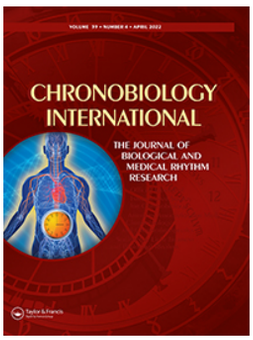

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ORIGINAL ARTICLE

Impact of jet lag on free throw shooting in the National Basketball Association

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ABSTRACT

Jet lag can impair a variety of physical and mental functions. The impact of jet lag on athletic performance has been assumed but difficult to prove methodologically. The challenges have involved eliminating the impact of the quality of the opponent and the difficulties determining when an athlete actually traveled across time zones. Analyzing free throw (FT) shooting in the National Basketball Association allowed these challenges to be overcome. 48,309 games across 19 consecutive seasons were examined of which 675 games involved a team that met our definition of jet lag. In these games, players on the jet lagged teams made 12,154 of 16,286 (74.6%) FTs that were attempted while in the remaining games of that season, the same players on these teams made 993,962 of 1,318,188 (75.4%) FTs attempted, X^2 (1, N = 1,334,474) = 5.21, p = .02. There was no significant impact of jet lag on the players who took the most number of FTs in these jet lagged games. However, the remaining players on the team made 7,394 of 10,016 (73.8%) FTs attempted in jet lagged games while the same players made 794,009 of 1,056,587 (75.1%) FTs in other games that season, X^2 (1, N = 1,066,603) = 9.35, p = .002. When subcategorized further, the impact on the players on jet lagged teams was only seen when they traveled from east to west but not when travel was from west to east. Our analysis reveals that jet lag does negatively influence athletic performance, primarily through circadian rhythm disruption. However, elite athletes appear to be able to overcome this impact if they are given enough opportunities to do so.

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Introduction

Travel is a frequent, inescapable component of a professional athlete's career. This may involve a short road trip to a nearby destination or, more commonly, a flight across time zones to a distant location. When traveling across multiple time zones, the internal body clock of an individual can get out of synchronization with the time clock of the destination leading to jet lag (Manfredini et al. 1998). The American Academy of Sleep Medicine defines jet lag as a syndrome that can occur after travel across at least two time zones (American Academy of Sleep Medicine 2014). Jet lag negatively impacts both physical and mental functions. It can result in insomnia and/or excessive daytime sleepiness, fatigue, reduced physical strength and psychomotor coordination, impaired cognition and memory, anxiety, depression, and somatic symptoms such as constipation and decreased appetite (Challet 2013; Cho et al. 2000; Coutinho et al. 2015; Forbes-Robertson et al. 2012; Horsey et al. 2020; Katz et al. 2002; Takahashi et al. 2002; Waterhouse et al. 2007; Zhang et al. 2020). These effects are caused by the body continuing to operate on the day-night cycle of the original time zone. The body eventually adapts to the new time zone's day-night cycle and these physical and mental side-effects gradually disappear (Herxheimer 2014).

The negative impact of jet lag on sports performance has always been assumed but difficult to demonstrate methodologically for two main reasons. First, most aspects of the performance of an athlete or a team on any given day is influenced by the quality of the opponent. To quantify and eliminate this effect is challenging. Second, it is difficult to retrospectively determine when an athlete traveled between performances in different time zones and so the degree of jet lag at the time of the second performance is hard to quantify. For instance, in a study done on results in the National Football League, east coast teams were shown to perform significantly worse than predicted during Monday Night Football games when they traveled to the west coast (Smith et al. 1997). This was attributed to a circadian rhythm disadvantage suffered by the east coast teams playing at a time closer to their human performance nadir compared to the west coast teams who were playing in their home time zone and therefore closer to their peak athletic performance time. In another study done

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in Major League Baseball, jet lag was thought to be the main factor leading to a decreased slugging percentage and an increased number of home runs allowed by those teams who traveled across at least two time zones (Song et al. 2017). In another study on Major League Baseball teams published in *Nature*, Recht et al. showed that the home team could be expected to score 1.24 more runs than usual when the visiting team was jet lagged (Recht et al. 1995). However, these and other similar studies have not been able to eliminate two major confounding factors (Nutting and Price 2017; Steenland and Deddens 1997). In all these studies, differences in the quality of opposition between the two groups were not examined and may have played a role in the disparities that were uncovered. Secondly, and possibly more importantly, these studies did not look at when the teams or players traveled and so the degree of jet lag could not have been accurately quantified. For instance, in the Monday Night Football study, teams played their previous game over a week prior to the Monday night game but the study did not determine when the east coast team traveled to the west coast between the two games. This data would have been needed to confirm that that team was still suffering from the ill-effects of their travel across three time zones.

The primary goal of this study was to explore the impact of jet lag on athletes by examining an aspect of sports performance that is only influenced by jet lag and not by the other confounding variables that can impact athletic performance on a given day. Free throw (FT) shooting by players on National Basketball Association (NBA) teams is a variable that met this requirement. Examination of this variable also allowed us to overcome some of the challenges faced by the studies referenced earlier. As FT shooting is an action independent of the opponent, the quality of the opposition has no impact on its performance. In addition, since NBA games are played temporally close to each other, the travel times of athletes and the extent of their jet lag can be assessed accurately by knowing the exact number of days the athletes had to recover between games.

The impact of travel and jet lag on sports performance can also be due to circadian rhythm disadvantage. By examining the effect of eastward and westward travel on FT shooting separately, another goal of this study was to determine the extent of this impact.

Methods

Data from all the NBA teams were collected for 19 consecutive seasons starting with the 1999–2000 season. Individual game details were obtained from Basketball Reference (https://www.basketball-reference.com/) and then crosschecked for accuracy by obtaining the same data from Land of Basketball.com (https://www.landofbasketball.com/). The date and location of each game was recorded to determine whether players from that game experienced jet lag or not. A team, which could be a home or away team, was considered jet lagged if it played a game in the Eastern Time zone followed by a game in the Pacific Time zone (three time zones to the west) or vice versa with only a day's gap between the two games. By examining the box scores of each jet lagged game from the sources above, the player or players who took the most number of free throws in that game was identified and their free throw shooting performance in that game as well as that season was recorded. The players who took fewer FTs in these games were analyzed as a group as the number of FTs attempted by them individually in these games was not large enough to generate meaningful data.

The FT data of the jet lagged team for these games was then compared to the FT data of that team for the season after excluding the jet lagged game's data from the season's statistics. Similar analyses were also done for the player or players who took the most number of FTs in that game. A chi-square (X^2) test of independence with one degree of freedom was performed using IBM SPSS Statistics software in order to determine statistical differences between groups. A p value < .05 was considered significant.

Results

Out of 48,309 games analyzed, 675 games qualified as jet lagged games (Table 1). Of these, 358 involved travel from east to west while 317 involved travel from west to east. In 398 games, it was the away team that was jet

Table 1. Free throw shooting in jet lagged games.

	FTMs/FTAs in JL games	FTAs/FTMs in non-JL games	p value
Direction of travel: East to West + West to East (n = 675)			
Entire team	12,154/16,286 (74.6%)	993,962/1,318,188 (75.4%)	0.02
Player/players with most FTAs	4,760/6,270 (75.9%)	199,953/261,601 (76.4%)	0.34
Rest of team	7,394/10,016 (73.8%)	794,009/1,056,587 (75.1%)	0.002
Direction of travel: East to West (n = 358)			
Entire team	6,509/8,726 (74.6%)	526,011/696,411 (75.5%)	0.04
Player/players with most FTAs	2,516/3,290 (76.5%)	105,271/136,256 (77.3%)	0.29
Rest of team	3,993/5,436 (73.5%)	420,740/560,155 (75.1%)	0.005
Direction of travel: West to East (n = 317)			
Entire team	5,645/7560 (74.7%)	467,951/621,777 (75.3%)	0.24
Player/players with most FTAs	2,244/2,980 (75.3%)	94,682/125,345 (75.5%)	0.76
Rest of team	3,401/4,580 (74.3%)	373,269/496,432 (75.2%)	0.15

JL = jet lagged; FTM = free throw made; FTA = free throw attempt.

lagged while it was the home team that was jet lagged in 277 games. In these games, the teams that were jet lagged made 12,154 of the 16,286 FTs attempted (74.6%). In the other games that season, the same teams made 993,962 of the 1,318,188 FTs attempted (75.4%), X^2 (1, N = 1,334,474) = 5.21, p = .02.

Examining the performance of the players in these jet lagged games, the player or players who took the most number of FTs in these games made 4,760 of the 6,270 shots attempted (75.9%). In the other games that season, the same players made 199,953 of 261,601 FTs attempted (76.4%), X^2 (1, N = 267,871) = 0.91, p = .34. The remaining players on the teams that played in these jet lagged games made 7,394 of 10,016 FTs attempted (73.8%) while the same players made 794,009 of 1,056,587 FTs attempted in the other games that season, X^2 (1, N = 1,066,603) = 9.35, p = .002.

When the games were subcategorized further according to direction of travel, the jet lagged teams that traveled from east to west made 74.6% of 8,726 FTs attempted while the same teams made 75.5% of 696,411 FTs attempted in the other games that season, X^2 (1, N = 705,137) = 4.11, p = .04. There was no significant difference in the FT shooting performance of the player or players who took the most number of FTs in the jet lagged games compared to their other games that season (76.5% vs 77.3%), X^2 (1, N = 139,546) = 1.13, p = .29. However, there was a significant difference in the FT shooting performance of the remaining players on these teams in the jet lagged games compared to their other games that season (73.5% vs 75.1%), X^2 (1, N = 565,591) = 7.90, p = .005. However, when jet lagged teams traveled from west to east, there were no significant differences in any of these groups as outlined in Table 1.

Discussion

There are many confounding variables that can contribute to differences in a basketball player's performance on a given day. These include factors such as quality of the other players on the court, coaches, referees, spectators, altitude, and possibly jet lag. Aside from jet lag, none of the other factors significantly impact FT shooting percentage. While home court advantage is real, it is thought to be primarily due to decisions made by referees that tend to favor the home team (Berdell et al. 2013; Jones 2007; Nevill and Holder 1999). Despite attempts made by spectators to negatively impact FT shooting of an away team player, analyses have shown that there is no difference in the FT shooting percentage of NBA players at home and away games (De Rose 2004; Fromal; Varca 1980).

Our study shows that FT shooting performance of teams in games that met our definition of jet lag was significantly worse than their performance in non-jet lagged games that season. While this impact is relatively small, it is being felt on a part of a professional athlete's game that is heavily practiced and repetitive. Therefore, the impact of jet lag on other aspects of an athlete's performance that are not as rote could be reasonably expected to be greater. However, as previously detailed, it is extremely challenging to quantify and eliminate the various extraneous factors that influence most aspects of an athlete's performance. Therefore, an impact such as the one we have demonstrated, while small, may serve as an important source of evidence of the impact of jet lag on athletic performance.

When we analyzed individual player performance in these games, it appeared that the impact of jet lag on players who attempted fewer FTs was far greater than on those who attempted more FTs in these games. This would suggest that these elite athletes are able to recalibrate any dysfunctionality in their FT shooting due to jet lag if they are given enough opportunities to do so.

Our analysis also revealed that the impact of jet lag was unidirectional. In other words, traveling from east to west had an impact on FT shooting while there was no impact when travel was from west to east. However, with regard to jet lag, eastward travel is thought to be more impactful and more difficult to adapt to than westward travel (Leatherwood and Dragoo 2013; Monk et al. 2000; Waterhouse et al. 2007). The impact of traveling across time zones on athletic performance that was revealed in our study, which goes against this notion, is therefore likely to be primarily due to circadian rhythm disruption. NBA games are typically played in the evenings with games starting between 7 and 8pm and ending between 9.30 and 10.30 pm. Therefore, for an athlete who travels from the east coast to the west coast across three time zones without enough time to acclimatize, their internal body clock is likely to be past midnight when these jet lagged games end. This would put these athletes at a circadian rhythm disadvantage in these games as peak athletic performance tends to be earlier in the evening (Drust et al. 2005; Leatherwood and Dragoo 2013; Manfredini et al. 1998). When an athlete travels from the west coast to the east coast, those games start around 5pm as per their internal clock which does not then impact their performance.

There is evidence that the circadian rhythm disadvantage that we demonstrated in our study has explanations at the molecular level. Ezagouri et al. found that both mice and humans exhibit daytime variance in exercise capacity, with peak exercise performance occurring in the evening while Sato et al. showed that in mice, the least robust impact of exercise on skeletal muscle metabolism occurred at night (Ezagouri et al. 2019; Sato et al. 2019).

Limitations

While the games that we analyzed certainly involved a team that was jet lagged, it is possible that there were other games where a team was jet lagged that we could not identify. This would be because a team that would have had enough time between games to avoid the impact of jet lag by leaving immediately after a game chose to travel on a later date. However, without access to detailed travel information about each NBA team over these 19 seasons, it would be impossible to identify those games. However, there is no reason why our selection process, while it may not be complete, will lead to any kind of selection bias. In addition, uncovering such games would probably only have increased the significance of our findings as these games are being included and analyzed as non-jet lagged games in our study.

Conclusions

Jet lag is known to impair cognitive and physical performance due to decreased alertness and circadian misalignment. Our study demonstrates that in elite athletes, the impact on physical performance is almost entirely due to circadian rhythm disruption and that this impact can be overcome by repetition. To determine if the impact of jet lag on the physical performance of non-elite athletes is similar to what we demonstrated, further study will be needed. If jet lag does indeed have an impact on performance, professional athletes may become less willing to participate in jet lagged games if there is evidence that they are likely to underperform in such games. This may have important ramifications on the travel plans of athletes and on the scheduling of sports leagues.

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