SHORT NOTE

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The Impact of Circadian Misalignment on Athletic Performance in Professional Football Players

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Objective: We hypothesized that professional football teams would perform better than anticipated during games occurring close to their circadian peak in performance.

Design: We reviewed the past 40 years of evening and daytime professional football games between west coast and east coast United States teams. In order to account for known factors influencing football game outcomes we compared the results to the point spread which addresses all significant differences between opposing teams for sports betting purposes. One sample t-tests, Wilcoxon signed ranked tests, and linear regression were performed. Comparison to day game data was included as a control.

Setting: Academic medical center

Participants: N/A.

Interventions: N/A.

Results: The results were strongly in favor of the west coast teams during evening games against east coast teams, with the west coast teams beating the point spread about twice as often ($t = 3.95$, $P < 0.0001$) as east coast teams. For similar daytime game match-ups, we observed no such advantage.

Conclusions: Sleep and circadian physiology have profound effects on human function including the performance of elite athletes. Professional football players playing close to the circadian peak in performance demonstrate a significant athletic advantage over those who are playing at other times. Application of this knowledge is likely to enhance human performance.

Keywords: Circadian rhythm, athlete, performance, football, sleep

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INTRODUCTION

Human athletic performance is controlled by a number of variables including innate ability, training, prior experience, level of fitness/health, concentration, motivation, and even sleep physiology.[1] The importance of the body clock is often overlooked, despite substantial data showing daily fluctuations in many major physiological systems.[2] Elite athletes need to work at perfecting human performance given the small margin of difference between success and failure in today's competitive sports. Despite this recognition, circadian factors are rarely considered by professional sports teams or their followers.

Biological rhythms can determine specific times at which peak performance is likely to occur based on intrinsic circadian factors. Time of day and circadian physiology have substantial effects on physical and cognitive performance and thus these factors and their modification may be particularly critical in the optimal achievement of elite athletes.[2] Studies have shown peak performance in the late afternoon, with a nadir at roughly 3 AM, based on circadian factors.[3] Societal demands from media across many time zones require athletes to perform at various times of day, including some that may be disadvantageous for peak performance. For example, given a 3-hour time difference between the west and east coasts of the USA, a west coast (WC) team playing an evening game (8 PM-12 AM Eastern Standard Time) against an east coast (EC) team would be expected to have some advantage as the WC team body clock is essentially 3 hours earlier and therefore closer to the peak of athletic performance. Thus, various game times may be beneficial for one team as compared to another team.[4,5]

Based on the above logic, we sought to test the hypothesis that WC teams would have an advantage over EC teams in professional football games played after 8 PM EST. In order to account for known variables affecting outcomes of sports events, we used the Las Vegas point spread as a comparator. The point spread is the standard metric to predict outcomes used by sports experts which takes into account the quality of the teams, the injury reports, home field advantage, and any other factors thought to be important. To test our hypotheses, we examined data spanning 40 years and over 100 professional games.

METHODS

National Football League games since the 1970 AFL-NFL merger were reviewed for all games involving EC versus WC teams with start times after 8 PM EST, including all days of the week, home and away games, in both east coast and west coast (Pacific) time zones. EC teams were defined by a home field within the Eastern Time zone. Likewise WC teams were defined by the Pacific Time zone. Seventeen different EC teams have played 6 different WC teams for a total of 106 games meeting inclusion criteria. An additional 293 daytime games (with start times of 1 PM and 4 PM EST) involving the same EC vs. WC match-ups were similarly analyzed as a control group. The data

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were classified into two data sets: Set 1 (1970-1994, 64 games) and Set 2 (1995-2011, 42 games), since a prior pilot study[6] had assessed Set 1, whereas Set 2 is used for validation.

Game times and scores were verified by databases at espn.com, nfl.com, pro-football reference.com, goldsheet.com, and Jim Feist workbooks. Point spread data were sourced and cross referenced from Jim Feist workbooks, goldsheet.com historic database, and any missing point spread data from the early 1970s were collected from newspapers/microfiche and cross referenced whenever possible. Win-loss records relative to the point spread and to home field advantage were examined using logistic regression analysis. This regression analysis utilized the response variable of whether or not WC teams beat the point spread. Four of the games were considered a "push" (tie) relative to the point spread, and these were removed from further analyses.

A variable x was defined based on the score of the west coast team minus the score of the east coast team plus the point spread. Thus, the value of x would be positive if the west coast team beat the point spread and negative if the west coast team did not beat the point spread. One sample t-tests were performed to assess whether the x values were significantly greater than zero. Wilcoxon signed ranked tests were also performed in cases of non-normally distributed data. Linear regression was performed to assess the potential impact of confounding variables such as year of game, home field advantage, game time and point spread. Chi squared testing was performed to compare the performance of WC teams over EC teams for evening games as compared to daytime games. A P value < 0.05 was considered statistically significant.

RESULTS

The data showed a strong advantage for WC teams over EC teams even accounting for the point spread. For Set 1, x was significantly greater than 0 ($P = 0.009$) indicative of WC teams' exceeding expectations over EC teams (i.e., beating the point spread). Similarly for Set 2, x was significantly greater than 0 ($P = 0.006$) again indicating an advantage to performance of WC teams over EC teams, even accounting for the point spread. For the combined data set, WC teams beat EC teams beyond the point spread ($t = 3.95$, $P < 0.0001$). Linear regression was performed to assess for longitudinal trends over time ($P = ns$) and for a potential advantage to the home team ($P = ns$), suggesting the point spread had adequately taken into account the home field advantage.

During evening games the WC teams beat the point spread in 70 games vs. 36 games for EC teams. For daytime (control) games, there was no significant WC or EC advantage. WC teams beat the point spread in 143 games vs. 150 games for EC teams. A χ^2 test to compare the WC advantage in evening vs. daytime games rejected the null hypothesis ($\chi^2 = 9.29$, $P = 0.002$), suggesting the WC advantage manifests during evening but not daytime games. Regarding the evening games, WC teams beat the point spread vs. EC teams by 5.26 ± 1.33 points ($n = 106$), whereas for daytime games the value was 0.16 ± 0.80 ($n = 293$).

DISCUSSION

Our data add to the existing literature by defining a major impact of circadian rhythm physiology on human athletic performance.[7] We observed that WC teams have a consistent and major advantage in outcomes as compared to EC teams (above and beyond predicted outcomes) when playing evening professional football games. These findings are specific for evening games (and not daytime games) and not a function of the quality of the teams or their travel schedules. The robust nature of the findings, with consistency spanning 4 decades, defines the major impact of sleep and circadian physiology above and beyond accepted determinants of professional sports' outcomes. Our use of the point spread to reduce the effects of potential confounding variables suggests that circadian factors are grossly underrecognized and underappreciated.

The existing literature from laboratory based and field based study is consistent with a major impact of sleep and circadian factors on physiological variables.[2,3,8] Sleep deprivation can impair performance in athletes and can increase the risks of accidents and morbidity/mortality in the general public.[9] Although the effects of jet lag and shift working are well known, circadian rhythm effects on peak human performance outside of the experimental setting are less clear. Our hope is that the new findings will help to highlight the importance of underappreciated influences on human health.

Despite our robust findings, we acknowledge a number of limitations. First, based on our study design, we could not measure polysomnography or temperature/melatonin rhythms to define circadian phase.[10] As such, we have made assumptions regarding these factors, recognizing that detailed measurements over the course of 4 decades are unrealistic. Second, we could not measure caffeine intake or use of performance enhancing substances which could confound our results. Such data are not readily available even to team physicians. We would argue, however, that nonsystematic variations in such factors should bias towards the null hypothesis, making our observed findings more robust than had we accounted for such sources of variance. Third, the point spread is the best available metric to predict outcomes of professional sports events. However, we recognize that the point spread has several different sources and can change over time depending on gambling behaviors. As such, we have used at least two major sources for the point spreads where available and used the value closest to game time for the purpose of consistency. Thus, we have used point spread as the best available method to predict outcomes, despite these limitations. Fourth, we are unable to determine the exact mechanism underlying our findings. Whether the losing teams had a reduction in motivation, endurance, strength, reaction time, flexibility and/or cognitive performance is unknown. Lastly, the degree of a sleep homeostatic effect could not be measured. Experimental data suggest the observed effect to be multifactorial, but further data will be required in high performing athletes.

Awareness of this significant and natural advantage may encourage application to athletic performance enhancement strategies. For example, athletes may attempt to adjust their internal clock to its peak performance time, regardless of what clock time the athletic event is occurring. Coaches may design travel schedules to either enhance or avoid obvious issues when crossing several or more time zones. In this particular case, EC teams may wish to consider phase delaying their body clocks by 3 hours well before playing games with start times 8-9 PM EST regardless of their opponent or the game location.

This 40-year study of meaningful competitive athletic event data from the National Football League demonstrates a significant WC team advantage over EC teams during evening games above and beyond accepted predictors of performance. The results support our circadian hypothesis and the potential for a significant yet natural athletic performance enhancer. Translational application of circadian rhythm knowledge to benefit general public health and performance is also suggested.

DISCLOSURE STATEMENT

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