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Sports, Sleep, and Circadian Rhythms

Circadian Rhythms and Enhanced Athletic Performance in the National Football League

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Summary: Circadian rhythms produce daily changes in critical elements of athletic performance. We explored the significance of performing at different circadian times in the National Football League (NFL) over the last 25 seasons. West Coast (WC) NFL teams should have a circadian advantage over East Coast (EC) teams during Monday Night Football (MNF) games because WC teams are essentially playing closer to the proposed peak athletic performance time of day. Retrospective data analysis was applied to all games involving WC versus EC teams playing on MNF with start times of 9:00 p.m. Eastern Standard Time (EST) from the 1970–1994 seasons. Logistic regression analysis of win–loss records relative to point spreads and home-field advantage was examined. West Coast teams win more often ($p < 0.01$) and by more points per game than EC teams. West Coast teams are performing significantly ($p < 0.01$) better than is predicted by the Las Vegas odds (the point spread). This apparent advantage enhances home-field advantage for WC teams and essentially eliminates the beneficial effects of home-field advantage for EC teams during MNF games. These results support the presence of an enhancement of athletic performance at certain circadian times of the day. **Key Words:** Athlete—Performance—Advantage—Football—Circadian—Rhythm.

Many physiologic processes follow a circadian rhythm of oscillation from peak to nadir throughout a 24-hour period (circa—about, dies—a day) (1,2). Human circadian rhythms are primarily generated by the paired suprachiasmatic nuclei located in the hypothalamus (3). An obvious manifestation of these circadian rhythms is the sleep–wake cycle. Less obvious circadian rhythms cause daily fluctuations in measures of cognitive and physical performance (2). There are fluctuations in human performance relative to the time of day (4).

Studies that have examined fragments of athletic performance such as strength, flexibility, and reaction times, have suggested enhanced abilities in the late afternoon (5–11). Athletes subjectively perceive that their peak athletic performance often occurs in the afternoon (12). Some athletic teams show improved performance during night games (13). Human studies have also demonstrated adverse effects on physiologic and performance measures secondary to alteration or disruption of circadian rhythms (14–18). This information suggests the possibility of a circadian advantage or an enhancement of athletic performance when competing at certain times of the day.

To examine the possibility of a circadian advantage in meaningful, competitive athletic events we performed a 25-year retrospective study in the National Football League (NFL). We hypothesized that West Coast (WC) teams should have had an advantage over East Coast (EC) teams during Monday Night Football (MNF) games. The basis of this hypothesis is that regardless of game location, or the direction of travel of either team, MNF games begin at 9:00 p.m. Eastern Standard Time (EST) (ABC Sports). Relative to their endogenous circadian clocks (3-hour time difference between coasts) the WC teams essentially start these games at 6:00 p.m. The WC teams should theoretically demonstrate an advantage because they are playing closer to the proposed peak athletic performance time (late afternoon). On the other hand, EC teams essentially start playing at 9:00 p.m. and frequently play to 12:00 midnight, which is closer to the human performance nadir (late night, early morning) (3).

To reduce the confounding variables in this study, a comparison was made with the Las Vegas point spread

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for each game. The point spread essentially makes both teams equal by adding a certain number of points to the weaker team's score to ensure that an equal amount of money will be wagered on each team (19). Prior to each game, the point spread is carefully calculated by weighing the variables affecting each team's predicted performance (team record, injury reports, home-field advantage, winning streaks, playing surface, etc.) (20). The distribution of the margin of victory over the point spread is approximately Gaussian and can be computed from a table of standard normal distribution (21). Therefore, important confounding variables are frequently nullified by the point spread.

METHODS

Retrospective data analysis was applied to all games involving EC versus WC teams playing on MNF with start times of 9:00 p.m. EST over the last 25 years (1970–1994 seasons) (22). East Coast teams were defined as those teams whose home field was within the Eastern Standard time zone. Likewise, WC teams were defined by the Pacific time zone. Twelve different EC teams have played five different WC teams over the 25-year period for a total of 63 games (22).

Win–loss records, relative to the point spreads (23,24) and to home-field advantage, were examined using logistic regression analysis. This regression analysis utilized the response variable of whether or not the WC teams beat the point spread. In the first logistic regression, we included home games as the indicator variable for home-field advantage. In the second logistic regression, we included the point spread as a predictor variable in addition to including home games as the indicator variable for home-field advantage. Point spreads from 1970 to 1972 could not be located. Therefore, these seven games were excluded from the point-spread logistic regression.

All-time winning percentages for home and away games in the NFL, as well as overall win–loss records since 1970, were calculated for each NFL team included in this study. These winning percentages were compared to those demonstrated on MNF. Winning percentages for MNF games involving teams from the same time zone were also calculated (92 total games).

RESULTS

West Coast teams won more often ($p < 0.01$) and by more points per game than EC teams. West Coast teams won 63.5% of the games and EC teams won only 36.5% of the games. West Coast teams won games by an average of 14.7 points per game, whereas

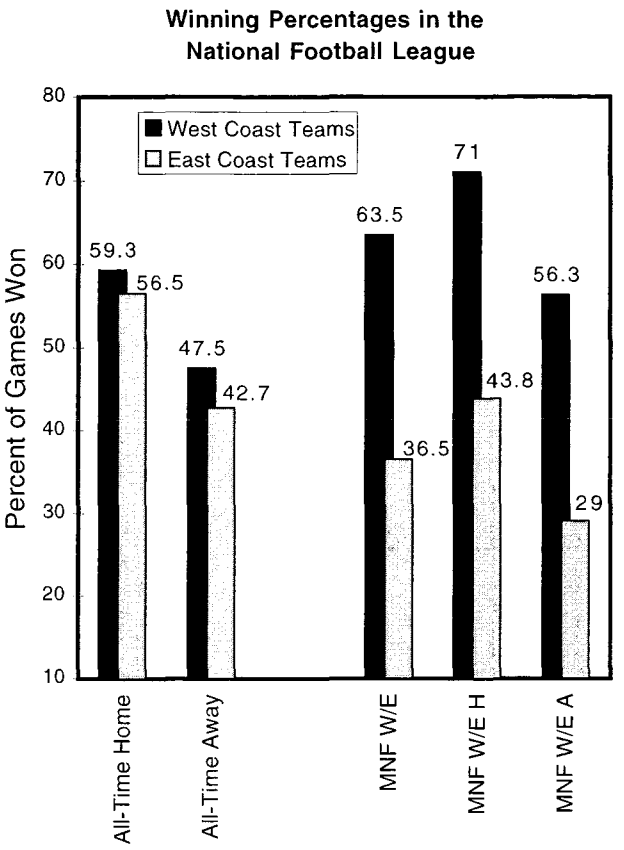

FIG. 1. MNF, Monday Night Football games; W/E, West Coast teams versus East Coast teams; H, home games; A, away games.

EC teams won by an average of 9.0 points per game. West Coast teams won 59.3% of all their home games and 71.0% of their MNF home games. In contrast, EC teams won 56.5% of their home games, but only 43.8% of their MNF home games. When EC teams play a team other than a WC team on MNF, their home winning percentage increases by 23.7 percentage points, to 67.5%. Likewise, when WC teams play someone other than an EC team on MNF, their home winning percentage decreases by 12.9 percentage points to 58.1%. A comparison of winning percentages for WC and EC teams are illustrated in Fig. 1.

The first logistic regression, which examined whether or not the WC teams beat the point spread and included home games as the indicator variable for home-field advantage, demonstrated a clearly significant edge to the WC teams with a p value of less than 0.01. The second logistic regression included the point spread as a predictor variable in addition to including home games as the indicator variable for home-field advantage, and it also revealed a highly significant result in favor of the WC teams ($p < 0.01$). In this 25-year sample, simply selecting a WC team without considering any other variable successfully predicted the winner against the point spread 67.9% of the time.

TABLE 1. *Other possible explanations for the observed West Coast advantage demonstrated on Monday Night Football*

West Coast team superiority
Home-field advantage
Playing surface
Winning streaks
Jet lag (circadian rhythm disruption)
Sleep homeostatsis (sleep deprivation)
Travel
East Coast teams play poorly on Monday Night Football
West Coast teams play closer to the time of day they train

West Coast and EC teams played nearly equal numbers of home games in the point-spread comparison (26 and 30, respectively) and in the general comparison (31 and 32, respectively). Overall, WC team records since 1970 are 4.4 percentage points better than EC team records (0.542 vs. 0.498). However, when WC teams play EC teams during MNF games, WC team records are 27.0 percentage points better than EC team records (0.635 vs. 0.365).

DISCUSSION

Over the last 25 years of MNF, WC teams have won more often ($p < 0.01$) and by more points per game than EC teams. The WC teams have also performed significantly ($p < 0.01$) better than predicted by the Las Vegas point spread. These findings support our hypothesis and suggest the possibility of a circadian advantage or an enhancement of athletic performance when competing at certain times of the day.

Other possible explanations for these results are unlikely (Table 1). The WC teams may simply be better than the EC teams. However, although the overall WC team records are slightly better than EC team records since 1970 (0.542 vs. 0.498, respectively), this is nowhere near the 27 percentage point advantage demonstrated by WC teams on MNF.

Confounding variables potentially affecting other research (13,25) were essentially nullified in this study by the logistic regression analysis involving the point spread. These variables include the team's past and present record, injury reports, home-field advantage, winning streaks, playing surface, etc. (see explanation of point spread in Introduction).

It is unlikely that the results of this study were due to jet lag. The adverse effects of jet lag on either coastal team should be nearly equal because they are traveling across the same number of time zones. If anything, the EC teams should demonstrate an advantage because they would experience a more rapid adjustment to the new time zone due to their flight in the westward direction (14). Homeostatic sleep mechanisms or sleep deprivation would not account for the findings in this study for the same reasons.

Likewise, travel in and of itself should not differentially affect the WC and EC teams to the degree seen in this study. When EC teams travel to other destinations in the same time zone for a MNF game, they demonstrate a winning percentage of 44.8%. This is in contrast to a winning percentage of 29.0% when they travel to the West Coast for MNF games. West Coast teams traveling to play an EC team for a MNF game actually demonstrate an 8.8 percentage point improvement in their record relative to all-time away games.

The results in this study were not secondary to the EC teams simply playing poorly on MNF as they experienced a home winning percentage of 65.2% when their MNF opponent was from the same time zone. One possible contributing explanation for the results is that WC teams may be competing closer to the time they typically train each day. Enhanced athletic performance has been suggested when competition and training times coincide (26).

The degree of this advantage appears to be substantial when compared to other advantageous positions in competitive sports. For example, home-field advantage is subjectively regarded as a clearly favorable position that objectively represents a home winning percentage of approximately 55–60% (Fig. 1) (25,27). The home winning percentage for WC teams was 71% during MNF games with EC teams (Fig. 1). Conversely, the beneficial effects of home-field advantage were essentially eliminated for EC teams during MNF games with WC teams (Fig. 1). Therefore, the effect of performing at certain times of the day can be at least as beneficial or detrimental as playing a home or away game, respectively.

The exact circadian time of each athlete at game time and the idiosyncrasies of adjustment to time zone changes for each athlete could not be determined in this retrospective study. However, the impact of these potential confounding variables is minimized in light of the 25 years of data and the large numbers of athletes involved. Another limitation of this retrospective study is that the travel strategies of each team have undoubtedly changed over the years. However, when traveling across three time zones, it is unlikely for complete circadian acclimation to occur in 1–2 days and may take even longer than 3 days (14,28).

Present travel strategies employed by the NFL teams (four WC and nine EC teams surveyed) demonstrate some use of circadian rhythm knowledge. West Coast teams now travel to the East Coast 2 days prior to game time, and most EC teams presently travel to the West Coast 1 day prior to game time. Although other factors help determine travel plans (e.g. practice-field availability) most teams' travel plans were based on

jet lag recommendations that imply a longer period to acclimate to the new time zone when traveling in the eastward direction (14). Based on circadian rhythm physiology, the present travel strategies of WC and EC teams allow approximately equal degrees of acclimation. Our results indicate that it may be more advantageous to perform closer to one's peak performance time of day rather than try to acclimate to an opponent's time zone. For example, EC team athletes may consider phase delaying their endogenous circadian clocks by 3 hours prior to MNF games with WC teams.

CONCLUSIONS

Research on circadian rhythm physiology, fragments of athletic performance, and meaningful competitive athletic events suggests the possibility of an enhancement of athletic performance when competing at certain times of the day. This advantage appears to be substantial relative to the margin of victory in today's elite athletic competition. The challenge of future research will lie in constructing study designs with sufficient specificity, but noninterference with, the athletes' performances during meaningful competitive events.

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