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Measuring Circadian Advantage in Major League Baseball: A 10-Year Retrospective Study

W. Christopher Winter, William R. Hammond, Noah H. Green, Zhiyong Zhang, and Donald L. Bliwise

Purpose: The effect of travel on athletic performance has been investigated in previous studies. The purpose of this study was to investigate this effect on game outcome over 10 Major League Baseball (MLB) seasons. ***Methods:*** Using the convention that for every time zone crossed, synchronization requires 1 d, teams were assigned a daily number indicating the number of days away from circadian resynchronization. With these values, wins and losses for all games could be analyzed based on circadian values. ***Results:*** 19,079 of the 24,121 games (79.1%) were played between teams at an equal circadian time. The remaining 5,042 games consisted of teams playing at different circadian times. The team with the circadian advantage won 2,620 games (52.0%, P = .005), a winning percentage that exceeded chance but was a smaller effect than home field advantage (53.7%, $P < .0001$). When teams held a 1-h circadian advantage, winning percentage was 51.7% (1,903–1,781). Winning percentage with a 2-h advantage was 51.8% (620–578) but increased to 60.6% (97–63) with a 3-h advantage (3-h advantage > 2-hadvantage = 1-h advantage, P = .036). Direction of advantage showed teams traveling from Western time zones to Eastern time zones were more likely to win (winning percentage = .530) than teams traveling from Eastern time zones to Western time zones (winning percentage = .509) with a winning odds 1.14 (P = .027). ***Conclusion:*** These results suggest that in the same way home field advantage influences likelihood of success, so too does the magnitude and direction of circadian advantage. Teams with greater circadian advantage were more likely to win.

Keywords: athletic performance, circadian rhythms, jet lag, time zone, travel

The effects of jet lag on individual and team athletic performance have been evaluated in several different sports and performance measures.[1–10] Generally, it has been shown that rapid time zone changes without time allowed for acclima-

Winter, Hammond, and Green are with the Martha Jefferson Hospital Sleep Medicine Center, Charlottesville, VA. Zhang is with the Department of Psychology, University of Notre Dame, Notre Dame, IN. Bliwise is with the Emory Healthcare Program in Sleep and Department of Neurology, Emory University School of Medicine, Atlanta, GA.

tion is detrimental to performance. Many studies have tended to focus on more extreme time zone changes such as bicoastal or intercontinental travel.[11,12]

Travel between time zones happens frequently on a much smaller scale among professional athletic teams. In North America, these games most commonly occur in one of four contiguous time zones: Western Standard Time (WST), Mountain Standard Time (MST), Central Standard Time (CST), and Eastern Standard Time (EST). The effects of travel among professional sports teams has been studied previously in both football, basketball, and baseball.[7–10]

Because of the significant time off between games in other leagues, particularly football, evaluation of the rapid travel and high number of games played make studying Major League Baseball (MLB) ideal to understand the role of adaptation to time zones in relation to team performance. Games often occur daily with relatively few days off. Commonly, the MLB regular season occurs during the months of April through September.

We hypothesized that as teams traveled during the MLB season, their performance would be affected by how synchronized they were to their current time zone of play in relationship to the synchronization of their opponent. We named this *circadian advantage* when one team was more synchronized to their current time zone of play compared with their opponent. We sought to not only quantify how often MLB games were played with one team holding a circadian advantage over another team, but to also determine whether this was a statistically significant factor in game outcome.

Methods

Data Collection and Analyses

All MLB games from the 1997 to 2006 were included in this study. Individual game information was acquired from MLB through MLB.com. We tracked winning/losing team and home/away status for each game. During this time period, there were 24,133 games played; 12 tie games occurred during this 10-y period and were excluded from analysis.

For the remaining 24,121 games, individual teams were tracked throughout their seasons by being assigned a *circadian time* based upon the convention that for every time zone crossed, adaptation to the new time zone takes 24 h. At the onset of the season, all teams, regardless of location of play, were assigned a circadian time of 0, as it was concluded that they would be acclimated to their current time zone of play. As the season began and progressed, the daily travel of each team was followed and their circadian times changed based upon direction and magnitude of travel. Because of the difficulty acquiring exact travel logs for each team over the last 10 y, we used the convention that as soon as a game was concluded before a team traveling, they traveled immediately and their circadian acclimation began at that time.

In our study, eastward travel was designated by positive values and westward travel by negative values. Therefore, travel that resulted in a 1-h time zone change would be designated +1 if the travel was to a time zone 1 h east (eg, Los Angeles to Denver) and −1 if the travel was to a time zone 1 h west (Atlanta to St. Louis).

As the magnitude of travel increased, so too did circadian time. For example, a trip from Boston to San Diego would result in a circadian time of −3.

Travel caused circadian time changes, and so did time spent within a given time zone. After 24 h spent within a time zone, a team's assigned circadian time would move 1 h closer to 0. For example, a team acclimated to EST would have a circadian time of −2 after traveling to Denver (MST). After a day, their circadian time would change to −1. After another day, their circadian time would be 0. For the rest of the time that team remained on MST, their circadian time would remain at 0, indicating acclimation to their current time zone of play.

Off days, canceled games, and the midseason All-Star break were included and all resulted in teams moving closer to a circadian time of 0. Run total and margin of victory was not included, nor were any other individual or team statistic (eg, runs scored, margin of victory, home runs).

All statistical analyses were performed using the SAS statistical software package. To evaluate the circadian advantage, we used Fisher's exact test and the logistic regression model with multiple predictors and employed a statistical significance level of $P < .05$.[13,14]

Results

Of the 24,121 games, 19,079 games involved teams at an equal circadian time. In these games, as defined here, no circadian advantage existed. Of these games, 18,134 were between teams at a circadian time of 0 (both acclimated to their current time zone), 590 games involved teams at either a +1 h or −1 h circadian time, 276 games at a ±2 h circadian time, and 79 at a ±3 h circadian time (see Table 1). The remaining 5,042 games (20.9% of games evaluated) featured teams playing at unequal circadian times indicating one team having a circadian advantage (being closer to time zone acclimation than their opponent) over another.

Statistical analysis showed that circadian advantage was a significant factor in overall game outcome in which one team held a circadian advantage over another to the extent that the team with the circadian advantage won 2,620 times

Table 1 Game characteristics of the 24,121 Major League Baseball games comprising the data analyzed

	Number of Games	%
No circadian advantage		
Both teams adapted to current time zone	18,134	75.2
Both teams 1 h off from adaptation to current time zone	590	2.4
Both teams 2 h off from adaptation to current time zone	276	1.1
Both teams 3 h off from adaptation to current time zone	79	0.3
Circadian advantage present		
One team 1 h closer to time zone adaptation than opponent	3,684	15.3
One team 2 h closer to time zone adaptation than opponent	1,198	5.0
One team 3 h closer to time zone adaptation than opponent	160	0.7

and lost 2,422 times. The winning percentage of .520 was significantly greater than chance (.500, $P = .003$).

Home field advantage was also detectable in these data and calculated as a winning percentage of .537 ($P < .0001$). In trying to separate home field advantage from circadian advantage, we isolated games in which the away team held the circadian advantage. Away teams holding circadian advantage won 618 games and lost 744 for a winning percentage of (45.4%), but this did not differ significantly from the overall away team winning percentage (46.3%, $P = .6448$).

The direction of the circadian advantage proved to be important. Teams traveling from western time zones to eastern time zones won 53.0% of their games (1,318 won, 1,167 lost, $P = .0028$), whereas teams traveling from eastern time zones to western time zones won only 50.9% of their games (1,302 won, 1,255 lost, $P = .374$). Even after controlling the number of time zones traveled and the hours of circadian advantage, the direction of the circadian advantage is significant ($P = .027$).

The magnitude of the circadian advantage was important in winning percentage. With a 3-h advantage, the overall record was 97 to 63 (60.6%). With a 2-h advantage, the overall record was 620 to 578 (51.8%), and with a 1-h advantage, the record was 1,903 to 1,781 (51.7%). Teams with a 3-h advantage won more games than teams with 1-h and 2-h advantages ($P = .036$). These data represent any team (ie, home or away) having a 1-, 2-, or 3-h advantage. If we limit analyses to only the home team, the winning percentage of a 1-, 2-, or 3-h advantage (or disadvantage; ie, home teams could have recently returned from travel and traveling teams may be adapted already to a particular time zone in which the home team plays), these effects are even larger (Figure 1).

Discussion

Practical Applications

These analyses demonstrate that a comprehensive and exhaustive compilation of Major League Baseball win–loss records yields evidence of game outcome being influenced by travel across time zones. It is well documented that the negative effects of transmeridian flight are increased as the number of time zones crossed increases.[12] The magnitude of the effect we studied was related to the number of time zones crossed, with the maximal effect being seen for three time zones crossed before a given game, and somewhat reduced effects seen for two or 1 time zones crossed, respectively. This three–time zone circadian advantage was a substantial effect, even relative to a more commonly acknowledged effect in many team sports, the home-field advantage. Moreover, circadian advantage was shown to be a more powerful effect than home-field advantage, specifically as evidenced when the team playing on the home field had undergone travel across time zones immediately before playing on their home field relative to the visiting team who had not.

This study presents a novel method for tracking this effect. This method could be used to track the performance of other team sports as well as individual ath-

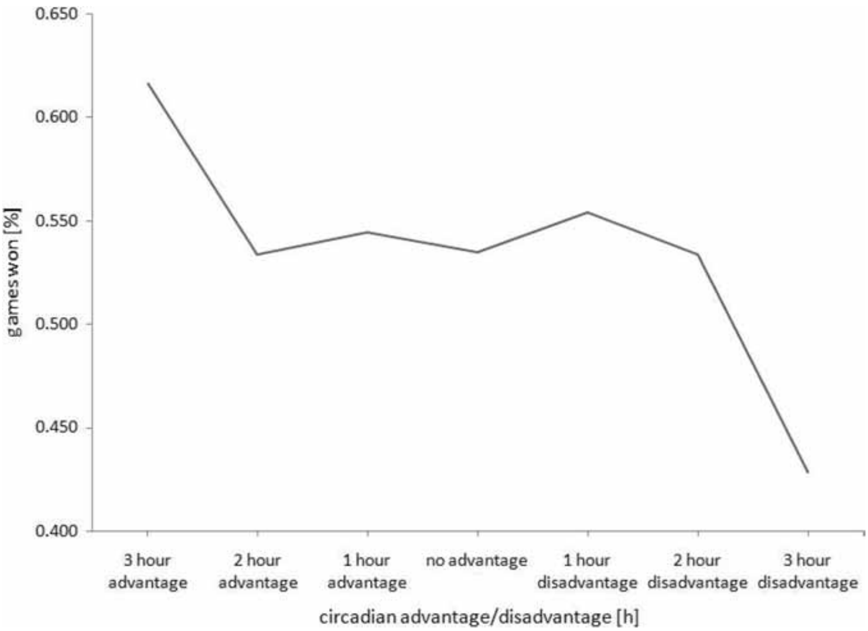

Figure 1 — Home team winning percentage under relative circadian advantage/disadvantage. Advantage exists when home team is time zone adapted by 1, 2, or 3 d relative to visiting team (corresponding to a 1-, 2-, or 3-h advantage). Disadvantage exists when the visiting team is time zone adapted by 1, 2, or 3 d relative to the home team (corresponding to a 1-, 2-, or 3-h disadvantage).

letes. Being able to better quantify this effect may be useful in designing specific preadaptive strategies to overcome it in specific situations.

Unlike home field advantage, which exists theoretically in any game not played at a neutral site, circadian advantage does not exist for all games in an MLB season, only about 20%. In sports that feature longer breaks between games, the percentage may be even lower. The frequent travel of MLB teams and the high number of games played every season makes MLB an ideal sport in which to study circadian advantage.

In contrast to other analyses of team sports, which have suggested that east coast teams traveling to the west coast held an advantage over west coast teams traveling to the east coast, our data showed no such clear effect with baseball.[15,16] In fact, our analyses appeared to suggest that such directional circadian advantage, if present at all, might have been slightly more pronounced for teams in western time zones traveling to eastern time zones. We have no ready explanation for such an effect, but given the number of games analyzed in this study (over 24,000) and the inclusion of all possible games played (ie, data involving teams crossing zero, one, two, or three time zones), it does raise the possibility that the supposed directional advantage for baseball (and perhaps other team sports as well) may be more a function of time zone shifts per se, rather than apparent phase advances or phase delays.

Data such as these have numerous weaknesses. First, it is difficult to extrapolate from the performances of individuals, who may be undergoing shifts of their circadian rhythms, to the performance of entire teams, whose ability to win and lose games is determined by a multitude of factors. Individual variables that impact circadian acclimatization include age, fitness level, and chronotype can be lost in team analyses such as this.[1] Perhaps the thrust of future studies could be isolating the individuals with adjustment difficulties and studying the variables that influence their performance outside of their team.

Another weakness is that our modeling of win–loss records as a function of travel across time zones does not take into account the fact that when a relatively better team plays a relatively worse team, factors such as home field and circadian advantage may be offset or completely mitigated by the higher skill level of the more successful team. Our analyses were unable to model these situations, as we estimated that we might require 10 times the amount of data that we have at our disposal to analyze for this. Furthermore, it is difficult to define a better or worse team at any given point in a season because typically this is done retrospectively by evaluating records, at the end of a season. In this way, the relative strength of a team can be incorrectly assessed if a team improved throughout the season and peaked late with increasing wins. This does not necessarily mean a team was stronger early in the season. Consideration and incorporation of such factors would have required more data than we had access to for this study. The use of the Las Vegas point spread may have been helpful in minimizing these and other confounding factors.

On the other hand, the difference between highly successful and unsuccessful baseball teams may vary as little as .20 (ie, a 60% winning percentage versus a 40% winning percentage), which is smaller than in many other team sports, such as professional football and basketball, which play far fewer games in a season and have many more "off" days. In the analyses that we have presented, we assume that, given the fact that teams play the majority of their games against other teams within their league (during much of the time period under study here, in fact, there was no interleague play), the influence of a relatively better team playing a relatively poorer team is offset by the fact all teams within a league play each other multiple times over the course of a season with an even distribution of home games and away games (and consequently an equally number of time–zone advantageous, time–zone disadvantageous, or time–zone neutral games) for any two teams playing each other. This essentially means that the circadian advantage that we have presented here has occurred in spite of, rather than because of, these overall differences in winning and losing percentages.

The method of evaluating all teams, regardless of their home city/time zone, during the season seems to be a more comprehensive method of capturing circadian data than just focusing on teams based on the east or west coast, as has been done in previous studies. Any team, regardless of its home city, can experience jet lag and circadian shifts. Once a season begins and teams start traveling, their home city is largely irrelevant. Many previous reports have excluded teams in the MST and CST time zones, giving the impression that these teams do not experience the same degree of travel effect or that these teams do not experience bicoastal travel. This study may provide a better method of examining team performance in the future and minimize some of the previous criticisms of this type of analysis.

Despite the day-by-day analysis method used in this study, little effect was seen when teams were at 1- and 2-h disadvantages. Perhaps the explanation for this comes in the inability of this study to differentiate between games played at different times of the day. As was noted by Smith et al[7] looking at professional football team performance in Monday Night Football games, team performance seemed to be influenced strongly by the relative time of day at which each team was performing and how this time corresponded to peak athletic performance time (generally between 1800 to 2000).[3] Kline et al demonstrated that the performance of swimmers seemed to be circadian and independent of environmental affects.[17] Future studies could be strengthened by including both the time in which a game was played as well as a more accurate estimate of time of travel after the game.

Besides the alteration of circadian variables, there are also inherent difficulties and consequences of travel. Factors such as total sleep amounts, stress associated with long flights, stiffness brought about by decreased range of motion, sleep inertia (for morning competitions), alterations in diet, coaching (rather than player) impairment, and motivation could also account for performance decline.[3]

Conclusions

Circadian 3-h advantage is a significant effect, and in some circumstances may be more influential than home field advantage. Moreover, circadian advantage may represent one of the many components of home field advantage, if a team has not traveled recently. This study offers one novel method of tracking circadian time throughout a season. More specific investigation remains to delineate the full effects of transmeridian travel on athletic performance.

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References

1. Waterhouse J, Edwards B, Nevil A, et al. Identifying some determinants of “jet lag” and its symptoms: a study of athletes and other travelers. *Br J Sports Med*. 2002;36:54–60.
2. Atkinson G, Reilly T. Circadian variation in sports performance. *Sports Med*. 1996;21(4):292–312.
3. Youngstedt J, O’Connor P. The influence of air travel on athletic performance. *Sports Med*. 1999;28:197–207.
4. Reilly T, Atkinson G, Waterhouse J. *Biological rhythms and exercise*. Oxford: Oxford University Press; 1997.

5. Antal LC. The effects of changes of the circadian body rhythm on the sharpshooter. *Br J Sports Med*. 1975;9:13–21.
6. Sasaki T. The effects of jet lag on sports performance. In: Scheving LE, Halberg F, eds. *Chronobiology—Principles and applications to shifts in schedules*. 1980:417–432.
7. Smith RS, Guilleminault C, Efron B. Circadian rhythms and enhanced athletic performance in the National Football League. *Sleep*. 1997;20(5):362–365.
8. Steenland K, Deddens JA. Effect of travel and rest on performance of professional basketball players. *Sleep*. 1997;20(5):366–369.
9. Jehue R, Street D, Huizenga R. Effect of time zone and game time changes on team performance: National Football League. *Med Sci Sports Exerc*. 1993;25(11):127–131.
10. Recht LD, Lew Robert A, Schwartz WJ. Baseball teams beaten by jet lag. *Nature*. 1995;377:583.
11. Graeber RC. Alterations in performance following rapid transmeridian flight. In: Brown F, Graeber R, eds. *Rhythmic aspects of behavior*. London: Lawrence Erlbaum Associates; 1982:173–212.
12. Wright JE, Vogel JA, Sampson JB, Knapik JJ, Patton JF, Daniels WL. Effects of travel across time zones (jet-lag) on exercise capacity and performance. *Aviat Space Environ Med*. 1983;54(2):132–137.
13. Fisher RA. On the interpretation of χ^2 from contingency tables, and the calculation of P. *J R Stat Soc [Ser A]*. 1922;85(1):87–94.
14. Cohen P, Cohen J, West SG, Aiken LS. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. 3rd ed. Lawrence Erlbaum; 2002.
15. Graeber RC. Jet Lag and sleep disruption. In: Kryger MH, Roth T, Dement WC, eds. *Principles and practice of sleep medicine*. Philadelphia: WB Saunders; 1994:463–470.
16. Suvanto S, Prtinen M, Harma M, et al. Flight attendants' desynchronosis after rapid time zone changes. *Aviat Space Environ Med*. 1990;61:543–547.
17. Kline CE, Durstine JL, Davis M, et al. Circadian variation in swim performance. *J Appl Physiol*. 2007;102:641–649.