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Modelling home advantage in the Summer Olympic Games

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Home advantage in team games is well proven and the influence of the crowd upon officials' decisions has been identified as a plausible cause. The aim of this study was to assess the significance of home advantage for five event groups selected from the Summer Olympic Games between 1896 and 1996, and put home advantage in team games in context with other sports. The five event groups were athletics and weightlifting (predominantly objectively judged), boxing and gymnastics (predominantly subjectively judged) and team games (involving subjective decisions). The proportion of points won was analysed as a binomial response variable using generalized linear interactive modelling. Preliminary exploration of the data highlighted the need to control for the proportion of competitors entered and to split the analysis pre- and post-war. Highly significant home advantage was found in event groups that were either subjectively judged or rely on subjective decisions. In contrast, little or no home advantage (and even away advantage) was observed for the two objectively judged groups. Officiating system was vital to both the existence and extent of home advantage. Our findings suggest that crowd noise has a greater influence upon officials' decisions than players' performances, as events with greater officiating input enjoyed significantly greater home advantage.

Keywords: crowd noise, officiating, subjective judging.

Introduction

Baron Pierre de Courbertin proposed the revival of the Olympic Games in 1892, with the modern Olympic Games beginning in Athens in 1896. Since then, the Olympic Games has grown in number of events, number of competing nations, number of competitors and number of home competitors (although not proportionally to all competitors). There are now more than 40 times more competitors than in 1896, 14 times more nations competing and nearly seven times more events (43 in Athens *vs* 300 in Sydney). Although such growth has led to concerns about gigantism (Wallechinsky, 2000), the Olympic Games has evolved into perhaps the world's foremost sporting event, and provides a rare opportunity to examine differences in home advantage between sports.

The existence of home advantage in major team sports has been well established (for a review, see Nevill and Holder, 1999). Examples include baseball (Adams and Kupper, 1994), football (Pollard, 1986; Nevill *et al.*, 1996), ice hockey (Agnew and Carron, 1994) and basketball (Moore and Brylinsky, 1993). Courneya and Carron (1992) proposed four possible factors that are thought to account for home advantage: travel factors, learning/familiarity, rule factors and crowd factors. The present study focuses primarily upon crowd factors and specifically the influence of officials upon home advantage. For major league baseball, Schwartz and Barsky (1977) identified increasing home advantage with crowd density, while also attempting to control for team quality. Subsequently, Nevill *et al.* (1996) demonstrated frequency of penalties and sendings-off to favour the home side, this discrepancy increasing with crowd size. The authors concluded that the crowd might either influence away players to play more recklessly or affect the match officials' decisions in favour of the home side. There is now growing experimental support for the latter hypothesis, with Nevill *et al.* (1999, 2002a) showing the presence of crowd noise to result in an imbalance of refereeing decisions in favour of the home side.

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The prevalence of home advantage in both individual sport and unbalanced competition is less clear. Some evidence of home advantage has been identified in cross-country running (McCutcheon, 1984), wrestling (Gayton and Langevin, 1992) and World Cup alpine skiing (Bray and Carron, 1993). In contrast, once quality of athlete had been accounted for, home advantage was not found to be a major influence on performance in individual 'grand slam' tennis or 'major' golf tournaments (Nevill *et al.*, 1997). Holder and Nevill (1997) confirmed these findings, suggesting that any apparent home advantage is mainly an artefact of selection procedures that favour increased entry of lower ranked home competitors. The authors suggested that lack of home advantage could be due to both objective scoring systems and relatively little subjective input from officials. Multi-event competition such as the Olympic Games allows examination and comparison of home advantage between team and individual events, as well as between events relying on differing scoring systems. Previous research on home advantage in the Winter Olympic Games (Balmer *et al.*, 2001) has shown home advantage to vary between events, with a significantly greater advantage for disciplines in which officials directly judge outcome. It is suggested that officials in such sports (e.g. figure skating, freestyle skiing) may be scoring home competitors disproportionately highly.

There is extensive evidence of officiating bias in subjectively judged sports. Most of this evidence relates to specific nationalistic or political bias, rather than a more general home advantage. Nationalistic and/or political bias has been demonstrated for a range of subjectively judged events, including Olympic diving (Park and Werthner, 1977), figure skating (Seltzer and Glass, 1991) and gymnastics (Ansorge and Scheer, 1988; Whissell *et al.*, 1993). With the exception of Balmer *et al.* (2001), who provided some evidence, it is unclear whether the officiating bias observed in subjectively judged sports extends to home advantage.

Several recent studies have examined performance in the Olympic Games (e.g. Lozano *et al.*, 2002; Morton, 2002; Nevill and Stead, 2003). All of these studies examined performance at a nation level, reclassifying success while controlling for gross national product and population size (Lozano *et al.*, 2002), gross domestic product and population size (Morton, 2002) and gross national product alone (Nevill and Stead, 2003). Adjusted indices of success produced dramatic changes in ranking (compared with observed medal tables), with Eastern European and island nations fairing particularly well (Morton, 2002) and Cuba finishing top by a clear margin (Morton, 2002; Nevill and Stead, 2003). Although these three studies did not formally consider home advantage, it was acknowledged as a potential influence (e.g. Morton, 2002), though evidently the authors' main conclusion (regarding Cuba's performance) remains unaffected, since Cuba has never hosted the Olympic Games. Clarke (2000) examined home advantage in the Summer Olympic Games at a nation level (across all events). Home nations were shown to win approximately three times more medals in home Olympics (compared with away) and, interestingly, approximately two times more in Olympic Games either side of their home Olympics. Clarke's (2000) primary aim was to assess Australia's upcoming Sydney 2000 performance; although competitor participation was discussed (as an influential factor in 1956) it was not controlled for, as the paper was concerned with predicting performance rather than explaining home advantage. Indeed, Clarke (2000) was particularly successful in this respect, as Australia's predicted success (of approximately 20 gold medals and 60 medals in total) was remarkably similar to their observed medal tallies (16 gold medals and 58 medals in total).

As in tennis and golf tournaments (Nevill *et al.*, 1997), team/competitor quality is also a major consideration in the Olympic Games, given the highly variable medal winning potential of host nations. In Summer Olympic Games competition, for example, the United States has won nearly 50 times more medals than Mexico, even though both have been host nations. Assessing home advantage must, therefore, involve only a comparison of home and away performances of the same nation or team. Previous research has highlighted team quality as a likely influence, with 'superior' teams tending to exhibit greater home advantage (Schwartz and Barsky, 1977), although some authors have made reservations regarding the classification of quality (Madrigal and James, 1999). While earlier examples concerned team games, in which an assessment of the quality of home and away teams can be fairly easily made, Olympic competition typically involves many competitors with a diverse range of abilities, creating some difficulty in formally assessing quality. Madrigal and James (1999) proposed that a proportion of this 'team quality effect' may be due to superior teams enjoying larger or denser and more supportive audiences, although this is not the case for Summer Olympic Games, as success is not related to large home crowds. The year of the Olympic Games is more significant for spectator attendance, as numbers simply increase over time. For Olympic competition, stronger nations' dominance in a given event would severely reduce weaker host nations' opportunities for home advantage. Similarly, stronger nations, with more competitors capable of winning medals, should be able to produce more consistent home advantage. Evidently, then, team quality must be considered to correctly measure home advantage.

The aim of the present study was to compare home advantage between groups of events with varying styles of officiating. Realization of this aim would put the consistent home advantage observed in team games in context alongside both objectively and subjectively judged individual competition. We hypothesized that significant home advantage would be observed in subjectively judged events (gymnastics, boxing) in which the potential for biased officiating is at its greatest (Ansorge and Scheer, 1988). We also hypothesized that significant home advantage would be observed for team games, in which the crowd may have an influence upon subjective decisions made by officials (Nevill *et al.*, 1999, 2002a). In contrast, we hypothesized that events such as athletics and weightlifting, which have predominantly objective scoring and little input from officials, would show no home advantage.

Methods

Establishing unbiased home advantage

Inclusions and exclusions

Given the vast amount of Summer Olympic Games data, a subset of event groups was chosen, made up of track and field athletics, gymnastics, team games, boxing and weightlifting. The rationale for the choice of events is presented in the next subsection.

Assessment of home advantage concerns only nations who have hosted an Olympic Games (hosting nations) with intra-nation comparison (home *vs* away by nation) being central to a fair assessment. The inclusion of a large number of weaker non-hosting nations as away data would simply lead to unrealistically large home advantage. To produce the maximum number of hosting nations, only male data were analysed, as females typically did not compete until 1928 and, in many cases, much later (prohibiting a thorough pre-Second World War analysis). Having no data before 1928 alone excludes all data for Greece, France, Belgium and Holland, while the omission of women's hockey (first played in 1980) or basketball (first played in 1976) would result in significant loss of data.

Additionally, if a given hosting nation has neither won home nor away in an event, at any Olympic Games, they were excluded. This resulted in a differing number of hosting nations between events, both as a result of which Olympic Games each event was held at and hosting nation performance. A single medal won, home or away, qualifies a hosting nation for inclusion in the analysis, classifying them as a successful hosting nation for a given event or group of events.

Selection of events

Event groups were chosen on the basis of longevity (i.e. how many Olympic Games events have been contested) and, most importantly, to allow contrasts between officiating style. Officials have little or no input in weightlifting or athletics. In contrast, they decide most outcomes in boxing and all outcomes in gymnastics. In team games, although the outcome is decided by goals, points or baskets, officials make many subjective decisions. The following groupings were included:

1. Track and field athletics were included as they form the focal point of modern Olympic Games, as well as a comprehensive and continuous source of data. Athletics as a whole contributes 12 of the 16 individual events contested at all Olympic Games (Greenberg, 2000). Most importantly, events have objectively measurable outcomes and little subjective input from officials. As a result of this, track and field athletics should have little or no home advantage assuming our research hypothesis about subjective decisions leading to home advantage is correct.
2. Weightlifting is also an almost entirely objective discipline. Outcome is generally decided by an aggregate measure of weight lifted in two or three disciplines, which have changed on several occasions over time (notably the abolition of single-handed lifts in 1928). Although judges adjudicate on the success of each lift, it is assumed that their input is minimal, with most decisions clear-cut. Moreover, any ambiguity was further reduced when the 'press' component was removed in 1976 owing to judging difficulty (Greenberg, 2000). Given its predominantly objective officiating, weightlifting should again have little or no home advantage.
3. For gymnastics, judges have a large subjective input and directly assess performance. Ansorge and Scheer (1988) claimed that the 'effects of biased officiating are potentially most dramatic in sports in which the officials actually score the points through judging the performance of competitors with some combination of objective and subjective criteria' (p. 103). Gymnastics provides an example of such artistic events and should exhibit highly significant home advantage.
4. Historically, boxing has generated the most controversy of any Olympic sport, including such connected events as attacks on officials, sit-down protests and full-scale riots. Much of this controversy has focused upon the five ringside judges and referee. Indeed, recent measures (since Barcelona 1992) have included banning officials from cocktail parties and the administration of daily alcohol tests

to ensure they are 'out of reach' of influence from national associations and their officials (Wallechinsky, 2000). Despite such concerns, little research has addressed possible inflated home advantage in boxing. Although a small proportion of boxing matches are decided by knockout, most Olympic bouts rely on the subjective assessment of judges (85.95% of Olympic bouts; Lyberg, 1999c). Given this subjective judging, boxing should display highly significant home advantage.

5. Olympic team games have an objective scoring system (e.g. goals, baskets), although officials have substantial subjective input during matches. Home advantage for major team games is well known (Nevill and Holder, 1999), although it has not been put into context alongside other major individual sports. Given the proven influence of crowd noise upon referees in an experimental setting (Nevill *et al.*, 1999, 2002a), team games should be associated with significant home advantage, although perhaps not as much as artistic event groups, where judges directly decide outcome.

Points and maximum points

Performance was measured using a simple points system, with 3 points allocated for a gold medal, 2 points for silver and 1 point for bronze. A fair estimation of performance requires not only points scored, but also a consideration of the number of points available. Points were considered as a proportion of maximum points available, this maximum varying with event. In most team games or events (e.g. football, hockey, 4×100 m) the maximum is 3 points (i.e. a single gold), as only one team may be entered. Elsewhere, the maximum is typically 6 points, as three or more competitors of the same nationality could win gold, silver and bronze (6 points) in a given event and Olympic Games.

Both points and maximum points were combined for each event group (defined in the previous subsection). Combined maximum points also considered number of competitors or teams, so they never exceeded the number of points achievable by the number of competitors or teams entered. The result is a sum of points for all relevant events, for each Olympic Games at which the events were contested. Event groups and number of constituent events or weight categories are presented in Table 1. Each observation is a proportion for a given country, in a given event group and Olympic Games (e.g. Germany won 11 of 48 boxing points at the 1936 Olympic Games). A nation was removed if it had never contested the events or had never won a point (home or away) in a given event group. All data were obtained from the Olympic museum, Lausanne (Lyberg, 1999a,b,c,d,e,f,g,h,i). The results from Sydney 2000 were not included, since although medal winning performance was available, detailed participation figures were only available up to 1996.

Response variable

The response or dependent variable was the number of points won by each nation as a ratio of the maximum number of points available.

Explanatory variables

Home versus away

A binary home versus away indicator variable was entered to allow assessment of the difference between home and away performance.

Proportion of competitors or teams competing

The number of competitors or teams for each nation, entered as a proportion of the total competitors or teams, was included as a covariate likely to influence the proportion of points won. Most pre-Second World War

Table 1. Event groups included in the analysis and number of constituent events

Event group	No. of events/ weight divisions	Dates competed	Observations in analysis (*n*)		No. of Olympic Games
			Pre-war	Post-war	
Track and field	25	1896–1996	71	144	23
Gymnastics	8	1896–1996	32	86	23
Weightlifting	10	1896, 1904, 1920–1996	25	115	20
Boxing	12	1904–1908, 1920–1996	29	142	20
Team games	5	1900–1996	44	103	22
Total			201	590	

Olympic Games had few limits on the maximum number of competitors, leading to inflated home team sizes, or even additional teams in some early team games. At the 1904 St. Louis Olympic Games, the host nation entered two of a total of three competing football teams (Wallechinsky, 2000). Even after the instigation of maxima, many nations used the opportunity of a home Olympic Games to reach the maximum when otherwise further competitors at considerable cost would not have been worthwhile. Evidently further competitors at home would enhance the given host nation's ability to win medals (however slightly). To reach an unbiased home advantage, a competitor (competitor or team) covariate indicating the number of competitors or teams entered by each nation in each event group was included in the analysis.

This covariate was equal to the number of competitors or teams divided by the total number for all nations (i.e. the proportion of competitors entered by each 'hosting nation', in each event or event group, at each Olympic Games). Using this value rather than raw number of competitors or teams accounts for changing (generally growing) competitor or team participation over time. This covariate will be referred to as 'proportion of competitors' in the analyses.

Host nation

Evidently, stronger host nations win more points and may enjoy greater home advantage (e.g. Schwartz and Barsky, 1977; Madrigal and James, 1999). Consideration of differences between host nations as a repeated-measures 'within-subject' factor ('host') allows differences in nation quality to be evaluated and accounted for.

Pre-war/post-war differences

Differences over time exist both in the number of competitors entered (especially home competitors) and number of nations entering. Generally, after 1936, restrictions were placed upon the number of competitors entering, preventing vast numbers of home competitors. An increased number of away nations has also increased competition and may further reduce home advantage. For this reason, separate analyses were conducted pre- and post-war to allow for differences in the proportion of competitors covariate. The full rationale for this split is explained in the Analysis section below.

Event group/officiating style

Consideration of the above variables allows both accurate (unbiased) measurement of home advantage in each event group and a comparison between groups with different officiating styles. A five-category event group factor was included in the analysis to highlight differences in home advantage between groups (home/away × event group interaction). Analysis was then split by event group to examine absolute home advantage for each group.

Changing nations

Two major medal-winning nations that have also hosted Summer Olympic Games have seen considerable changes in composition. First, Germany split into East and West Germany after the Second World War, before re-unifying in time for the 1992 Olympic Games. Similarly, the Soviet Union collapsed before the 1992 Olympic Games (though a unified team competed in 1992). For simplicity, Germany is defined as West Germany between 1952 and 1988 (Federal Republic of Germany from 1968 onwards), although it should be noted that Germany did enter a combined team on three occasions within this period (1956–1964). After the collapse of the Soviet Union, Russia is defined as Russia and not former constituents of the Soviet Union. We attempt to control for changes in the proportion of total athletes or teams entered (and subsequent success) as a result of these changes (and of boycotts) by using the proportion of competitors or teams as a covariate.

Analysis

The proportion of medals won by each nation was analysed using two separate methods. First, traditional analysis of covariance (ANCOVA) was used, with measurements relating to the proportion of competitors entered as a covariate. The general linear model used assumes normality. However, the response variables consisting of proportions of points (of total points) resulted in predictable departures from normality due to many especially large or small proportions (Zar, 1998). An arcsine transformation (Winer, 1972) to stabilize variances and produce a more acceptable normal distribution failed to significantly improve deviations from normality in either the pre-war or post-war analyses. Preliminary exploration of the data also highlighted the need to split the analysis pre- and post-war. This was mainly a result of post-war competitor restrictions leading to a far less influential 'proportion of competitors' covariate, with a markedly different slope (see Fig. 1).

Proportions of points won by each nation were analysed as a binomial response variable (e.g. if a nation won a silver medal in the 100 m athletics final, 2 of 6 points would be allocated to that nation for that Olympic Games) using generalized linear interactive

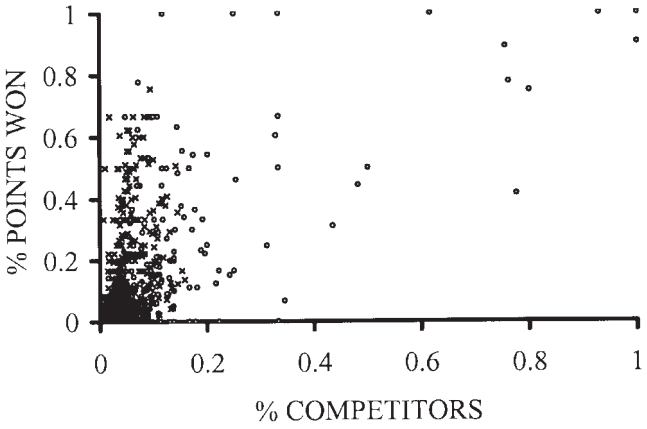

Fig. 1. Proportion of competitors entered versus percentage of points won, for each Olympic Games, nation and event group. O, pre-war; ×, post-war.

modelling (GLIM; Aitkin *et al.*, 1989; Nevill *et al.*, 2002b). Although proportion of points won is not strictly a binomial proportion (as it is not generated from repeated yes/no responses), it is a discrete distribution with an upper bound (which differed with event, Olympic Games and number of competitors entered). In such a case, the binomial distribution provides the most accurate approximation (rather than the Poisson distribution where there exists no upper bound). Rather than assuming the response variable has a linear function of the covariates with an approximate normal error, GLIM is able to assess the effect of all the explanatory variables on the proportion of points won assuming the exact binomial error distribution (*r* points from a possible *n*). Separate GLIM analyses were performed on the pre- and post-war data because of differing 'proportion of competitors' covariates. Analyses were then split by event group both pre- and post-war.

Results

Pre-war

Fitting the covariate of 'proportion of competitors', the main effects of 'host', 'event group' and 'home *vs* away' plus the interaction between 'event group' and 'home *vs* away' term explained a loss in deviance of −1628.9 with 17 degrees of freedom ($P < 0.0001$). When we attempted to remove the interaction term, the covariate or any of the main effects from the model, the increase in deviance was too large in all cases ($P < 0.01$). Consequently, all terms were retained in the final pre-war model describing the proportion of points won by the eight 'hosting' nations. The unadjusted and adjusted proportions of points won (obtained by calculating the mean intercepts for proportion of points won having fitted the covariate 'proportion of competitors') by hosting nations pre-war are presented in Figs 2 and 3, respectively. All error bars in the figures denote the standard error of the estimate.

Five simplified models were then fitted for each event group, with the single 'proportion of competitors' covariate and main effects 'host' and 'home *vs* away'. This allowed absolute measurement of home advantage for each group. Table 2 presents the direction (home advantage/away advantage) and significance (change in scaled deviance as a result of removal from final model) of the factor 'home *vs* away' for both pre- and post-war analyses.

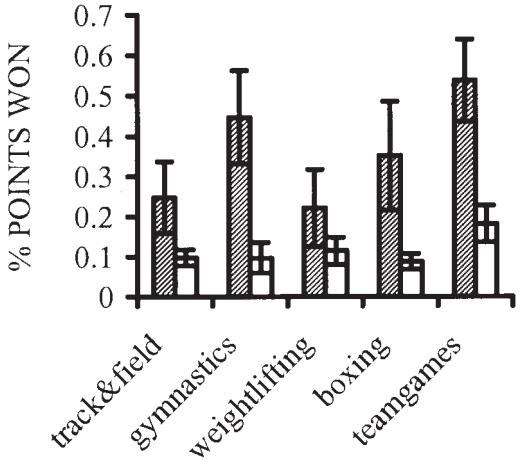

Fig. 2. Percentage of points (±standard error of the estimate) won by all successful hosting nations pre-war. ▨, home; □, away.

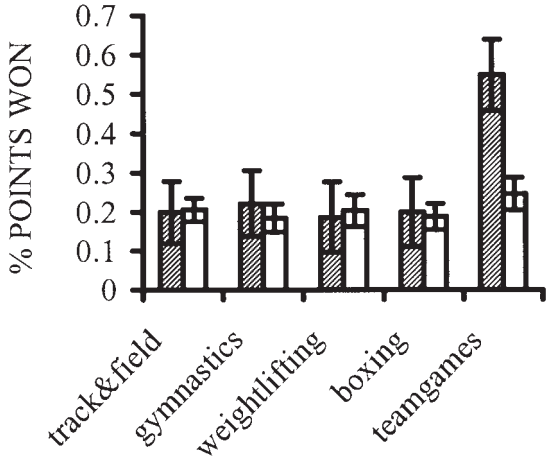

Fig. 3. Adjusted percentage of points (±standard error of the estimate) won by all successful hosting nations pre-war. ▨, home; □, away.

Table 2. Extent and direction of home advantage for each of the five event groups pre-war (Pre) and post-war (Post)

	Direction of advantage		Change in scaled deviance, χ^2		Degrees of freedom		*P*-value	
Event group	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Track and field	Away	Home	0.22	0.20	1	1	0.64	0.66
Gymnastics	Home	Home	5.24	25.23	1	1	0.022	< 0.001
Weightlifting	Home	Away	1.46	6.21	1	1	0.23	0.013
Boxing	Home	Home	2.47	42.92	1	1	0.12	< 0.001
Team games	Home	Home	19.38	9.99	1	1	< 0.001	0.0015

With the factor 'host' and covariate 'proportion of competitors' entered, no home advantage was found for 'track and field', 'weightlifting' or 'boxing'. In contrast, 'gymnastics' yielded significant home advantage ($\chi^2_1 = 5.24$, $P = 0.022$), as did 'team games' ($\chi^2_1 = 19.38$, $P < 0.001$). For each event group, as with the global analysis, increase in deviance was too large to remove either 'host' or 'proportion of competitors', confirming the need to retain them in each pre-war model.

Post-war

Adopting the same methodological approach to analysing the pre-war results, the covariate of 'proportion of competitors', the main effects of 'host', 'event group' and 'home *vs* away' were fitted, plus the interaction between 'event group' and 'home *vs* away', to explain the proportion of points won by the 12 hosting nations. These terms explained a loss in deviance of −2657.1 with 21 degrees of freedom ($P < 0.0001$). As with the pre-war analysis, when we tried to remove the interaction term, the covariate or any of the main effects from the model, the increase in deviance was too large in all cases ($P < 0.01$). All terms were retained in the final post-war model describing the proportion of points won by the 12 'hosting' nations. The unadjusted and adjusted (for proportion of competitors) proportions of points won by hosting nations post-war are presented in Figs 4 and 5, respectively.

Separate models were fitted for each event group, using an identical procedure to that of the pre-war analysis. As for the pre-war analyses, Table 2 presents the direction (home advantage/away advantage) and significance (change in scaled deviance as a result of removal from final model) of the factor 'home *vs* away'.

As with the pre-war analysis, 'track and field' yielded no home advantage. Interestingly, once 'proportion of competitors' had been accounted for, 'weightlifting'

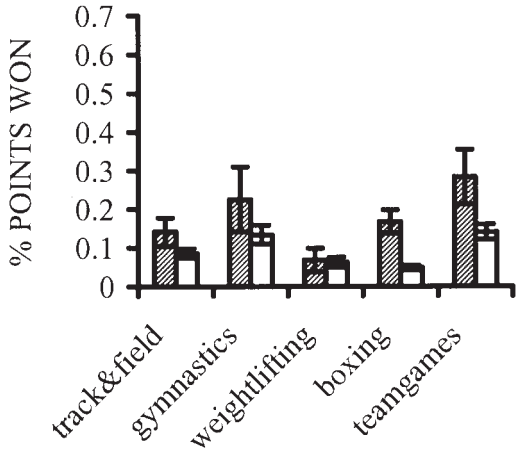

Fig. 4. Percentage of points (±standard error of the estimate) won by all successful hosting nations post-war. ▨, home; □, away.

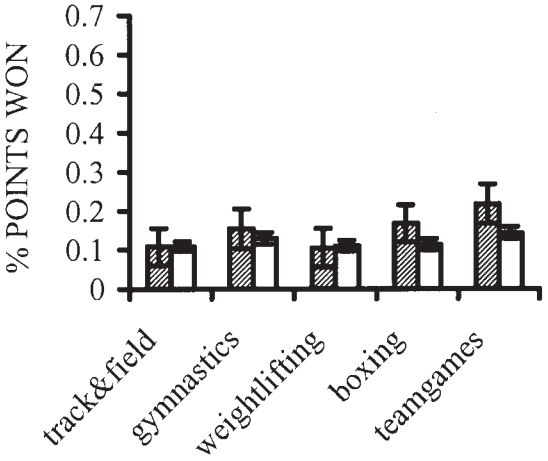

Fig. 5. Adjusted percentage of points (±standard error of the estimate) won by all successful hosting nations post-war. ▨, home; □, away.

now exhibited significant away advantage ($\chi^2_1 = 6.21$, $P = 0.013$). Meanwhile, a large significant home advantage was observed for 'gymnastics' ($\chi^2_1 = 25.2$, $P < 0.001$), 'team games' ($\chi^2_1 = 9.99$, $P = 0.0015$) and 'boxing' ($\chi^2_1 = 42.9$, $P < 0.001$). As with previous analyses, increase in deviance was too large to remove either 'host' or 'proportion of competitors', confirming their importance in the model.

Discussion

The present study had two objectives. The first was to assess the significance of home advantage in a subset of Summer Olympic Games event groups, while identifying and controlling for confounding factors. The second was to examine differences in home advantage between groups of events relying on differing officiating styles. We hypothesized that sports requiring subjective judgement (boxing, gymnastics) or subjective decisions (team games) would yield highly significant home advantage. In contrast, little or no home advantage was expected for sports for which officiating is less overt or predominantly an objective process (track and field, weightlifting).

In both the pre-war and post-war analyses, overall home advantage was found to be significant, highlighted by the large change in deviance when attempting to remove the 'home *vs* away' main effect. The 'proportion of competitors' covariate was also found to be highly influential both pre- and post-war, indicating the importance of proportion of competitors or teams to successful performance. Controlling for this covariate proved central to a fair measure of home advantage, highlighted by the marked difference between unadjusted (Figs 2 and 4) and adjusted performance (Figs 3 and 5). A similar measure of participation could prove valuable in the further development of allometric models of Olympic performance (e.g. Lozano *et al.*, 2002; Morton 2002; Nevill and Stead, 2003).

Significantly different slopes for the 'proportion of competitors' covariate illustrated the need to split the analysis pre- and post-war, as shown by Fig. 1. Similarly, significant differences were noted between 'host' nations' point-winning performances. Entry of a nation main effect accounted for a large proportion of variance (due to substantial differences between nations), confirming 'team quality' concerns of previous research (e.g. Schwartz and Barsky, 1977; Holder and Nevill, 1997; Nevill *et al.*, 1997; Madrigal and James, 1999). The success of different nations is also likely to have been influenced by numerous boycotts. These include Spain, Switzerland, Egypt, Iraq and Lebanon in 1956, various African nations in 1976, the United States in 1980 and the Soviet Union at the following Olympic Games. These boycotts, particularly the final two, clearly enhanced the performance of host nations and, therefore, increased home advantage. Fitting the 'proportion of competitors' covariate attempted to control for such boycotts (by modelling increases in proportion of competitors), although it is unlikely that it completely accounted for the quality of competitors lost. When we assessed differences in home advantage between event groups, the conclusions remained unaffected. However, analysis at the level of nations (e.g. attempting to predict a particular nation's future medal-winning performance; e.g. Clarke, 2000) would require further consideration of boycotts and quality of competitor.

The most important finding was the significance of the home/away × event group interaction, both pre- and post-war. Subsequent analysis for each individual event group revealed the source of this significant interaction term. Pre-war, the significant home/away × group interaction term was a result of a small (non-significant) away advantage in the two objectively judged groups, compared with significantly greater positive home advantage for gymnastics and substantial home advantage for team games. Post-war, when competitor participation had stabilized to some extent due to restrictions, the home/away × group interaction was a result of significantly greater home advantage in event groups that are either subjectively judged (gymnastics, boxing) or rely on subjective decisions (team games). Home advantage for these three groups was significantly greater than that of the two objectively judged groups (track and field, weightlifting) once we had controlled for the proportion of competitors/teams.

Objectively judged groups showed no home advantage either pre- or post-war (Figs 3 and 5) and, in the case of post-war weightlifting, even showed some indication of away advantage. This may be explained by nations which have never hosted the Olympic Games beginning to enter participants in weightlifting and becoming increasingly strong as time progresses. Notable examples include Bulgaria, Romania and China, none of whom featured in men's weightlifting medals tables between 1948 and 1968. Bulgaria then topped the table with six medals in 1972 and won six again in 1976. Similarly, Romania and China occupied the top two weightlifting table spots in 1984, winning 14 of 30 medals between them. An increasing number of strong away nations may reduce home nations' chances of winning medals compared with earlier away Olympic Games in which such nations were not present or competitive.

With respect to subjectively judged events, our results confirm previous Winter Olympic Games findings

(Balmer *et al.*, 2001) that such disciplines enjoy significantly greater home advantage than events with little officiating input. Evidently, this officiating component is vital for home advantage in individual sports. This could explain why significant home advantage has been observed in wrestling (Gayton and Langevin, 1992), even at high school level, but not international tennis or golf (Holder and Nevill, 1997; Nevill *et al.*, 1997). It would appear that the potential for biased officiating in subjectively judged events predicted by Ansorge and Scheer (1988) is confirmed in terms of home advantage.

As hypothesized, team games demonstrated highly significant home advantage both pre- and post-war, although the size of this imbalance was surprisingly large. Team games demonstrated by far the largest home advantage pre-war and highly significant home advantage post-war (Table 2). Pre-war, a lack of competitive away teams and failure to completely account for additional home teams ('proportion of competitors') may partially explain this imbalance. Post-war, following instigation of entry restrictions, home advantage remains highly significant, although somewhat less so than for the subjectively judged groups.

Previous research has highlighted crowd factors as a dominant cause of home advantage. Crowds are able to influence players and officials to alter performance to favour the home side or nation (Pollard 1986; Nevill *et al.*, 1996). Competitors in all of the event groups enjoy consistently large and vocal crowds. If these crowds were able to influence competitors' performance, home advantage would be observed for all event groups, which was not the case. Far greater home advantage in the three event groups with substantial officiating input supports the latter hypothesis, that the crowd is able to influence officials to favour the home side. Experimental research has provided support for a crowd influence upon officials in association football (Nevill *et al.*, 1999, 2002a). However, while an imbalance of decisions was identified, this was not quantified in terms of home advantage. The results of the present study suggest that the imbalance observed with crowd noise in football translates to a sizeable home advantage, significantly larger than that for objectively judged events and comparable to that for subjectively judged events.

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