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Out of your zone? 21 years of travel and performance in Super Rugby

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The extent to which travel has affected Super Rugby teams' performances was analysed using outcomes of all matches played from the beginning of the competition in 1996 to the end of the 2016 season. Points difference and matches won or lost were predicted with general and generalized mixed linear models The predictors were the linear effects of number of time zones crossed and travel duration based on the teams' locations for each match and their locations in the previous week. The away-match disadvantage was also estimated, along with trends in all these effects. In 1996 the predicted combined effect of eastward travel across 12 time zones was a reduction of 5.8 points scored per match, resulting in 4.1 more matches lost every 10 matches. Corresponding effects for westward travel were 6.4 points and 3.1 matches. In 2016 effects travelling eastward were 3.7 points and 2.3 matches, whereas travelling westward the effects were 3.7 points and 1.5 matches. These travel effects were due mainly to the away-match disadvantage: 5.7 points and 3.2 matches in 1996; 5.2 points and 2.3 matches in 2016. Teams in Super Rugby are dealing successfully with long-haul travel and should now focus on reducing the away-match disadvantage.

Word Count: 200/200

Keywords: travel, jet lag, match analysis, performance analysis, away-match disadvantage, Rugby Union

Introduction:

Success in competition is the ultimate goal for every professional athlete or team. One of the keys to achieve success is to reach the highest level of performance possible on the competition day(s) required. However, performance in sport is a complex and multi-factorial process (Glazier, 2010) that can be influenced by physiological, psychological, environmental (e.g. the weather) and sport specific factors, including skills and technical/tactical aspects (Armstrong, 2006; Glazier, 2010). For team sports in particular, frequent air travel may have a negative influence on performance (Bishop, 2004; Jehue, Street, & Huizenga, 1993; Winter, Hammond, Green, Zhang, & Bliwise, 2009) that seems to be related to travel fatigue and jet lag (Forbes-Robertson et al., 2012; Fowler, Duffield, & Vaile, 2014; Leatherwood & Dragoo, 2013).

Travel fatigue is the summation of physiological, psychological and environmental factors that accrue after a single trip and accumulate over time (Samuels, 2012). Travel fatigue is characterized by persistent weariness, recurrent illness, changes in mood, and lack of motivation (Samuels, 2012). Jet lag is a common complaint that travellers report after travelling across time zones (Herxheimer & Petrie, 2002). All the physiological functions and systems of the human body follow rhythmic patterns, called circadian rhythms (from Latin circa dies = about a day). These rhythms are internally driven biological phenomena with periodic oscillation of 24.2 hours on average when measured in experimental conditions (Czeisler et al., 1999). Jet lag occurs whenever the rhythms are not synchronized with the external clock, for instance when athletes have to rapidly travel across time zones in order to compete (Waterhouse, Reilly, & Edwards, 2004). Jet lag symptoms include sleep disturbances, fatigue, changes in mood and a deficit in cognitive skills (Eastman, Gazda, Burgess, Crowley, & Fogg, 2005). The duration and severity of these symptoms depend on the number of time zones crossed (Revell & Eastman, 2005) and the direction of travel (Herxheimer & Petrie, 2002).

The effects of travel fatigue and jet lag on athletes' performance have been investigated before. However, performance was evaluated mostly for athletes competing in individual sports such as skeleton and gymnastic (Bullock, Martin, Ross, Rosemond, & Marino, 2007; Lemmer, Kern, Nold, & Lohrer, 2002). When assessing team sports athletes' performance, the markers used were generic or not sport specific (i.e. grip strength, or general physical tests) (Fowler, Duffield, & Vaile, 2015; Reilly, Atkinson, & Waterhouse, 1997). Only a few studies have assessed the effects of travel fatigue and jet lag on team sport, using match outcomes and points scored to assess performance for away-matches (Bishop, 2004; Jehue et al., 1993; Winter et al., 2009). However, in most of these studies, the importance of the away-match disadvantage, which is a combination of factors, such as crowd support and potential officials' bias, that deteriorate the psychological and behavioural states of athletes, along with their performance, when a match is played away (Carron, Loughhead, & Bray, 2005; Courneya & Carron, 1992; Lazarus, Hopkins, Stewart, & Aughey, 2017) was neglected or underestimated.

Frequent travel and its effects on performance are particularly important in Super Rugby, which is one tier down from international rugby and the most important Rugby Union competition in the southern hemisphere. During the history of Super Rugby, the competition format and number of participating teams changed. Originally, the tournament involved 12 teams, which grew first to 14 and then 15 from Australia, New Zealand and South Africa. In 2016, the competition expanded to include two new countries (Argentina and Japan) and three new teams (SuperRugby, 2014). Depending on the format of the competition and the number of teams involved in each season, teams played a number of weekly matches, ranging from 11 to 17 rounds in the first phase followed by two to three rounds of finals. Away-matches were played by a team in its own country against a local opponent, or in a different country and against an overseas opponent. As such, teams had to travel frequently throughout each season. Travel could have been as little as a one-hour flight with no time zone change or up to 24 hours, crossing up to 12 time-zones. The nature of the competition makes Super Rugby a perfect sample to analyse the effects of travel on team performance.

The purpose of this study was to determine the effects of travel on match outcomes and points scored in Super Rugby from its first season in 1996 until the last completed season at the time of the analysis (2016). The importance of the away-match disadvantage in determining the effect of travel on team performance was also investigated.

Material and methods:

Archival data from 21 years of Super Rugby matches (1996-2016) were retrieved from the official SANZAAR (South Africa, New Zealand, Australia, Argentina Rugby) web site, (http://www.sanzarrugby.com/superrugby). SANZAAR operates all international Rugby Union competitions in the Southern hemisphere. The analysis was conducted according to the ethical guidelines of the authors' institution. All data are from a public domain so did not require ethical approval. All data were de-identified prior to inclusion. Match outcomes and difference in points scored were used for the statistical analysis. Individual and team performance indicators are available only for the last ten years of the competition and were not used. Number of time zones crossed and flight duration were calculated based on the relative position and distance between the city where a match was played and the location of both teams the previous week. Number of time zones crossed was also adjusted for Daylight Saving time when required. Travel time was calculated considering the shortest itinerary of all the possible available solutions. In total, 3,854 observations from 1,927 Super Rugby matches were used.

The analysis covered all iterations of the competition. In particular, 690 matches (1,380 observations) from the Super 12 era (1996-2005), 470 matches (940 observations) from the Super 14 era (2006-2010), 625 matches (1,250 observations) from the Super XV era (2011-2015) and 142 matches (284 observations) from the Super Rugby era (2016) were analysed. For the New Zealand teams, matches that were not played at their home ground but in a nearby location in their union territory were also considered home-matches. When a match was played in a neutral ground (one match in England in 2011 and one in Fiji in 2016) they were considered away for both teams. The matches played in Singapore by the Japanese team in 2016 were considered home-matches for home ground advantage calculation. However, the distance covered whilst travelling by the Japanese team was included in the analysis. In 2011, a New Zealand team was unable to play at their home-ground due to an earthquake. In the analysis, unless played in their union territory, all matches played by this team were considered away-matches, due to travel.

Statistical analysis:

Data were imported into the Statistical Analysis System (version 9.4, SAS Institute, Cary, NC) for analysis. The match outcomes were analysed with logistic regression using a generalized linear mixed model (Proc Glimmix). Effects were derived as odds ratio and then converted to extra matches won or lost every ten close matches played (Higham, Hopkins, Pyne, & Anson, 2014; Hopkins, Hawley, & Burke, 1999; Lazarus et al., 2017; Liu, Hopkins, & Gomez, 2015). Linear numeric fixed effects were included for the number of time zones crossed in each direction of travel (east, west), for flight duration, and for the away-match disadvantage (0=home 1=away). To estimate and adjust for differences in the winning ability of teams, their identity was included as a random effect. Separate analyses were performed initially for each year of the competition. Year of competition was then included as a linear numeric fixed effect interacted with the fixed effects to estimate overall trends in these effects, their predicted means over the 21 years, and their predicted means at the beginning and end of this period. This model included a random effect for the interaction of team identity and year as a nominal effect to estimate and adjust for changes in the winning ability of teams over years.

The effects of travel and crossing time zones were evaluated for the maximum values in the Super Rugby competitions: 24 hours and 12 time-zones respectively (Auckland to Cape Town). These effects were combined with the away-match disadvantage to get the combined effect on match outcomes when competing at a remote venue. Each effect was also assessed separately for its pure contribution on match outcomes. Finally, the combined effect of travel and number of time zones crossed, excluding the away-match disadvantage, was assessed to determine the real importance of long-haul travel. Similar analyses were performed for difference in points scored in each match using a general linear mixed model (Proc Mixed).

Uncertainty in the two outcomes was expressed as 90% confidence limits and as probabilities that the true effect was substantially positive and negative (derived from standard errors, assuming a normal sampling distribution). These probabilities were used to make a qualitative probabilistic non-clinical Bayesian inference with a disperse uniform prior about the true effect (Hopkins & Batterham, 2018). The smallest worthwhile effect for the match outcomes analyses was set to one extra match won every 10 matches played (Higham et al., 2014). Magnitudes of clear effects were evaluated as follows: <1, trivial; 1-3, small; 3-5, moderate; 5-7, large; 7-9, very large. The smallest worthwhile effect and the other magnitude thresholds for the difference in points scored were as follows: <1, trivial; 1-3, small; 3-5.3, moderate; 5.3-8.3, large; >8.3, very large; these were based on 0.3, 0.9, 1.6 and 2.5 of the variation in the points scored by a team in an evenly matched match (Higham et al., 2014; Hopkins, Marshall, Batterham, & Hanin, 2009). The likelihood of the effects for both match outcome and difference in points scored analyses was calculated as follows: 25-75%, possibly; 75-95%, likely; 95-99%, very likely; >99%, most likely (Hopkins et al., 2009). To account for inflation of Type 1 error, only clear effects clear with 99% confidence intervals were highlighted (Liu et al., 2015). Uniformity and linearity where assessed through visual inspection of residuals vs predicteds as well as residuals vs predictors analyses. Both inspections showed no evidence of non-linearity or non-uniformity.

Results:

The combined effects of travel on match outcomes each year are presented in Figure 1 for away-matches involving travel east and west. The predicted effects at each end of the monitored period were substantial, and there was a substantial positive trend (Figure 2), although the trend was clear only at the 90% level. In particular, over the 21 years, teams increased their ability to win 2.0 more matches (90% confidence limits ±2.3; small, likely positive effect) travelling east and 1.5 more matches (±2.4; small, possibly positive effect) travelling west.

Figure 1 near here. ***Figure 2 near here***

The pure effect of flight duration, number of time zones crossed in both directions, and away-match disadvantage on match outcomes are presented in Figure 3. The away-match disadvantage appeared to account for most of the long-haul effect shown in the previous figures: in 1996 a loss of 3.2 more matches for every 10 played away (±0.6; moderate, most likely negative effect), and in 2016 a loss of 2.3 extra matches for every 10 played (±0.8; small, most likely negative effect). Over the 21 years the effect of the away-match disadvantage reduced and teams increased their ability to win by 1.0 extra match for every 10 played (± 0.9; small, possibly positive effect). The corresponding effects of travel time and number of time zones crossed were mainly trivial, or at most, small, but all were unclear.

Figure 3 near here.

When the effects of travel duration and crossing time zones were combined, the resulting long-haul travel effects were sometimes clear but still only trivial to small (Figure 4). In 1996, travel east made teams more likely to lose 1.0 extra match every 10 played (±1.4; small, possibly negative effect). After travelling west, teams were likely to win 0.1 extra matches every 10 played (±1.6; trivial, unclear effect). At the end of the 2016 season teams were likely to win 0.0 more matches (±1.3; trivial, unclear effect) when travelling east and 0.9 more matches (±1.3; trivial, possibly positive effect) when travelling west. Over the 21 years teams increased their ability to win up to 1.0 more match (±2.2, small, unclear effect) travelling east and 0.8 more matches (±2.4, trivial, unclear effect) travelling west. The mean effect of travel over the 21 years was likely trivial for both directions of travel (losing 0.5 ±0.7 extra matches travelling east and winning 0.5 ±0.8 extra matches travelling west).

Figure 4 near here

The combined effects of travel, crossing time zones and away-match disadvantage on difference in points scored for close matches were similar to the effects for match outcomes. The predicted effects at each end of the monitored period were substantial and there was a positive trend (Figure 5). Although the trend was unclear, over the 21 years, teams increased their ability to score (by 2.0, ±5.5 points travelling east; 2.7, ±5.5 points travelling west).

Figure 5 near here

Pure and long-haul travel effects on the difference in points scored were similar to the effects on match outcomes. For the away-match disadvantage in particular, in 1996 the difference in points scored was -5.7 (±1.4; large, most likely negative effect). In 2016 the difference in points scored was -5.2 (±1.1; moderate, most likely negative effect). Over the 21 years, the effect of the away-match disadvantage reduced and teams narrowed the margin by 0.5 points (±2.1; trivial, unclear effect). For the long-haul travel effect, in 1996, travel east changed the difference in points scored by -0.1 (±3.3; trivial, unclear effect). After travel west, the difference was -0.7 (±3.4; trivial, unclear effect). At the end of the 2016 season the difference in points scored was an increase of 1.4 (±2.8; small, unclear effect) when travelling east and 1.5 (±2.9; small unclear effect) when travelling west. Over the 21 years, the difference in points scored increased by 1.5 (±5.1; small, unclear effect) travelling east and by 2.2 (±5.3; small, unclear effect) travelling west. The mean effect of travel over 21 years was trivial and possibly positive for eastward travel (0.7, ±1.6 points) and unclear for westward travel (0.4, ±1.7 points).

Discussion:

Performance can be influenced by many different factors (Glazier, 2010). Whilst it was not attempted to address all these measures in this study, it was quite clear that throughout the first 21 years of Super Rugby, there was a substantial impairment of performance following the longest flights and greatest time zones shifts, although there was a gradual reduction of the impairment. The major contributor to this performance impairment was the away-match effect, which also declined somewhat, such that by 2016 the impairment was still small to moderate. The individual contributions of travel time and zone shift were unclear, presumably because of collinearity: longer travel time was usually associated with more time zones crossed. However, when travel time and zone shift were combined, the effects were sometimes clear with the possibility of a small beneficial effect of travel. These findings are in contrast with previous reports supporting the popular idea that travel fatigue and jet lag are the main factors accounting for the effects of travel (Forbes-Robertson et al., 2012; Fowler et al., 2014; Leatherwood & Dragoo, 2013).

The limited effect of travel length and consequent travel fatigue on performance can be explained by the fact that, according to personal communications, Super Rugby teams reach the venue at least one day prior to the match and a full night of rest is usually enough to recover from the effects of travel fatigue (Reilly et al., 1997). Similarly, crossing time zones appears to minimally impair performance, although to a marginally larger extent. The direction of travel seems to largely dictate the magnitude of this effect, with eastward travel being slightly more detrimental than westward travel. Eastward travel requires a phase advance of the circadian rhythms whilst travelling westward requires a phase delay. As circadian rhythms are, on average, slightly longer than 24 h (Czeisler et al., 1999; Srinivasan et al., 2010), the human body shows a natural tendency to drift slightly each day and, therefore, is more capable to cope with a delay than an advance in time (Eastman & Burgess, 2009). Thus, after eastward travel, the symptoms of jet lag are more severe (Herxheimer & Petrie, 2002; Srinivasan et al., 2010), the time required to recover is longer (Eastman & Burgess, 2009) and performance may be more impaired (Jehue et al., 1993).

The combination of travel duration and crossing time zones represents what happens when a team travels. This combination appears to have a stronger effect on match outcomes than the isolated components, although most of the observed substantial negative effect of travel on performance can be ascribed to the away-match disadvantage. The estimated changes in the away-match disadvantage were based on the reasonable assumption that this disadvantage is the same for matches played either overseas or after short, internal travel. As such, it was possible to isolate the away-match disadvantage from all the other travel factors and determine its predominant role on impairing match performance after long haul flights across multiple time zones.

A possible limitation of this study is that the number of matches and the distance covered travelling by the Super Rugby teams have changed during the history of the competition. However, the changes in format (e.g., the creation of national conferences and loosely geographical groups in 2016) that occurred during the history of Super Rugby helped to maintain the amount of travel required (SuperRugby, 2015). Another possible limitation is that the local time when a match was played was not considered. Super Rugby matches are usually scheduled for late afternoon and many aspects of exercise performance, for instance muscle strength, reach their peak at this time (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005; Reilly, 2009; Reilly & Waterhouse, 2009). As such, players should be able to perform at their best. However, each person has an internal clock that, in homeostatic conditions, is synchronized with the day/night cycle (Atkinson & Reilly, 1996; Czeisler et al., 1999). After trans-meridian travel, the body requires a certain amount of time to resynchronize with the new environment (Reilly et al., 2007; Samuels, 2012). That means a match may have been played when the physiological responses of athletes were not at their peak, thus affecting their performance. Further research should investigate the rate of desynchronization at the time of a match kick-off to better understand the individual response of each player after travel. Similarly, the travel management strategies used by teams to reduce the effects of travel on match performance should be investigated. Finally, individual and team indicators of performance were not analysed. These data are available on the SANZAAR web site, however starts only from the 2006 season. The purpose of this research was to analyse the effect of travel on the entire history of the competition up to 2016. As such, all partially available data were excluded.

In summary, it appears that continuous long-haul travel may have detrimental effects on individual and thus team performance. However, although several other factors may have impaired performance, at least in Rugby Union, the away-match disadvantage is likely to be the main cause of these negative effects. The reduction in the effects of travel over time suggests that teams in Super Rugby improved their travel management strategies. As teams are more successfully dealing with long-haul travel, they should now focus on reducing the effects of the away-match disadvantage, for instance enhancing players' psychological and behavioural response when playing away from home (Carron et al., 2005). The findings of this research can be of interest for all the coaches and supporting staff in sports that require international travel to compete.

The authors report no conflict of interest

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Word Count: 3018/400

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Figure 1. Combined effects of the away-match disadvantage with eastward (A) and westward (B) long-haul travel (12 time zones, 24 h travel) on close-match outcomes in Super Rugby. Data points are the predicted values from by-year analysis, with 90% confidence limits. Continuous lines were derived from the regression analysis of all data. Dotted lines are thresholds for the smallest important effect.

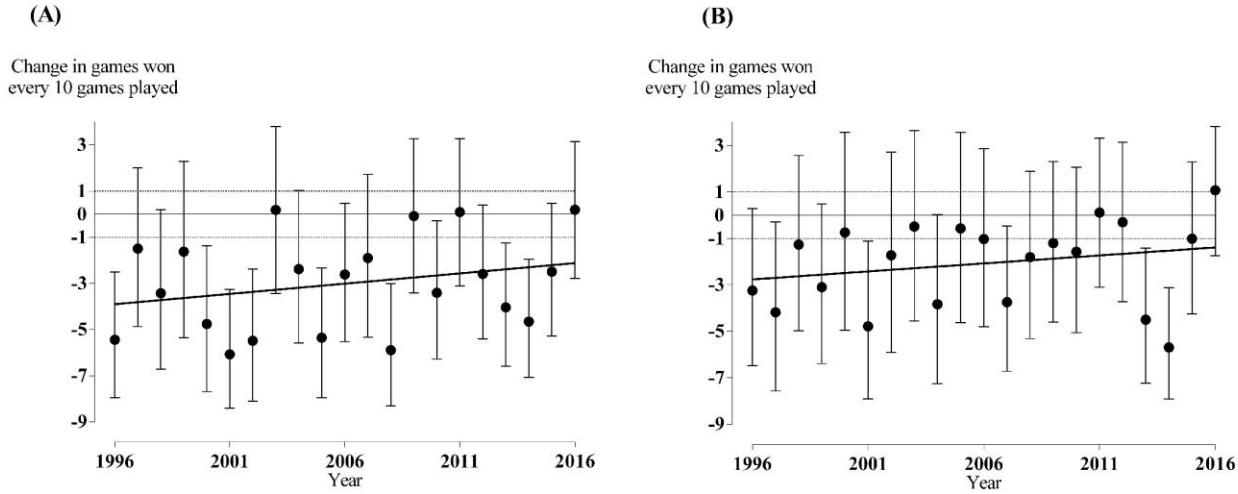

Figure 2. Predicted changes over 21 years (1996-2016) in the combined effects of the away-match disadvantage with eastward (A) and westward (B) long-haul travel (12 time zones, 24 h travel) on close-match outcomes in Super Rugby. Data points are the predicted values for 1996, 2016 and their difference, with 90% confidence limits. Dotted lines are thresholds for the smallest important effect. Asterisks indicate clear substantial effects as follows: *possibly, **likely, ***very likely, ****most likely; larger asterisks indicate effects clear at the 99% level.

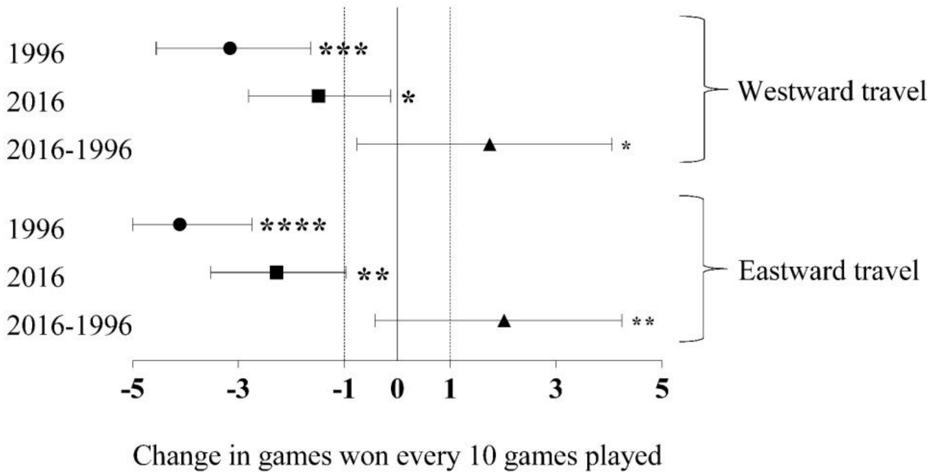

Figure 3. Pure effects of travelling eastward across 12 time zones (A), travelling westward across 12 time zones (B), flight duration (24h) (C) and the away-match disadvantage (D) on close-match outcomes in Super Rugby. Bars are 90% confidence intervals. Data points are the predicted values from by-year analysis, with 90% confidence limits. Continuous lines were derived from the regression analysis of all data. Dotted lines are thresholds for the smallest important effect.

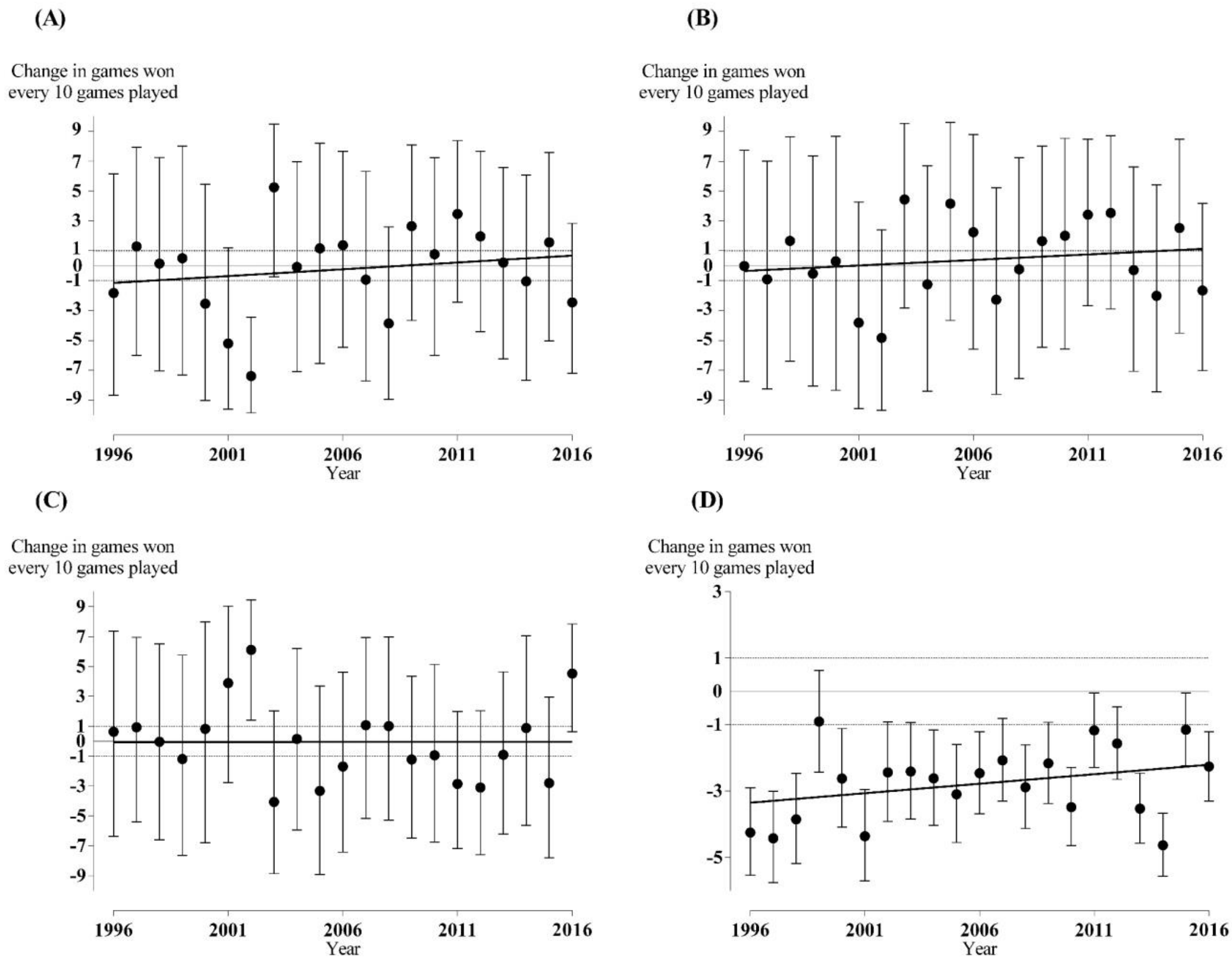

Figure 4. Effects of eastward (A) and westward (B) long-haul travel (12 time zones, 24 h travel) on close-match outcomes in Super Rugby. Data points are the predicted values from by-year analysis, with 90% confidence limits. Continuous lines were derived from the regression analysis of all data. Dotted lines are thresholds for the smallest important effect.

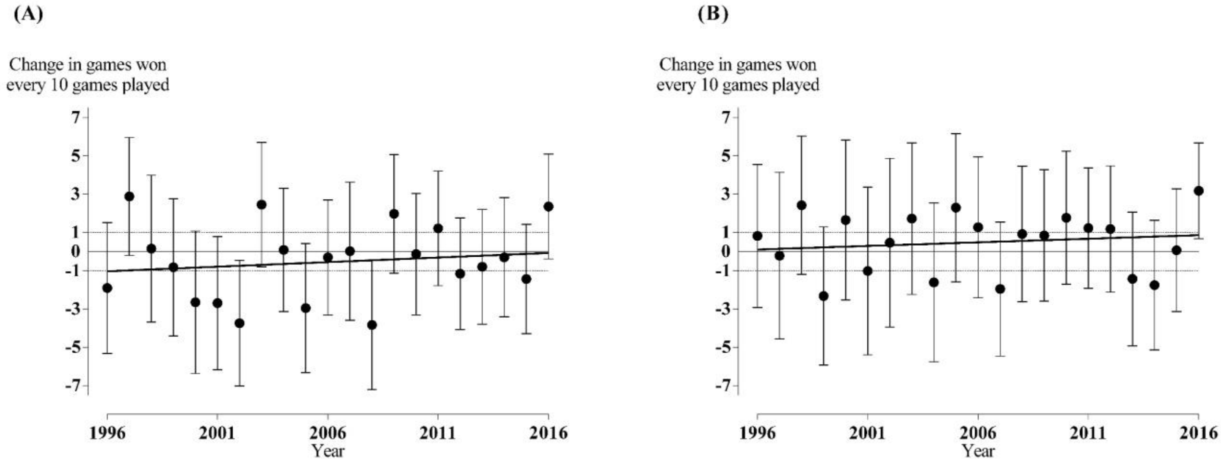

Figure 5 - Predicted changes over 21 years (1996-2016) in the combined effects of the away-match disadvantage with eastward and westward long-haul travel (12 time zones, 24 h travel) on difference in points scored for close-matches in Super Rugby. Data points are the predicted values for 1996, 2016 and their difference, with 90% confidence limits. Dotted lines are thresholds for the smallest important effect. Asterisks indicate clear substantial effects at the 90% level as follows: *possibly, **likely, ***very likely, ****most likely. No effects clear at the 99% level.