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Managing the Body Clock: Examining the Competitive Disadvantage Associated with Scheduling East Coast NFL Road Games for West Coast Teams in the Early Time Slot

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ABSTRACT

Stonelake B. Managing the Body Clock: Examining the Competitive Disadvantage Associated with Scheduling East Coast NFL Road Games for West Coast Teams in the Early Time Slot. **JEPonline** 2016;19(1):xx-xx. Among bettors and bookmakers, it is common knowledge that west coast NFL teams underperform when playing early, east coast road games. Physiological justifications for this underperformance are abundant, as the body clocks of west coast athletes are not in sync with those of their east coast opponents, and reaction times, flexibility, and muscle strength are just a few of the variables known to be superior later in their daily circadian rhythms. The purpose of this paper is to examine the NFL data from 2001 to 2014 and present clear evidence of the physiological disadvantage. In early east coast games, there is a statistically significant competitive disadvantage for a visiting west coast team (controlling for other factors). In addition to drastic differences in win percentage, the aforementioned physiological detriments manifest themselves in the form of increased penalties, turnovers, and pass-drop rate. These findings are consistent with physiological expectations. The findings indicate is that a morning game pitting a west coast road team against an east coast foe is unfair from a competition perspective, and represents an inferior quality of product from an entertainment perspective. To conclude, the prevalence of such games is examined. Also, it is suggested that, while nation-wide competition in the NFL necessitates trans-meridian travel, careful scheduling should be adopted to mitigate sub-optimal kickoff timing.

Key Words: Body clock, NFL, Circadian variations, Competitive disadvantage

INTRODUCTION

Chronobiology

The human body is regulated by circadian rhythms that consist of daily cycles of physiological responses that include core body temperature, melatonin secretion, and plasma level of cortisol. The study of investigating and quantifying the periodic changes in temperature and hormones and other time-dependent physiological oscillations is called chronobiology. Although biological rhythms exist with many different periods, the most studied, well-known and relevant to human physiology are the circadian rhythms (4). These daily biological fluctuations have been shown to be robust, regular, and predictable over time (4).

By definition, circadian rhythms are regulated endogenously, meaning that they are controlled internally. Isolation studies have shown that even in the absence of any outside stimuli, these rhythms follow roughly a 24-hr cycle (1,26). In humans, these rhythms are maintained primarily by the suprachiasmatic nucleus (SCN), which is a group of nerve cells located in the hypothalamus. Destruction of the SCN results in the complete absence of a regular sleep–wake rhythm.

Although endogenously regulated, the circadian rhythms are not immune to outside stimuli. For example, the retina contains specialized ganglion cells that are sensitive to light. The cells project directly onto the SCN, where they help in the synchronization of the master circadian clock (23). While rates vary considerably among individuals, this master clock is known to recover more quickly from a phase shortening than from a phase lengthening. Aschoff (2) calculated the rate of synchronization associated with westward trans-meridian travel to be 92 $min \cdot d^{-1}$ compared to a rate of 57 $min \cdot d^{-1}$ after eastward flights.

While the sleep-wake cycle may be the most obvious manifestation of circadian rhythms, more relevant to this paper are changes in factors such as grip strength, maximal ventilation, oxygen consumption, and tolerance to maximal effort which, along with body temperature, vary with time of day in a sinusoidal manner and peak in the early evening (4).

Manfredini and colleagues (18) reported that optimal timing in the circadian rhythm can result in as much as a 10% increase in athletic performance. To put this into context, a 10% decrease in peak performance is also associated with drinking the legal limit of alcohol (10) or getting only 3 hrs of sleep for three consecutive nights (24).

Chronobiology and Performance

Before measuring the decrease in athletic performance on a team basis, context is provided by focusing on the individual athlete. Effects of circadian rhythms both on the body at rest and on athletic performance are studied. In *Circadian Variance in Sports Performance* (4), Atkinson and Reilly document both, and their results are summarized below.

Circadian Variations on the Body at Rest

Many variables relevant to athletic performance are intimately tied to the circadian rhythm of body temperature. As depicted in Figure 1, core body temperature, like many circadian rhythms, follows a sinusoidal curve in its daily cycle. While variation exists among individuals, this curve tends to reach its nadir around 0400 hrs, increasing gradually to its apex around 1800 hrs. There is extensive evidence showing a considerable endogenous component for

the core body temperature cycle; in isolation and constant routine studies, the amplitude is largely unchanged (4).

Cardiovascular functions also follow circadian rhythms. Depending on the individual, heart rate tends to be between 5 and 15% above its daily mean at its apex, which happens around 1500 hrs (19,26). Stroke volume, cardiac output, blood flow, and blood pressure exhibit a similar rhythm.

Two key components of pulmonary airway resistance (i.e., forced expiratory volume and peak expiratory flow) are also cyclical and are least favorable to optimal performance in the morning; the nadir is between 0300 and 0800 hrs (12). This is one reason why asthmatic athletes are encouraged to avoid strenuous activity early in the morning.

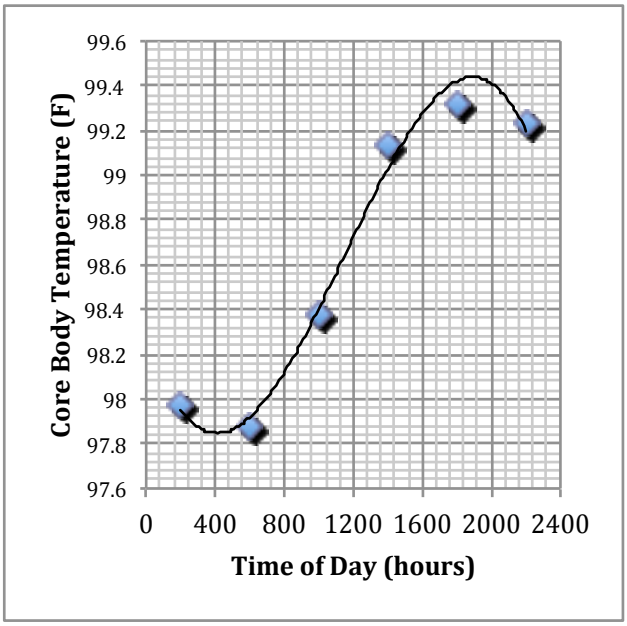

Figure 1: Sinusoidal Nature of Core Body Temperature (recreated with author's (4) permission)

Circadian Variations on Athletic Performance

An important component in most sporting events is simple reaction time to either auditory or visual stimuli. Reaction time peaks in the early evening, at the same time as the maximum body temperature (17), because every 0.1 °F increase in body temperature yields a nerve conduction velocity increase of 0.432 $m \cdot sec^{-1}$ (30).

Another important factor in both performance of athletes and their health is joint flexibility. Lumbar (low back) extension, glenohumeral lateral rotation, and whole-body forward (hip) flexion all exhibit circadian variances with maximal values 20% above their daily means (13). The occurrence of these maximal values can vary between 1200 and 2400 hrs among athletes. Similarly, stiffness in the knee joint mimics the body temperature curve with maximal range of motion values recorded in the early evening when measured independent of exogenous factors (29).

Muscle strength, independent of the muscle group measured or speed of contraction, consistently peaks in the early evening (4).

- Hand grip strength peaks between 1400 and 1900 hrs with a maximum value roughly 6% above the daily mean. It is known to have endogenous components, and it is resistant to changes in sleep-wake regimens (14).
- Elbow flexion strength is cyclic, peaking in the early evening (8).
- Back strength is roughly 6% greater than the daily mean in the early evening and lowest in the morning (6).
- The above strength variances occur in both concentric (shortening of muscle) and eccentric (lengthening the muscle) strength (4).

Finally, circadian rhythms have been identified in laboratory measures of anaerobic power and short-term dynamic ability.

- High-intensity, constant work-rate exercise was determined to be significantly higher in the afternoon compared with the morning (15).
- Longer work-times and higher peaks of lactate production were recorded at 2200 hrs compared with 0630 hrs (21).
- Maximal jumping length, which exceeded the 24-hr mean by 3.45%, peaked at 1745 hrs (10).
- Results similar to maximal jumping length were exhibited in vertical jumping performance (22).
- Both mean and peak power output recorded on a swim bench were shown to peak at 1800 hrs, at which point they exceeded daily averages by 11 to 14% (20).
- Self-chosen work rates on a cycle ergometer also varied by time of day, peaking at 1900 hrs with the amplitude roughly 7% above that of the daily mean. The higher work rates chosen in the evening were not accompanied by any increase in perceived exertion by the athlete (3,7).

Circadian Variations in Sport

With all of the aforementioned factors, significant variance in athletic aptitude as a function of time of day is expected. In fact, there is plenty of anecdotal evidence pointing to increases in athletic performance at the circadian-optimal hours of the early evening. For example, most world records are broken around this time of day. However, statistics like this do not account for biases (such as the propensity to have championship events scheduled in primetime). Specific cases that control for this are considered below.

In the world of competitive cycling, time trials are scheduled throughout the day. Performances of competitors improved when racing in the afternoon and evening, compared to those racing in the morning (5). Similarly, evening competitors in throwing contests outperformed their morning counterparts, when the frequency of trials is standardized at different times of day in simulated competitions (9).

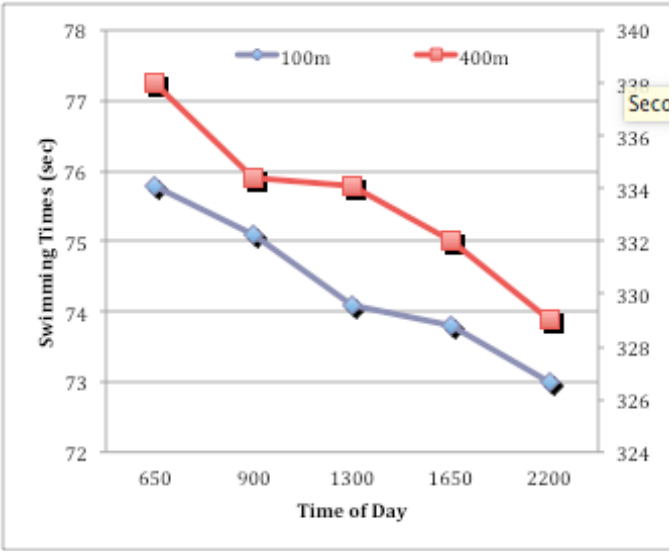

Figure 2: Improving Swim Times Later in Day (recreated with author's (4) permission)

Although scheduling bias was controlled for in the above examples, one could argue that the environmental factors may have played a role as well. Fortunately such factors are mitigated in swimming competitions. With environmental factors controlled, performance in both the 100 m and the 400 m races improved when occurring in the late afternoon and early evening (4) (Figure 2). Optimal circadian timing has been shown to increase swimming performances by 11 to 14% over the daily mean; a staggering amount which exceeds the effect of sleeping only 3 hrs for three consecutive nights (24).

METHODS

The main subject of this research is the claim that sub-optimal circadian timing associated with west coast teams playing in the early slot during east coast road trips has significant implications on the game. This result is not surprising, given the numerous physiological detriments already cited. However, given the importance of a single game in a league as competitive as the NFL, it is extremely important. Furtick (11) calculated that the difference between winning and losing a single NFL game translates to between 5 and 7 million dollars for an NFL franchise. In the period analyzed for this study, 52.4% of road games for TZ 1 & 2 teams were scheduled as morning body clock starts. Put differently, in more than a quarter of regular season games, these teams faced a significant competitive disadvantage.

Terminology

"Body clock time" for teams is based on the local time[1] at that team's home at kickoff. For example, New York hosting San Francisco with a 13:15 EST kickoff would have body clock start times of 13:15 and 10:15 for New York and San Francisco, respectively. Body clock start times prior to 11:30 are classified as "morning", while those after 16:45 are classified as "primetime" with all remaining given the slight misnomer of "afternoon". Afternoon and primetime starts were collectively referred to as "late" starts.

Not to be confused with body clock start times are "TV time slots". These are based on the fact that on a typical Sunday, football games start shortly after 10 am (PST), 1 pm (PST) or are played as "Sunday Night Football". The games are classified as being in the first, second or third TV time slots. Thursday, Saturday, and Monday games are classified into the most appropriate of these three slots, based on their kickoff time.

For ease of notation, teams from the western, mountain, central, and eastern time zones were referred to as TZ 1, TZ 2, TZ 3, and TZ 4, respectively. It was assumed that these time zones would observe daylight saving time. Thus, Arizona was switched between TZ 1 and TZ 2, where applicable. Similar adjustments were made for Indianapolis, prior to 2006. Because Denver is the only team that is always in TZ 2, it was aggregated with TZ 1 for much of the analysis. When teams from TZ 1 or TZ 2 travel east, a non-primetime game can be shown in the first or second TV time slot. When the first is chosen, it gives rise to a morning body clock start time for the visiting team. The cut-off times listed in defining the body clock start time classifications were chosen to segregate morning start times as arising in this situation.

Subjects

For this study, data from 3,564 NFL games was studied. This corresponds with all regular season games from 2001 to 2014 with the exception of games played in locations materially different from the home team's normal stadium. For example, the six games that the Buffalo Bills hosted in Toronto were included in this study, but the eleven games played in London as part of the NFL International Series were excluded. Also excluded was a 2014 Bills game moved to Detroit. For Hurricane Katrina, the New York Giants were classified as the home

[1] The only exception comes on the first Sunday in November. Technically daylight saving time ends on this day, but it is assumed to end the week after, to allow athletes' internal clocks time to adjust.

team when their 2005 road game at New Orleans was moved to East Rutherford. Remaining Saints home games that year, which were played in Tiger Stadium or the Alamodome, were left in the study and classified as home games.

RESULTS

Competitive Disadvantage

The most obvious measure for decreased performance is to examine the win rate associated with morning body clock start times. To do so home field advantage must be controlled for, as morning body clock start times are exclusive to (TZ 1 & 2) road teams.

Despite the relatively small number of regular season football games each year, home field advantage was fairly consistent over the time period studied. In these 14 yrs, the home team won 57.5% of its games (n = 3,562). In nine of those 14 yrs, the home team win percentage was within one percentage point of that figure. The sample standard deviation of the annual home team win percentage was only 1.5%.

With data split by body clock start time, a remarkable outlier (Figure 3) appears. While home teams win 57.2% of games when the visitor has an afternoon body clock start time (n = 2,631), and 54.6% when the visitor's body clock start time is evening (n = 582), that win percentage jumps to 64.8% for the home team, when the visitor's body clock start time is in the morning (n = 349).

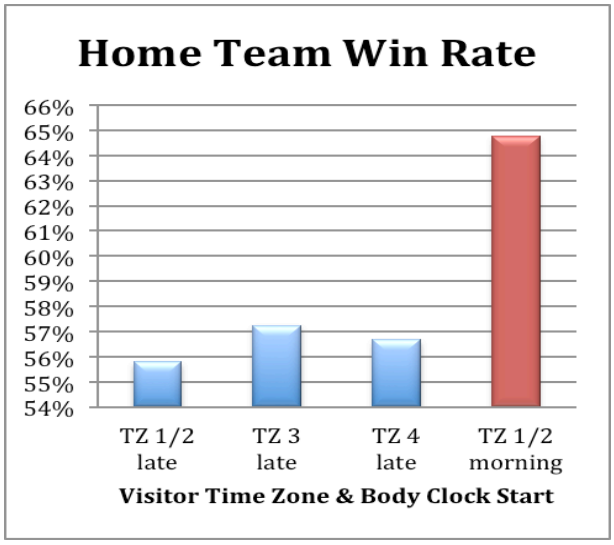

Figure 3: Competitive Disadvantage Associated with Morning Body Clock Start Teams

The disproportionately small win percentage of (TZ 1 & 2 road) teams playing morning body clock start times may be enough to convince the reader of the competitive disadvantage that is associated with them. To better quantify this disadvantage, the statistical significance of the difference between this win percentage and that of road teams playing non-morning body clock start times is tested. Not surprisingly, this difference in win percentage is statistically significant (P = 0.0021).

To control for opponents, comparisons between the win rate in morning body clock games and those games pitting TZ 1 & 2 road teams against TZ 3 & 4 home teams in non-morning body clock games were made. The home team win percentage in the latter case was 54.4% (n = 114) and relative to this group, despite the small sample size, the 64.8% win rate of home teams against visiting morning body clock start time teams is statistically significant with P = 0.0237.

While both TZ 1 and TZ 2 teams can face morning body clock start times when playing in either TZ 3 or TZ 4, as expected the effect is more pronounced when the road team is from TZ 1, where 65.6% of games are won by the home team (n = 279) compared to a 61.4% win percentage for home teams facing TZ 2 foes (n = 70). While only incrementally, the further

east a west coast team travels, the more of a disadvantage they face, as expected. Against TZ 1 & 2 teams in morning games, home TZ 3 teams win at a 64.5% clip (n = 152), while home TZ 4 teams win at a 65.0% clip (n = 197). This further parsing of the data is presented anecdotally, as both the differences and the sample sizes are relatively small and the more general claim has already been proven to be statistically significant.

This same competitive disadvantage can be seen when examining margin of victory. Against road teams with a morning body clock start, the home team won by an average of 5.07 points. This is far in excess of the 2.35 points by which home teams won on average when their opponents were not facing morning body clock start times.

To control for opponent, comparisons were made with margin of victory in games where TZ 3 & 4 teams hosted a TZ 1 or a TZ 2 opponent, when the body clock start time for the visitor was not morning. In this situation, the home team won by an average of 1.32 points. Informally, a morning body clock start time costs the visitor about 3 points in excess of the normal home field advantage. Approximately 23% of NFL games in the time period studied were decided by 3 points or less.

Sloppy Play

With the aforementioned effects of disrupted circadian rhythms to both physical and cognitive performance, increases in parameters such as turnovers and penalties for teams playing body clock morning games are expected. In fact, the data confirm these suspicions as well. Thus, the data were examined not only to serve as justification for the competitive imbalance, but also as evidence that these games do not represent the best product that the NFL can put forward.

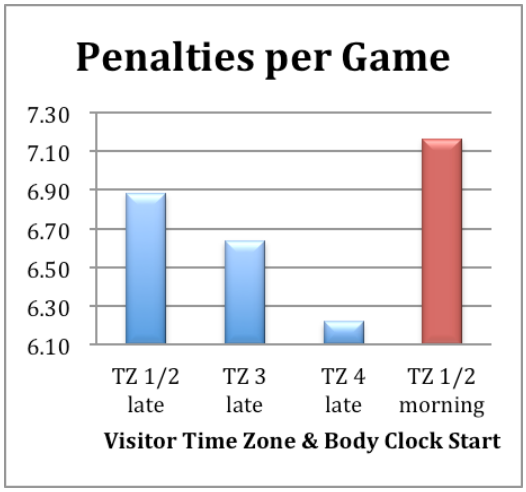

Figure 4: Increased Penalty Prevalence for Morning Body Clock Start Teams

A surprisingly small difference exists in both penalties accepted by the opponent (henceforth "penalties") and turnovers per game, when comparing home and road teams in aggregate. The home teams averaged 6.11 penalties and 1.62 turnovers per game compared to 6.49 penalties and 1.71 turnovers for the visiting team[2]. Even though this difference was not pronounced, to protect against any home/visitor bias (and for the sake of conservatism) data from morning body clock start teams were compared to that of other visiting teams. Teams playing a morning body clock start time amassed 7.16 penalties and turned the ball over on average 1.83 times per game (Figures 4 and 5). These findings indicate increases of 10.3 and 7.1% over the visiting team averages, respectively.

The increases in turnovers and penalties associated with playing morning body clock start times (relative to all other visiting road teams) are both statistically significant. Due in part to a

[2] Turnover and penalty data collected from 2003-2014 as figures for 2001 and 2002 were unavailable.

smaller (relative) variance in penalties, the increase in penalties is statistically significant at a higher level (P<0.0001) than for turnovers (P = 0.0435).

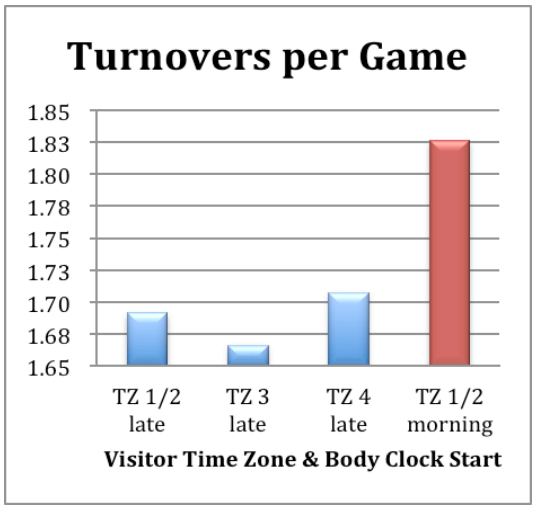

Figure 5: Increased Turnover Rate Associated with Morning Body Clock Start Teams

The data can be parsed further to see the expected results that both penalties and turnovers are even more prevalent in morning games for TZ 1 teams than for the TZ 2 counterparts. In morning body clock start times, TZ 1 teams amassed 7.29 penalties and 1.83 turnovers, compared to 6.68 penalties and 1.81 turnovers per game for TZ 2 teams.

As Figure 4 shows, road TZ 1 & 2 teams committed more penalties than their road TZ 3 & 4 counterparts. In fact, independent of venue, TZ 1 & 2 teams committed on average 0.3 more penalties per game than TZ 3 & 4 teams. This was due in large part to the Oakland Raiders, who committed 7.94 penalties per game (no other team averaged more than 7). If controls for team are made, the expected increases continue to exist, but the sample size becomes too small to be statistically significant.

To further support the narrative of sloppy play, the data were analyzed for dropped passes. To avoid the possible bias of trailing teams throwing more frequently, pass drop rates were used in lieu of pass drop totals. This data were only available from 2006 to 2014.

The data showed the expected increase in pass drop rate among teams playing body clock morning games (5.41% compared to the 4.97% rate of all other visiting teams), but it was not conclusive (P = 0.0719). The relatively small sample size and such factors as prevent defenses employed late in games by teams with large leads may have masked this correlation. This is left as a topic of further study.

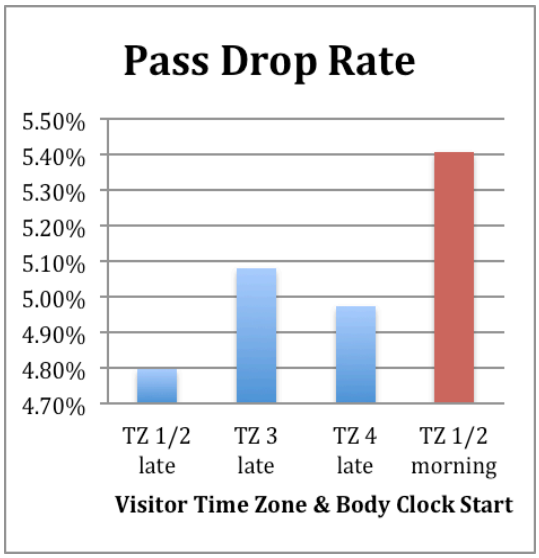

Figure 6: Increased Pass Drop Rate Associated with Morning Body Clock Start Teams

Injury Risk

Unfortunately the injury data were unavailable for this study. However, studies have shown correlations between sleep deprivation and increased injury risk. For example, Wolski (28) reported that Matthew D. Milewski, MD of Elite Sports Medicine found that athletes who slept less than 7 hrs had a 1.7 times greater chance for injury than those who had a good night's sleep. Studies focusing on potential dangers to athletes (NFL players specifically) playing at sub-optimal body clock were not found, but given the abundance of physiological detriments associated with mornings, a correlation seems possible if not probable. This is also left as a topic of further study.

DISCUSSION

Suggested Solutions

While total eradication of morning body clock games would be difficult given the complexity of the NFL schedule, it seems as though such occurrences should be greatly reduced. This topic was brought to the attention of Commissioner Goodell prior to the 2009 season, at which point he was quoted as saying that he “had not seen specific information suggesting early starts [for west coast teams traveling east] could create a competitive disadvantage for visiting teams.”

To Commissioner Goodell’s credit, he revisited the subject in October 2012 with a much more sympathetic stance of the situation, saying that "Several of our teams on the West Coast have raised that [issue of morning body clock games] and we have been studying it. We have tried to put as many of those games on the East Coast at 4 pm. You can imagine the thousands of different issues you have to put into the schedule. But the 10 o'clock starts are pretty tough."

Despite this statement, little has been done in terms of scheduling. In the 14 yrs of data studied in this paper, there was an average of 25 morning body clock start time games per year. This accounts for more than half of all road games for TZ 1 & 2 teams. In 2015, there were 26 such games.

The NFL scheduling process is an extremely complicated process with many variables considered and potential schedules found using in an intricate scoring process. Taking Commissioner Goodell at his word, morning body clock games are viewed as unfavorable and scored as such, but based on the recent schedules produced, this aspect of the scoring system needs to be revisited and prioritized.

It is worth noting that of the non-primetime games in this study, there is a 68 to 32% split between TV times 1 and 2. This amounts to 2,018 games in TV time 1 and 966 in TV time 2. In this same time period, there were 349 games featuring a team playing at a body clock morning time. To examine the extreme case, had all 349 games been moved to TV time 2, it would have amounted to 1,669 games in TV time 1 and 1,315 games in TV time 2. This more equitable 56 to 44% split is advantageous to the fan who prefers to watch as much football as possible. The rise in popularity of fantasy sports, for example, would seem to suggest a preference toward a more equal split of games among these time periods.

CONCLUSIONS

Given the overwhelming evidence showing the correlation between morning body clock start times and a competitive disadvantage, change seems prudent. Beyond fairness issues, data showing increases in penalties and turnovers indicate that the product put forth by the NFL in these situations is inferior.

Further study should address the implications of the reduction or elimination of morning body clock games. Possible implications (negative and positive) on attendance figures and TV ratings should be considered in addition to logistical scheduling concerns.

The possibility of a higher pass drop rate would further speak to both the fairness and quality of product narratives, and should be studied further with the appropriate data and controls. However, the most important topic for further study is that of the athlete's health. The physiological detriments associated with early start times are too pronounced to be ignored. Even if the NFL could not be found liable for placing their athletes in harm's way, they would be wise to avoid such situations in the interest of presenting the highest quality product to the fans.

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