

## Please cite the Published Version

Read, Dale B, Williams, Sean, Fullagar, Hugh HK and Weakley, Jonathon JS (2022) The effects of travel on performance: a 13-year analysis of the National Rugby League (NRL) competition. Science and Medicine in Football, 6 (1). pp. 60-65. ISSN 2473-3938

DOI: https://doi.org/10.1080/24733938.2021.1876243

Publisher: Informa UK Limited

Version: Accepted Version

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- 1 Title
- 2 The effects of travel on performance: A 13-year analysis of the National Rugby League (NRL)
- 3 competition
- 4 Submission Type
- 5 Short communication
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- 24 Abstract Word Count: 200
- 25 Word Count: 1500
- 26 **Tables / Figures:** 0 / 3
- 27

#### 28 Abstract

29 The purpose was to investigate the effects of travel on performance in the National Rugby League 30 (NRL). A total of 4,704 observations from 2,352 NRL matches (2007-2019) were analysed. The effect 31 of travel on match outcome (i.e., win/loss) was analysed using a generalized linear mixed model, and 32 the points difference using a linear mixed model. For every 1,000 km travelled in the NRL, the estimated 33 probability of winning a match was reduced by -2.7% [-5.7 to 0.3%] and the estimated points difference 34 by -1.1 [-2.0 to -0.2] points. In relation to every 1,000 km travelled, the 2007-2009 seasons had the 35 greatest reduction in the likelihood of winning a match (-2.7% [-4.7 to -0.6%]), with the 2018-2019 36 seasons having the greatest likelihood (1.1% [-1.2 to 3.3%]). Regarding inter-state travel, teams from 37 the state of Queensland had the greatest reduction in the likelihood of winning a match while the team 38 from the state of Victoria had the greatest likelihood, although there were no clear differences between 39 states. These data suggest that travel has impacted performance in NRL matches although this effect 40 has reduced over time. These findings are useful for practitioners that prepare athletes in sports where 41 frequent short-haul travel is required.

42

43 *Keywords:* Rugby league, travel fatigue, short-haul travel, analytics, match outcome, football

#### 44 Introduction

Since the inaugural 1998 National Rugby League (NRL) season, there have been various changes to the number of teams involved, however, the current make-up and format of the competition has remained unchanged from 2007<sup>1</sup>. There are eight matches between the 16 teams each week across Australia and New Zealand, which are typically played throughout Thursday to Monday, with varying kick-off times. Therefore, given the schedule of NRL matches, travel is potentially significant to the performance of teams in the competition.

51

Teams in the NRL undertake a return journey every two weeks on average during the season and despite travel typically being short-haul (e.g., 1-3 but up to 6 hours), travel fatigue can still occur<sup>2,3</sup>. Different to jet lag, travel fatigue is temporary exhaustion and tiredness that accumulates over time<sup>4,5</sup>. The potentially negative effects of travel on performance have previously been assessed in rugby union<sup>6,7</sup>, American football<sup>8</sup>, netball<sup>9,10</sup>, and Australian football league<sup>11</sup>. However, similar information for the NRL is currently unknown.

58

Two studies have previously examined the effects of travel on individual NRL teams<sup>3,12</sup>. However, no studies have investigated the effects of travel on measures of performance such as match outcome, throughout the entire NRL. Therefore the purpose of this study was to investigate the effects of travel on performance in all NRL teams over a 13-year period. The study had three research questions; 1) Does travel affect performance in the NRL? 2) Have the effects of travel on performance changed over 13 seasons? 3) Is the performance of certain states or regions of Australia and New Zealand affected more than others by travel? 66 Methods

67 Design

68 Data from 13 seasons (2007 - 2019) of matches were obtained from the official NRL website<sup>1</sup> and were 69 analysed using an exploratory retrospective design.

- 70
- 71 Participants

All 192 matches from each season were initially included in the dataset, providing a total of 4,992 observations (2,496 matches). Due to a relatively small sample (0.5%), 12 drawn matches were excluded, in addition to 132 matches where teams played a home fixture outside of their home city. Play-off matches were not included. There was a total of 4,704 observations from 2,352 league matches used in the analysis. All data were freely available in the public domain and therefore ethics approval was not required. The ethics guidelines and principles of the lead author's institution were adhered to throughout.

79

### 80 Procedures

Performance was measured using; the binary match outcome of win or loss and the continuous variable of points difference between scored and conceded. Away travel (km) was calculated using a function in Google Maps<sup>®</sup> (https://www.google.com.au/maps/; Mountain View, CA) that provided a straight line distance between the venue of the match and the away teams home stadium<sup>8</sup>. Return travel was not considered as part of the match in question as this occurred following the fixture. The home venue of each team was identified and used as the reference for calculating travel distance.

87

## 88 Statistical Analyses

Bescriptive statistics are reported as mean (standard deviation) unless stated otherwise. The data was imported into R (version 4.0.2, R Foundation for Statistical Computing, Vienna, Austria) for analysis with the *lme4* package<sup>13</sup>. Match outcome was analysed via logistic regression using a generalized linear mixed model, and the points difference was analysed using a linear mixed model. Effects were converted to estimated probability of winning a match or points difference per 1,000 km travelled with

94 uncertainty expressed as 95% confidence intervals (CI). For research question one, linear numeric fixed 95 effects were included for travel distance, away-match disadvantage, turnaround time, and the 96 opposition's final league ranking and are presented as odds ratios (OR). The random effect was the 97 team identity nested within season. For research questions two and three, interaction effects were added 98 to assess the change/difference in the impact of travel upon performance over time and across 99 states/regions, respectively. The 'season' variable was originally explored as a linear effect but after 100 initial inspection, the effect was non-linear and therefore was parsed into five levels (i.e., 2007-2009, 101 2010-2012, 2013-2014, 2015-2017, 2018-2019) to allow for non-linear changes over time. These 102 models included a random effect for team identity only. The 'state/region' variable was treated as 103 categorical (i.e., Auckland (n = 1), New South Wales (n = 11), Queensland (n = 3), Victoria (n = 1)). The *emmeans* package<sup>14</sup> was used to report pairwise contrasts and estimated marginal means. 104

## 105 **Results**

106 Figure 1 shows the main effect of travel on performance. For every 1,000 km travelled, the estimated 107 probability of winning a match was reduced by -2.7% [-5.7 to 0.3%] and the estimated points difference 108 was reduced by -1.1 [-2.0 to -0.2] points. Analysis of the covariates demonstrated that the away team 109 had an OR of 0.56 [0.48 to 0.66] of winning a given match, and were estimated to have a points 110 difference of -6.0 [-7.1 to -4.9] points. Every additional day turnaround between matches was associated 111 with an OR of 0.98 [0.97 to 1.02] on winning a match, with an estimated points difference of -0.1 [-0.3 112 to 0.1] points. Playing a team one position lower in the final league standings was associated with an 113 OR of 1.15 [1.14 to 1.17] in regards to winning the match and was estimated to result in a 1.2 [1.1 to 114 1.3] points difference. Figure 2 presents the effects of travel for each season category. Figure 3 displays 115 the effects of travel for each state/region. 116 117 \*\*\* Insert figure one here \*\*\* \*\*\* Insert figure two here \*\*\* 118

119 \*\*\* Insert figure three here \*\*\*

#### 120 Discussion

The aim of the study was to investigate the effects of travel on performance for all NRL teams over a 13-year period (2007-2019). The main findings were that for every 1,000 km travelled, the estimated probability of winning a match was reduced by -2.7% [-5.7 to 0.3%] and the estimated points difference by -1.1 [-2.0 to -0.2] points. This is the first study to analyse the effects of travel on performance in the entire NRL competition. These findings demonstrate that travel can negatively affect performance and can support practitioners in their preparation of athletes.

127

On initial inspection, a reduction of -1.1 [-2.0 to -0.2] points and a -2.7% [-5.7 to 0.3%] likelihood in winning per 1,000 km might seem trivial. However, as teams regularly travel over >2000 km for away matches, a resultant -2.2 points and -5.4% winning likelihood can occur. Notably, 15% of the 2,352 matches in the study were decided by two points or less and in 12 of the 13 seasons, making the playoffs was determined by two competition points (i.e., the points allocated for a single win). Thus, when placed into context, changes of this magnitude might take on greater importance.

134

Playing away from home had an OR of 0.56 [0.48 to 0.66] and therefore is associated with a decrease in the odds of winning. Home advantage has previously been shown to exist<sup>6,8,15</sup>. Through surveys with NRL players, McGuckin et al.<sup>16</sup> identified that the home crowd, normal travel/transport and the presence of family/friends were the key factors that players perceived to have a positive influence on performance in home matches. When playing away from home, the same players ranked the different meals and sleeping arrangements as the largest negative influences, which might explain some aspects of the reduction in performance<sup>16</sup>.

142

There was an increase in total travel from 2007 to 2019 in the NRL, although a diminishing effect of travel on performance was found. These findings are similar to that of a study in rugby union<sup>6</sup>, which found that the impact of travel reduced over time, and might be linked to improvements in travel fatigue management, the recovery strategies implemented, or the increasing professionalism and physical development of athletes. The current study also showed that in regards to inter-state travel, there were no clear differences between the states/regions. Notably, the one team based in Victoria showed a 0.5%
[-3.4 to 4.4%] increase in the likelihood of winning a given match per 1,000 km travelled and no effect
on points difference (0.0 [-2.7 to 2.7] points). Given this team won the league six times in the 13 seasons,
this suggests that a teams ability can potentially offset the negative effects of travel on performance.
The differing effects of travel on teams within the same state/region might have contributed to the lack
of differences and suggests analysis on a team-by-team basis is required.

154

155 It is important to acknowledge this study was unable to account for or collect data on all factors 156 associated with travel, and more individualised measures of athlete responses are required. 157 Additionally, travel undertaken by teams or individual players outside of matches was unknown and 158 therefore could not be included.

# 160 Practical Applications

- 161 Coaches could use the information provided to estimate the potential negative effect of their journey on
- 162 performance in NRL matches. Consequently, this might inform several aspects of athlete preparation,
- 163 including; training, travel logistics, sleeping arrangements and nutritional options.

## 164 **Conclusion**

- 165 This study investigated the effects of travel in the NRL. For every 1,000 km travelled, the estimated
- 166 probability of winning a match was reduced by -2.7% [-5.7 to 0.3%] and the estimated points difference
- 167 was reduced by -1.1 [-2.0 to -0.2] points. In summary, these data suggest that travel has impacted
- 168 performance in NRL matches although this effect has reduced over time.

# 169 Acknowledgements

- 170 The authors can confirm no conflict of interest. No external financial support was provided for this
- 171 study.

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Figure 1. The effect of travel on the estimated probability of winning a fixture (a) and estimated pointsdifference (b).

nb. The solid black lines represent the estimated effect and the shaded grey areas represent the 95%confidence interval.

211

Figure 2. The effects of 1000 km of travel on the estimated probability of winning a fixture (a) and estimated points difference (b) across each season category.

214 nb. The black point represents the marginal mean effects of travel. The grey shaded area represents the

215 95% confidence interval. The black arrow enables pairwise comparisons between seasons (clear effects

are evident when the arrows do not overlap, with the lowest and highest effect arrow truncated).

217

Figure 3. The effects of 1000 km of travel on the estimated probability of winning a fixture (a) and estimated points difference (b) across each state.

220 nb. The black point represents the marginal mean effects of travel. The grey shaded area represents the

221 95% confidence interval. The black arrow enables pairwise comparisons between states (clear effects

are evident when the arrows do not overlap, with the lowest and highest effect arrow truncated).







