, as a sequence or set of one- or two-way interactions between the subject and a teammate, a teammate and defender, or two teammates, it makes sense that distance covered per position is the critical statistic. There may be 6 or 11 teammates on the field at the same time but

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8 At the cost of some detail a player can sometimes process a group of more than two players as a “chunk,” for example, the back line in soccer, but this chunk is perceived as moving as a unit with little individual variation.
people cannot anticipate the movements of more than two interacting others.\textsuperscript{10} In short, the hypothesis (and the rationale behind it) need to be modified, so that the former reads: “The greater the distance typically covered by a team per game the greater the disadvantage to the team playing away.”

Next Steps
The main result of this study is that home advantage in the five major team sports for men in North America is strongly associated with how much ground a team in the sport typically covers in the course of a game. Looking forward, the two main threats to this result are sampling variation and secular change over time.

The estimates of home advantage listed in Table 2 for the five sports are statistically reliable. American football has the largest standard error and it is less than 1%. The standard errors for the other estimates are smaller (soccer) to much smaller (basketball and hockey) to very much smaller (baseball).

As for change over time, home advantage has been declining since the end of the Second World War in both soccer and basketball but slowly, by 5 points in soccer and 4 in basketball over a span of 60 years. In football home advantage has been increasing but again slowly, less than 3 points over the same span of years. The home advantage in baseball hasn’t changed appreciably in more than a century. Hockey is the only major sport to have undergone a steep

\textsuperscript{10} It is worth noting that in physics there is no general analytic solution to the three-body problem. It seems presumptuous to suppose that athletes, with no general laws to help them, can anticipate the movements of three interacting bodies in space when physicists, with the most exact and best established laws in science, cannot.
change in home advantage in the post-war years. In the 1990s the home advantage in the NHL dropped 6 points and has remained low since then. A comparable change could, of course, occur again but, even if it did, it would not become obvious for several years.

Standard errors for two of the estimates of distance covered can be calculated. The estimate for soccer (107.0 km) was calculated from 96 individual game results in the group stage of the 2014 World Cup. The standard deviation was 6.15 km, the standard error of the mean 0.63 km, and the coefficient of variation (standard deviation/mean) 5.7%. The estimate for basketball (26.9 km) was calculated from the average distance covered per game of the 16 teams in the 2014-15 playoffs. The standard deviation was 0.59 km, the standard error 0.15 km, and the coefficient of variation 2.2%.

The three measures of variation cannot be calculated for baseball because the estimates of distance covered were obtained by dividing sums for the year by the number of games per year. However, the coefficients of variation for soccer and basketball are very small and the mean for baseball very low. If the coefficient for baseball was as much as ten times that for soccer (57%), the standard deviation for baseball would still be small. In short, with respect to sampling variation, the extremes for distance covered (soccer and baseball) are well anchored. Basketball, with a mean distance covered about a quarter of the way from baseball to soccer, is still many standard errors above the distance estimate for baseball.

Wellman et al. (2016) presented standard deviations (σs) as well as means for distance covered for each of the nine positional groups in their study of Division 1 football. If these σs are taken as population estimates, assumed to be independent of each other, and weighted for the number of positions in each group, it is possible to calculate a standard error for the estimate of
distance covered in football. So calculated, the error equals 3.95 km, which puts it five standard errors below the estimate for soccer and many more than that above the estimate for baseball.

However, the distance estimate for football is clouded by an assumption that two omitted sources of information not only counteract but nullify each other; no information at all is available as to the variability of the estimate for hockey; and no information is available either as to secular change in distance covered for any of the five sports. Several pieces relevant to reliability are known and supportive. Nevertheless, the data points for distance covered are in one or perhaps two cases more safely regarded as hypotheses than as facts and need to be tested. That test will come when aggregated tracking statistics are available for all five sports. There will then be two main questions. First, do the associations between away disadvantage and distance covered agree or disagree with the findings and estimates presented in this study; and second, if they disagree, are the differences favorable or unfavorable to the teamwork theory.

In the meantime there are all the sports other than the major five in North America: lacrosse, rugby (two forms), volleyball (two forms), cricket, crew, water polo, polo, field hockey, and many more. The teamwork theory of away disadvantage cannot be assumed to hold in them even if it is shown to hold in the major five; it still must be shown to do so.

Finally, there is the likelihood that other factors than distance covered may affect or associate with away disadvantage. This study has focused on distance covered to the obvious exclusion of speed, how long a game lasts, and the size of the playing field, all possible factors in the importance of teamwork. The surface or medium that a sport is played on or in, ice, water, horseback, skates, hardwood floors, sandy beaches, or terra firma, would also seem possibly to affect distance covered and therefore to play a role in away disadvantage, at least interactively.

References


FIFA World Cup (2017). Team tracking statistics. Available at: www.fifa.com/


and Motor Skills, 107, 51-54.


Table 1. Calculation of distance covered by the team at bat in Major League Baseball (2013).

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Bases</th>
<th>90 ft ± Games (4862)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outs at Bat</td>
<td>82,287</td>
<td>1</td>
<td>1,523.2</td>
</tr>
<tr>
<td>Sacrifice Bunts or Flys</td>
<td>3,732</td>
<td>1</td>
<td>69.1</td>
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<tr>
<td>Runs</td>
<td>20,255</td>
<td>4</td>
<td>1,499.8</td>
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<tr>
<td>Left on Base 1</td>
<td>33,658</td>
<td>1.74</td>
<td>1,084.1</td>
</tr>
<tr>
<td>Left on Base 2</td>
<td>33,658</td>
<td>1</td>
<td>623.0</td>
</tr>
<tr>
<td>Forced Outs*</td>
<td>4,036</td>
<td>2.07</td>
<td>154.6</td>
</tr>
<tr>
<td>Double Plays</td>
<td>4,356</td>
<td>2.07</td>
<td>166.9</td>
</tr>
<tr>
<td>Caught Stealing</td>
<td>1,007</td>
<td>2</td>
<td>38.6</td>
</tr>
<tr>
<td>Picked Off</td>
<td>174</td>
<td>1</td>
<td>3.2</td>
</tr>
<tr>
<td>Other Outs on Base</td>
<td>871</td>
<td>2.07</td>
<td>33.4</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td>5,195.9 ft (1.58 km)</td>
</tr>
</tbody>
</table>

* The number of batters who reach first base (Hits+Walks+Hit By Pitch+Reached on Error+Fielder’s Choice+Catcher Interference) equals the number of men on base who score or are otherwise accounted for (Runs+Left on Base+Double Plays+Caught Stealing+Pickoffs+Other Outs on Base). Forced Outs are not included in the latter sum, even though a man already on base is retired. The reason is that the runner is replaced by the batter who reaches first base safely, although not for any of the reasons included in the first sum. The replacement, however, is on first base while the runner was put out at second, third, or home. Thus, the free ride for the batter, while it balances the retirement of the runner, does not balance distance covered by the runner. The batter covers one base, while the runner covers mainly two but, many fewer times, three or even four. The same average number of bases per runner has been assumed to apply to Double Plays and Other Outs on Base.
Table 2. Home advantage, positions (1 and 2), distance covered, and distance covered per position 1 and 2, for all five sports.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Home Advantage*</th>
<th>Positions 1 (at a time)</th>
<th>Positions 2 (over time)</th>
<th>Distance Covered</th>
<th>Dist. Cov./ Position 1</th>
<th>Dist. Cov./ Position 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>soccer</td>
<td>12.1</td>
<td>11</td>
<td>11</td>
<td>107.0</td>
<td>9.73</td>
<td>9.73</td>
</tr>
<tr>
<td>basketball</td>
<td>9.4</td>
<td>5</td>
<td>5</td>
<td>26.9</td>
<td>5.38</td>
<td>5.38</td>
</tr>
<tr>
<td>baseball</td>
<td>4.0</td>
<td>9</td>
<td>9</td>
<td>3.2</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>football</td>
<td>7.0</td>
<td>11</td>
<td>22</td>
<td>85.5</td>
<td>7.77</td>
<td>3.89</td>
</tr>
<tr>
<td>hockey</td>
<td>4.5</td>
<td>6</td>
<td>14</td>
<td>48.1</td>
<td>8.02</td>
<td>3.44</td>
</tr>
</tbody>
</table>

* Averaged over the entire decade.
Fig. 1. Home advantage in regular-season, élite, professional sports for men: soccer, basketball, baseball, football, and hockey, 2006-07 to 2015-16.
Figure 2. Home advantage as a function of Distance Covered (km) Per Position 2.
Highlights

—Home advantage is not associated with the number of positions.

—Home advantage is strongly associated with distance covered by the entire team.

—Especially so in relation to the number of positions over the course of a game.