The longest journeys in Super Rugby: 11 years of travel and performance indicators

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Regular air travel is common in sport. The aim of this study was to understand the extent to which travel has affected Super Rugby teams' performance from 2006, the first season with available Key Performance Indicators (KPIs), to 2016. Data were analysed with mixed linear models for the effects of number of time-zones crossed (east or west), travel duration, the away-match disadvantage, difference in ranking, a set of amendments to the laws of Rugby Union in 2008, a change in competition format (introduction of a conference system) in 2011, and a secular trend. In 2006 the predicted combined effects of travelling 24 hours across 12 time-zones and playing away were trivial or small and negative but generally unclear for most of the KPIs in both directions of travel. In 2016 more effects were clear, small and negative for westward travel, while most effects for eastward travel were clear, small to moderate and negative. Most KPIs showed small to moderate increases over the 11 years, while difference in ranking, the introduction of new rules and game format led to mostly small changes. Changes in the physical demands of the game, and inadequate recovery time for long-haul travel can explain these effects.

Word Count: 200/200

Keywords: Travel, jet lag, match analysis, performance analysis, away-match disadvantage

Introduction:

Maximising performance and succeeding in competition are the final goals of every professional athlete and coach. Measuring performance and its variations during a season is crucial to increase the chance of winning a competition. Notational analysis is based on the identification of Key Performance Indicators (KPIs) and it is the most common form of performance assessment in team sports (Hughes & Bartlett, 2002) as it is relatively inexpensive and the results are easily understood by both coaches and athletes (Barris & Button, 2008). However, performance in team sport is a complex process and several constraints can influence athletes' outcomes (Glazier, 2010). Frequent air travel is one of these constraints (Leatherwood & Dragoo, 2013) and is particularly common in Super Rugby, which is arguably the most important Rugby Union competition for the southern hemisphere. The competition is currently contested by 15 teams from five countries (four from South Africa, five from New Zealand, four from Australia, and one respectively from Argentina and Japan) and therefore travel is a key factor (SuperRugby, 2014a). Travel in Super Rugby ranges from a one hour flight with no time-zone change to a 24 hour flight crossing 12 time-zones. As such, Super Rugby teams are an ideal sample to analyse the effects of travel fatigue and jet lag on performance.

Travel fatigue is a state of persistent weariness, recurrent illness, and lack of motivation that arises after every travel and tends to accumulate over time (Samuels, 2012). Jet lag occurs when the circadian rhythms, the rhythmic pattern of all the physiological functions and systems of the human body (Czeisler et al., 1999), are not synchronised with the external clock, typically after rapid travel across time-zones (Waterhouse, Reilly, & Edwards, 2004). The number of time-zones crossed and direction of travel dictate the duration and severity of jet lag symptoms, which include sleep disturbances, fatigue, changes in mood and a deficit in cognitive skills (Herxheimer & Petrie, 2002; Revell & Eastman, 2005). The effect of travel fatigue and jet lag on athletes' performance has been investigated before but mostly for athletes competing in individual sports (Bullock, Martin, Ross, Rosemond, & Marino, 2007; Lemmer, Kern, Nold, & Lohrer, 2002), using non-specific markers of performance, i.e. grip strength, or general physical tests (Fowler, Duffield, & Vaile, 2015; Reilly, Atkinson, & Waterhouse, 1997), or monitoring athletes travelling locally or crossing only a small number of time-zones (McGuckin, Sinclair, Sealey, & Bowman, 2014; Richmond et al., 2007).

The purpose of this study was to determine the effect of multiple time-zones (long-haul) travel on team KPIs in the Super Rugby competition over an 11 year period starting from the first season with available KPI data (2006). Other factors that could affect KPIs were included in the analysis to estimate and adjust for these effects and thereby potentially improve the precision of the estimate of the travel effects. These factors were the match venue (home and away), the difference in ranking, match locations and changes in rules and competition format.

Material and methods:

Archival data from 11 years of Super Rugby (2006-2016) 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 were from a public domain so did not require ethical approval. All data were de-identified prior to inclusion. The number of time-zones crossed and flight duration were calculated based on the location of the city where a match was played and the location of the city where the previous match was played. The time shift after crossing time-zones was adjusted for daylight-saving time when required. Travel time was calculated considering the shortest possible itinerary. Difference in ranking was calculated as the difference in the log of the ladder position at the end of each season (Phillips & Hopkins, 2017); base-2 logarithms were chosen for ease of interpretation (1 unit equal the doubling of the rank). In total, 2,474 observations from 1,237 Super Rugby matches were used, covering all iterations of the competition from 2006.

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.

All available KPIs were retrieved from the web site. KPIs related to infrequent events (e.g., drop goals), and KPIs available for less than eight years (e.g., mauls) were not included in the analysis. The selected KPIs were organised in two groups: those for which an increase would presumably represent an enhancement of team performance (positive KPIs) and those presumably representing an impairment (negative KPIs). The positive KPIs were counts per match for carries, clean breaks, conversions defenders beaten, kicks in play (available from 2009 onward), offloads, passes, tackles, tries, rucks won (%), scrums won (%), lineouts won (%, available from 2009 onward), and metres (m) run with the ball. The negative KPIs were counts of missed tackles, penalties conceded and turnover conceded.

Statistical analysis:

Data were imported into the Statistical Analysis System (version 9.4, SAS Institute, Cary, NC). The effects on KPIs were estimated with generalised linear mixed models (Proc Glimmix). For counts the model was over-dispersed Poisson regression and for proportion the model was over-dispersed logistic regression. Linear numeric fixed effects were included for the number of time-zones crossed in each direction of travel (east, west), for flight duration, difference in ranking and for a secular trend. Dummy variables were included for the away-match disadvantage (0 = home, 1 = away), for a set of amendments to the laws of Rugby Union (InternationalRugbyBoard, 2008) implemented in Super Rugby in 2008 (0 = pre2008, 1 = post2007), and for a change in competition format with the introduction of a conference system (SuperRugby, 2014b) that occurred in 2011 (0 = pre2011, 1 = post2010). To estimate and adjust for differences between teams and for changes within teams between years and following eastward and westward travel, team identity and its interaction with year of competition and eastward and westward travel as nominal variables were included as random effects. The analyses were also repeated with additional random effects to account for individual team differences in the effects of eastward and westward travel; the random effects consisted of team identity and its interactions with the linear numeric fixed effects for eastward and westward travel across time-zones, allowing for correlations between these effects (specified with an unstructured covariance matrix). Finally, to account for annual deviations from the secular trend, year of competition was also included as random effect. Simpler analyses, excluding all year effects, were performed for each year to justify inclusion of linear trends for the fixed effects in the full model.

The effects of crossing time-zones and travel were predicted for the maximum values in the Super Rugby competitions: 12 time-zones and 24 hours respectively (Auckland to Cape Town). These effects were combined with the away disadvantage to get the observed effect on team KPIs when competing at a remote venue. Each of these effects was also assessed separately for its pure contribution to team KPIs. 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. The secular trend was evaluated for the 11 years of competition analysed.

Effects were reported in percent unit with 90% confidence limits (Hopkins, Marshall, Batterham, & Hanin, 2009). Magnitude of the effects were assessed using standardisation, with threshold values for small, moderate, large and very large calculated as 0.20, 0.60, 1.2 and 2.0 of the observed between-teams standard deviation for each KPI in 2016; this standard deviation was estimated from the random effects and over-dispersed Poisson or logistic variance in the log- or logistic-transformed domain (Hopkins, 2016). Uncertainty in the standardized effects arising from uncertainty in the standardising standard deviation was assumed to be negligible, owing to the large number of games from which the standard deviation was derived (Hopkins & Batterham, 2019). Uncertainty in each effect 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): if the probabilities of the effect being substantially positive and negative were both >5%, the effect was reported as unclear; the effect was otherwise clear and reported with the probability that it was either substantial or trivial, usually whichever was the larger. The scale for interpreting the probabilities was as follows: 25–75%, possible; 75–95%, likely; 95-99.5%, very likely; >99.5%, most likely. To account for inflation of Type 1 error, only effects clear with 99% confidence intervals were highlighted (Liu, Hopkins, & Gomez, 2015). Visual inspection of residuals vs predicteds and residuals vs predictors showed no evidence of non-uniformity and non-linearity.

Results:

The mean and standard deviation for each KPI in 2016 are shown in Table 1 along with the secular trend and the effects of the difference in ranking and the changes in rules and competition format in 2008 and 2011. Figure 1 shows the mean and standard deviations for each year and the secular trend using the KPI carries as an example. The secular trend represents clear small to moderate increases for the majority of the KPIs, with only penalties conceded and tackles showing clear decreases. The remaining KPIs showed trivial changes that were unclear, except for turnovers conceded. The changes in rules and competition format had clear substantial effects on all KPIs, ranging from trivial (e.g., offloads) to mainly small increases (e.g., carries) and decreases (e.g., clean breaks). The difference in ranking had clear substantial effects on all KPIs, (increase in positive KPIs and decrease in negative KPIs) ranging from trivial (e.g., carries) to moderate (e.g., tries).

Table 1 near here

Figure 1 near here

The pure effects of the away-match disadvantage and the combined effect of flight duration and time-zones crossed for longest travel in both directions on each KPI are presented in Table 2. Figure 2 shows these effects for each year and the overall trend using the KPI carries as an example. The pure effects of the away-match disadvantage were mostly clear and trivial for 2016 and the 11-year trend. The travel effects in 2016 were trivial to moderate for both directions of travel and generally clearly negative travelling eastward and either positive (e.g., tries) or negative (e.g., carries) travelling westward. Trends were generally negative travelling eastward and either positive or negative travelling westward, although mostly unclear for both directions of travel, and ranging from trivial to moderate.

Table 2 near here

Figure 2 near here

The analyses of the individual differences between teams for each KPI produced mostly unclear results. However, there was some evidence of small differences between teams for some of the KPIs, including carries and passes, after travelling east (data not shown).

Discussion:

This study analysed the effects of travel on team KPIs in Super Rugby over 11 years. The main focus was the effects of long-haul travel consisting of 24 hours of travel across 12 time-zones, which were derived from an analysis of all available KPIs from all Super Rugby matches. By doing so, it was possible to properly adjust for secular trend, effects of rule and format changes, and the away-match disadvantage. The effects of the long-haul travel were predicted from a model based on the assumption that the travel and time-zone shift had simple linear numeric effects. The apparent absence of non-uniformity in the plots of residuals justified this assumption.

The positive secular trends for most of the KPIs show that, over time, players increased the number of actions performed during matches. As several of these KPIs, for example carries, clean breaks and defenders beaten, require high intensity efforts, these trends are consistent with the evolution of rugby toward a more physical game, despite clear reductions due to the changes in rules and competition format. Rugby union is a sport in continual evolution, with rules changed to increase safety of players as they become stronger and faster (WorldRugby, 2018). Similarly, Super Rugby expanded to include new countries and changed the competition format to make the game more entertaining and lucrative (SuperRugby, 2015). Despite the changes in rules, the moderate increases in clean breaks, defenders beaten, and tries, along with a similar increase in missed tackles, show that the game shifted toward a more offensive and physically demanding style, while the moderate decrease in penalties conceded could be due to the effects of changes in rule, an improvement in players' discipline or different interpretations of the rules by match officials. The difference in ranking, as expected, had a substantial positive impact (up to moderate) on most of the KPIs including metres and clean breaks.

The away-match disadvantage is due to a combination of factors, including changes in the psychological state of athletes (Carron, Loughhead, & Bray, 2005). When isolated from the travel component in our analyses, the away-match disadvantage had generally only trivial effects on performance. The estimates were based on the reasonable assumption that the disadvantage was the same for matches played either overseas or after short, internal travel. If the away match disadvantage was greater overseas, for example, then the effects of travel would have been biased high. Unfortunately, all matches after long-haul travel are away matches and there is no way to separately estimate an away disadvantage in a remote location. Previous studies showed the existence of an away-match disadvantage in Super Rugby on points scored (Du Preez & Lambert, 2007) and match outcomes (Morton, 2006) with adjustment for a travel effect in the first of these studies. Given the mainly trivial effects of the away-match disadvantage in our study, we suggest that playing away from home could impact match results by affecting tactical and strategic aspects of Super Rugby matches rather than technical skills and physical performance of players.

Throughout the monitored period the changes in KPIs are consistent with an impairment of performance following eastward long-haul travel across multiple time-zones, while performance did not change or slightly improved following westward travel. These findings support the idea that travelling east is usually more detrimental than travelling west. Eastward travel requires a phase advance of circadian rhythms while 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 is impaired (Fowler et al., 2017).

Rugby is an intermittent high intensity team sport (Gill, Beaven, & Cook, 2006) and fatigue may negatively influence players' performance (Kempton, Sirotic, Cameron, & Coutts, 2013). As the changes due to travel were more substantial for KPIs requiring repeated high intensity efforts, e.g., carries (Sayers & Washington-King, 2005), although not directly measured, fatigue may be the key factor that impaired performance after travel. Even if a full night of rest is usually enough to recover from travel fatigue (Reilly et al., 1997), fatigue related to jet lag affects performance for several days (Waterhouse, Reilly, Atkinson, & Edwards, 2007). The 11-year trends for the travel effects showed that in recent years the impairment in performance was more substantial for some KPIs, especially for eastward travel. A possible explanation is that there was a gradual decrease in the time between arrival and match-day, resulting in inadequate time to fully recover, but data to support this explanation are not available. The shift toward a more demanding game style may also have interacted with travel to increase player fatigue and affected performance. As there was evidence of small differences in the between-team individual responses to travel following east bounded flights, fatigue has the potential for being the most important mediator for the effects of travel on KPIs.

A possible limitation of this study is that match outcomes (win or lose) have not been included. A decline in team KPI after trans-meridian travel may have affected the chance of a team to win a match. However, the main aim of this study was to assess changes in performance indicators and, as winning is not just a matter of numbers, changes in KPI may not be indicative of changes in wining capability. As several components contribute in determining the outcome of a match, the introduction of the match result in the analysis may have only introduced an element of noise. It might be that players and teams performed worse in terms of sheer ‘match statistic’ after travel but perform better overall (i.e. won the match). Even if an improvement in KPIs influenced the chance of winning matches in Rugby 7’s (Higham, Hopkins, Pyne, & Anson, 2014) that may not be true for Rugby Union. Rugby Union is a peculiar game where territory occupation is as important as ball possession to achieve a victory (Bishop & Barnes, 2013) especially when compared with rugby 7’s where the disproportion between the number of players and the field dimension may enhance the importance of individual action in achieving victory. All the KPIs analysed were related to situations of ball possession (e.g., clean breaks) or non-possession (e.g., tackles), set pieces (scrums and lineouts) and discipline (penalties conceded). A reduction on these indicators does not automatically lead to a less functional occupation of the territory and therefore may not impact the ability of a team to win.

In summary, the findings of the present study suggest that long-haul travel and the increased physical demand of the game negatively impact players and team KPIs when overseas. Teams that underperform whilst overseas are less likely to finish high in the ladder and compete in the finals, which may also have a negative impact on team finance. As the increased physical demand of the game cannot be directly controlled, teams in Super Rugby should focus on implementing adequate recovery strategies to reduce the effects of travel. The findings of this research, although not directly translatable, can be of interest for all the coaches and support staff in sports that require international travel to compete.

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Table 1. Mean and standard deviation for each KPI in 2016 along with the secular trend and the effects of the difference in ranking and of the changes in rules in 2008 and 2011. Effects are reported in percent unit with 90% confidence limits.

				Effect of rule changes	
	Mean ± SD in 2016 (n=284)	**Secular trend, ±CL[a]**	**Difference in ranking, ±CL[a]**	**from 2008, ±CL[a]**	**from 2011, ±CL[a]**
Carries	107 ± 23	7.0, ±9.0 S*	2.0, ±1.7 T°°°	14.6, ±5.0 S****	7.5, ±5.0 S**
Clean breaks	10.2 ± 5.4	77.4, ±152.2 M	26.7, ±5.5 S****	-28.2, ±27.4 M**	-7.8, ±40.7 T
Conversions	2.3 ± 1.9	58.1, ±45.3 M***	56.7, ±8.2 M****	2.4, ±14.4 T°°	-24.9, ±11.7 S**
Defenders beaten	19.7 ± 7.8	58.6, ±74.5 L**	11.6, ±3.4 S***	-9.4, ±20.0 S	12.5, ±28.5 S
Kicks in play	22.0 ± 7.2	-0.0, ±30.0 T	2.9, ±2.9 T°°°	n/a	-11.8, ±13.8 S*
Lineouts won %	87 ± 11	10.0, ±4.0 M****	2.0, ±1.0 T°°	n/a	-2.0, ±2.0 T°°
Metres	430 ± 140	2.8, ±38.5 T	12.9, ±2.5 S****	10.0, ±24.1 S	-6.8, ±18.8 S
Offloads	10.8 ± 5.2	41.5, ±34.1 M***	9.6, ±4.0 S*	3.0, ±12.3 T°°	-2.3, ±13.0 T
Passes	140 ± 35	10.7, ±14.9 S*	3.9, ±2.0 T°°	6.4, ±7.1 S*	5.3, ±7.9 S*
Rucks won %	94.0 ± 3.1	0.0, ±2.0 T	0.0, ±2.0 T°°°°	-2.0, ±1.0 S**	1.0, ±1.0 T*
Scrums won %	89 ± 15	-1.0, ±8.0 S	2.0, ±1.0 T°°	-1.0, ±5.0 T	-2.0, ±4.0 T*
Tackles	104 ± 28	-9.5, ±19.0 S	0.5, ±1.9 T°°°°	19.5, ±12.1 M***	11.0, ±12.7 S**
Tries	3.2 ± 2.2	53.0, ±38.5 M***	59.5, ±7.5 M****	2.8, ±12.7 T°°	-25.2, ±10.3 S***
Missed tackles	19.7 ± 7.8	56.7, ±67.9 M**	-10.3, ±2.6 S***	-9.7, ±18.5 S	10.8, ±26.0 S
Penalties conceded	9.3 ± 3.0	-33.7, ±42.5 M	0.8, ±2.3 T°°°°	13.0, ±33.1 S	14.8, ±38.8 S
Turnovers Conceded	16.4 ±4.0	3.1, ±30.5 T	-3.3, ±1.9 T°°°	6.4, ±14.9 S	-4.0, ±15.5 T

Superscripted letters indicate effect size as follows: [T]Trivial, [S]Small, [M]Moderate, [L]Large.
Symbols indicate the probability of an effect being substantial or trivial (whichever was the larger).
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Figure 1. Example of a secular trend in Super Rugby matches using the KPI carries. Data points are means and standard deviations from the by year analysis. The continuous line represent the secular trend.

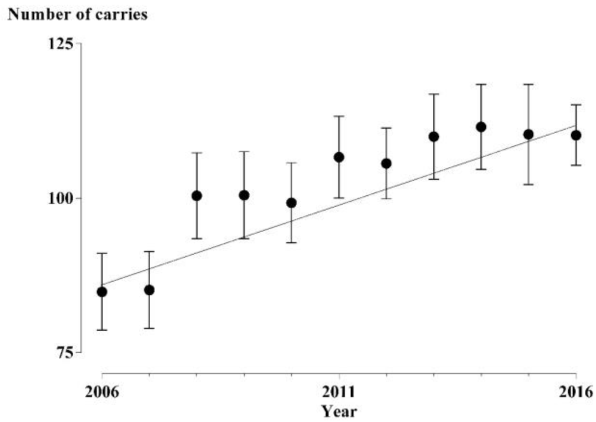

Table 2 – Pure effects of the away-match disadvantage and of eastward and westward long-haul travel, 12 time-zones, 24 h travel on team KPIs in 2016 and the 11-year trend over the monitored period (2006-2016). Predicted values are expressed as percent variation with 90% confidence limits.

	Means in 2016, ±CL[a]			**11-year trend, ±CL[a]**		
	Away-match disadvantage	**Travel east**	**Travel west**	**Away-match disadvantage**	**Travel east**	**Travel west**
Carries	-3.2, ±2.5 T°°	-9.3, ±6.4 S**	-9.4, ±6.6 S**	3.4, ±5.1 T*	-14.3, ±11.1 M**	-1.3, ±13.7 T
Clean breaks	-16.0, ±5.4 S**	-21.9, ±14.4 S**	8.4, ±18.3 T*	-6.2, ±11.2 T°°	-29.9, ±22.4 S**	22.2, ±39.9 S*
Conversions	-19.6, ±7.1 S**	-12.2, ±21.8 T*	21.2, ±27.6 S*	-3.8, ±15.7 T°°	5.8, ±48.7 T	11.0, ±48.2 T
Defenders beaten	-12.8, ±3.8 S***	-11.3, ±10.9 S*	3.0, ±12.2 T	-9.4, ±7.9 S*	-10.5, ±21.0 S	18.5, ±28.8 S*
Kicks in play	-2.1, ±4.4 T°°°	0.0, ±11.9 T	-0.5, ±12.0 T	1.4, ±11.1 T	-15.5, ±24.2 S	-3.0, ±29.6 T
Lineouts won %	0.0, ±2.0 T°°°	0.0, ±4.0 T	-2.0, ±4.0 T	1.0, ±4.0 T	-3.0, ±10.0 S	-1.0, ±10.0 T
Metres	-8.6, ±3.1 S**	-14.8, ±8.0 S***	0.4, ±9.2 T	-2.2, ±6.4 T°°	-21.0, ±13.5 M***	-3.8, ±17.3 T
Offloads	-6.4, ±5.0 T°°	-11.2, ±13.3 S*	-1.4, ±14.3 T	-4.3, ±9.9 T°°	-11.1, ±24.9 S	11.3, ±31.7 T
Passes	-2.3, ±2.7 T°°°	-10.0, ±6.9 S**	0.2, ±7.6 T	3.9, ±5.4 T*	-11.1, ±12.4 S**	4.9, ±15.2 T
Rucks won %	0.0, ±0.0 T°°	0.0, ±1.0 T	0.0, ±1.0 T	1.0, ±1.0 T*	0.0, ±2.0 T	-1.0, ±2.0 T
Scrums won %	-2.0, ±2.0 T*	3.0, ±5.0 T*	-6.0, ±4.0 S**	-2.0, ±3.0 T*	-2.0, ±8.0 T	-10.0, ±8.0 M**
Tackles	2.9, ±3.3 T°°	5.6, ±8.9 S*	10.3, ±9.6 S**	-4.8, ±5.7 T*	-10.0, ±13.7 S*	26.3, ±21.1 M***
Tries	-17.7, ±6.1 S**	-18.3, ±17.1 S*	20.3, ±22.8 S*	2.1, ±13.8 T°°	-10.9, ±33.6 T	21.1, ±43.7 S
Missed tackles	13.5, ±5.2 S**	12.0, ±13.3 S*	9.1, ±13.6 S*	6.2, ±9.6 T*	-1.7, ±22.5 T	34.9, ±34.8 M**
Penalties conceded	6.4, ±4.6 T*	-6.5, ±11.0 T*	6.1, ±12.3 T*	-0.8, ±7.7 T°°	-9.4, ±18.5 S	-4.1, ±20.0 T
Turnovers conceded	0.6, ±3.3 T°°°	4.7, ±9.0 T*	-3.8, ±8.7 T*	0.7, ±6.0 T°°	-0.4, ±15.3 T	0.3, ±16.6 T

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Figure 2. Pure effects of the away-match disadvantage (A) and effects of eastward (B) and westward (C) long-haul travel (12 time-zones, 24 h travel) on the number of carries, expressed as a percent variation, in Super Rugby matches. 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.