

Ger J Exerc Sport Res 2021 · 51:237–240

<https://doi.org/10.1007/s12662-020-00690-7>

Received: 26 August 2020

Accepted: 5 November 2020

Published online: 3 December 2020

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Shot distribution in the NBA: did we see when 3-point shots became popular?

Electronic supplementary material

The online version of this article (<https://doi.org/10.1007/s12662-020-00690-7>) contains supplementary material, which is available to authorized users.

Background

The National Basketball Association (NBA) is the main basketball league around the globe with estimated revenue of approximately US\$ 49.5 billion (Badenhausen, 2018). During its history, several rules were modified (NBA, 2008), leading to differences in the game dynamics throughout the years. A key change in NBA rules was the implementation of the three-point (3PT) line.

The 3PT line was implemented in the 1979–1980 season and its distance from the basket was 6.7 m (22 feet) in the corners, extending to 7.24 m (23.75 feet) at the top of the key. After 15 seasons the 3PT line was shortened to a uniform distance of 6.7 m around the basket, lasting with this measurement for three seasons: 1994–1995, 1995–1996, and 1996–1997. In the 1997–1998 season, the 3PT line returned to its original distance, which remained for the following seasons (NBA, 2008).

Recently, a popular conception claims that the NBA is passing through a 3PT revolution (Cohen, 2016). For example, one of the keys for the success of Golden State Warriors, present in five straight

NBA finals between seasons 2014–2015 and 2018–2019, and winning three of them, is attributed to the high volume of 3PT field goal attempts (3PTA). Indeed, the number of 3PTA had never been so high: the 78,742 3PTA in the 2018–2019 season (last season with a full calendar of 82 games prior the COVID-19 pandemic) broke the NBA record, a number 11.5 × higher compared with the first 3PT line season. Another team, the Houston Rockets, broke another 3PT-related record: they were the first team to shoot more 3PT than two-point (2PT) field goals (3470 vs. 3436, respectively) in one entire regular season, 2017–2018, and they were able to improve these numbers in the following season (3721 vs. 3442).

Although 3PTAs are so popular nowadays, few works have discussed its evolution. Previous reports (Romanowich, Bourret, & Vollmer, 2007; Štrumbelj, Vračar, Robnik-Šikonja, Dežman, & Erčulj, 2013) provided a brief overview, but did not offer an overall picture. Goldsberry (2019) presented a detailed visual analysis showing the evolution of shot locations in the NBA; however, the author mainly focused on the evolution of shot locations in recent seasons and did not perform any formal statistical analysis comparing two consecutive seasons. To fill this gap and to understand how shot pattern has evolved along the NBA history (e.g., will the short 3PT line distance lead to more 3PTA/3PT%), NBA shot data per 100 possessions for each player from all seasons since the 3PT line implementation were gathered to compare 2PT and 3PT shots.

Materials and methods

All data were retrieved from Basketball Reference website (Sports Reference LCC, 2020) using the ballr v. 0.2.6 package (Elmore, 2018). For each player, per 100 possessions statistics were downloaded between the first season with the 3PT line (1979–1980) and the last full season (2018–2019), resulting in 20,355 entries. To avoid pace differences between distinct teams and seasons, all statistics were adjusted by 100 possessions. The 100 possessions statistics were calculated using the following equation: $[ns_adjusted = ns \times 100 / np]$, where ns is the number of the statistics you want to adjust (e.g., shot attempts, rebounds, fouls) and np is the number of possessions. Then, only individuals that played more than 35 games (70% of the 50 games in the 1998–1999 lockout season and ~43% in a regular season of 82 games), more than 20 min per game (to avoid garbage time influence) and had less than 55% of 3PT% (to avoid outliers) in a specific season were selected. Next, only the season total statistics, “TOT” under the team columns, for an individual who played for two or more teams in the same season were kept. Furthermore, players with more than one position, e.g., “Center–Power Forward”, had their status changed to the first position: in this example, “Center”. The final dataset consisted of ~8,100,000 shots from 1418 distinct players spanning 40 full NBA seasons and distributed in a data frame of 7345 entries. As the main goal of this paper is to analyze the NBA shot pattern

All code used in this study is available at https://github.com/freitas-lucas/NBA_ShotDist

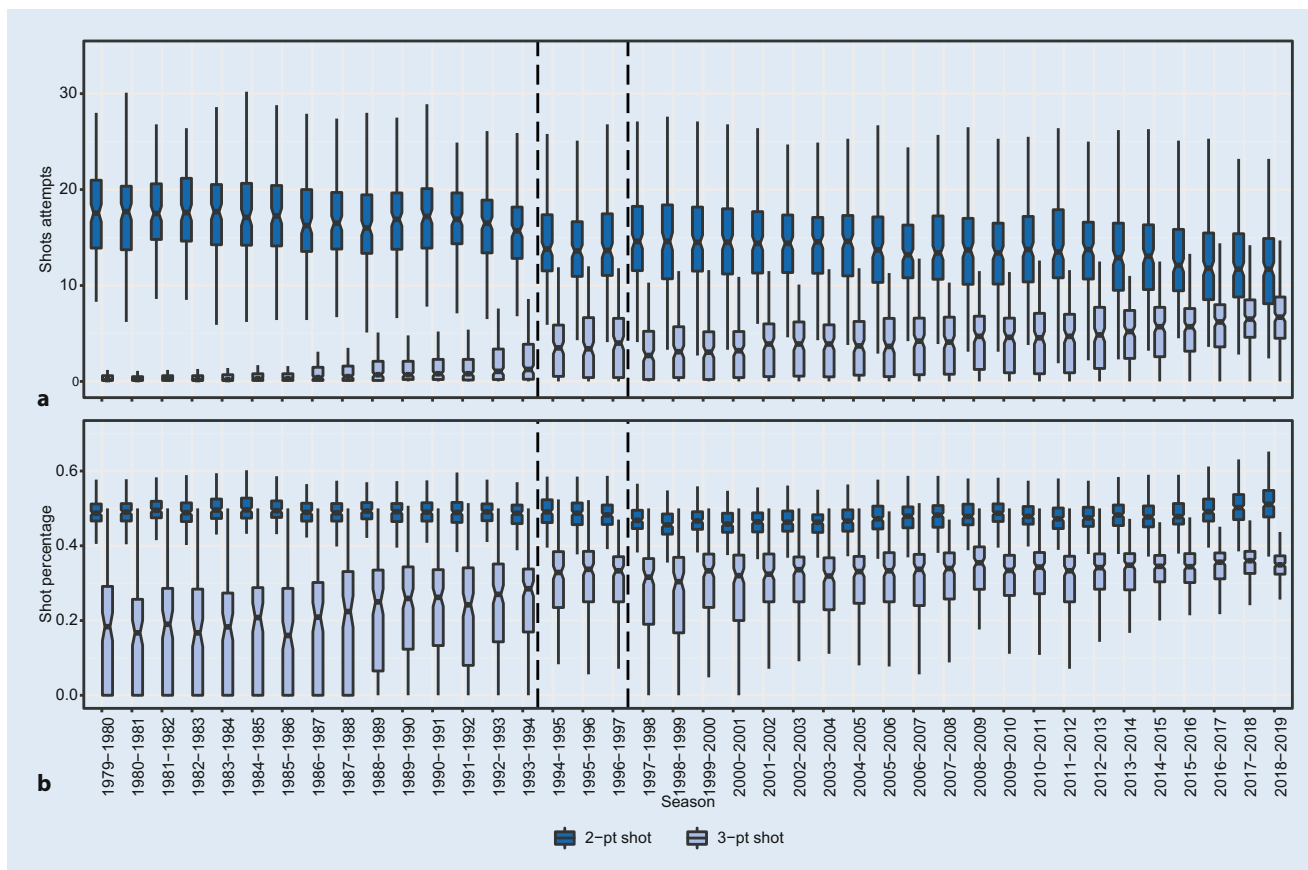


Fig. 1 ▲ Distribution of shot attempts (a) and shot percentage (b) through 1979–1980 and 2018–2019 seasons. Distributions are separated by 2PT (two-point, dark blue) and 3PT (three-point, light blue) shots (dashed black lines show changes in the 3PT line distance)

since the implementation of the 3PT line, this work focused in four observations:

- Three-point shot percentage (3PT%),
- Three-point field goal attempts (3PTA),
- Two-point shot percentage (2PT%), and
- Two-point field goal attempts (2PTA).

To identify statistically significant changes in shot patterns between two consecutive seasons, multiple Student’s t-tests (Student, 1908) were applied. Next, a false discovery rate approach to multiple testing (Benjamini & Hochberg, 1995) at 10% cutoff was applied to control the rate of false positives. All statistical analyses and graphics were done using R v. 3.6.1 (R Core Team, 2019) and the following packages: tidyverse v. 1.3 (Wickham et al., 2019), and cowplot v. 1.0 (Wilke, 2019).

Results

The results show the distribution of shooting patterns in NBA and the impact of the 3PT line on this pattern since its implementation in the 1979–1980 season. As shown in Fig. 1, between 1979–1980 and 1993–1994 seasons—prior to any modification in the 3PT line distance—the mean number of 3PTA increased from 0.62 to 2.27. Over the same period, the mean number of 2PTA decreased from 16.78 to 15.19. However, during this time span, the only statistically significant change between two consecutive seasons in the statistics analyzed in this work was the 3PTA for seasons 1985–1986 and 1986–1987 (0.76 to 1.05, adjusted $p = 0.0732$, Table 1). The mean 3PT% increased from 18% in 1979–1980 to 23% in 1993–1994 and the mean 2PT% remained around 48%, but no statistical difference between consecutive seasons was found. Supplementary

Table 1 contains detailed statistical information (t-values, p-values, degrees of freedom, confidence intervals, and sample estimates) for all tests performed and Supplementary Table 2 contains the same information grouped by position.

The decrease in the 3PT line distance during the 1994–1995 season resulted in statistically significant changes in the mean of 3PTA (2.27 in 1993–1994 to 3.39 in 1994–1995, adjusted $p = 0.0007$, Table 1). This change is clearly observed in Fig. 1. During the three seasons with this short distance, the number of 3PTA increased each year and the mean number of 2PTA decreased, while the mean of 3PT% remained around 26%. The mean of 2PT% did not significantly change between 1993–1994 and 1994–1995 but it significantly decreased between the 1996–1997 and 1997–1998 season (adjusted $p = 0.0235$), when the 3PT line returned to its original distance.

The return of the 3PT line to its original distance was also reflected in the shot pattern. While the mean number of 3PTA decreased (3.94 in 1996–1997 to 2.97 in 1997–1998), the mean number of 2PTA increased (13.11 in 1996–1997 to 14.16 in 1997–1998). Further, both means of 3PT% and 2PT% decreased compared with the previous year (27% in 1996–1997 to 25% in 1997–1998 for 3PT% and 47% in 1996–1997 to 46% in 1997–1998 for 2PT%), where the 2PT% difference between both seasons was statistically significant (adjusted $p = 0.0235$, **Table 1**). The years following the return to the 3PT line original distance did not show any statistically significant difference between two consecutive seasons in any of the statistics; however, in the last season (2018–2019) they reached their extreme means: 6.33 3PTA, 32% 3PT%, 51% 2PT% (maximum values), and 10.77 2PTA (minimum value), which is reflected in **Fig. 1**.

The same experimental procedure was performed according to each position but no statistically significant change was found.

Discussion

Previous research on NBA shots usually aimed to quantify shot quality in several ways such as spatial analysis framework (Chang et al., 2014; Gandhi, Tiwari, & Nelson, 2017; Goldsberry, 2019), body movement during shot (Felsen & Lucey, 2017), number of passes before shooting (Ciampolini, Ibáñez, Nunes, Borgatto, & do Nascimento, 2018), and defensive pressure (Chang et al., 2014; Ciampolini et al., 2018). However, they did not show the evolution of shooting pattern throughout all seasons regarding the 3PT line. Only Štrumbelj et al. (2013) and Romanowich et al. (2007) briefly discussed the topic.

Štrumbelj et al. (2013) focused on 10-year data from EuroLeague Basketball, where two rule changes happened in the last season of their dataset (2010–2011): the increment in the 3PT line distance and the reduction of the shot-clock time to only 14 s in specific situations. Between seasons 2009–2010 (old rules) and 2010–2011 (new rules) they in-

ferred statistically significant changes in 3PTA, 3PT%, 2PTA, 2PT%, free throw attempts, total rebounds, and number of possessions; however, they did not perform any correction for multiple tests.

Their results on 3PTA, 3PT%, 2PTA, and 2PT% following an increment in the 3PT line distance at EuroLeague are similar with my results on NBA data: 3PTA, 3PT% and 2PT% decreased and 2PTA increased, although only the 2PT% difference was statistically significant in this work. They also explored some NBA and NCAA (National Collegiate Athletic Association) data, but they did not perform any statistical test to infer differences between seasons.

Romanowich et al. (2007) grouped NBA data from nine seasons into three categories: 1991–1994, with the original 3PT line distance, 1994–1997, the period where the 3PT line distance was reduced, and 1997–2000, after the 3PT line distance returned to its original distance, and tested the difference on 3PT% and 2PT% among these three groups using data from 57 players. For 3PT%, they found a statistically significant increase between the 1991–1994 and 1994–1997 groups ($p < 0.05$), while for 2PT% they found a statistically significant decrease between the 1994–1997 and 1997–2000 groups ($p < 0.05$). Although the results presented in this work did not divided NBA seasons into groups as Romanowich et al. (2007), the decrease in the mean of 2PT% between seasons 1996–1997 (3PT line shorter distance) and 1997–1998 (3PT line original distance) was statistically significant.

It is worth to mention that Goldsberry (2019) also showed the evolution of the 3PT shooting in NBA, but he explored his results in a spatial context and did not perform any formal statistical analysis. Thus, in comparison with the current literature available, this work is the most extensive effort aiming to study 2PT and 3PT shot patterns in NBA, spanning all seasons, comparing season-by-season patterns and using data from all players. As expected, a reduction in the 3PT line distance increases the number of 3PTA while the increment of 3PT line distance decreases the number of 3PTA, showing that the distribution of shots is subject to

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Shot distribution in the NBA: did we see when 3-point shots became popular?

Abstract

The National Basketball Association (NBA) is the main basketball league around the globe with estimated revenue of approximately US\$ 49.5 billion. A key change in NBA rules was the implementation of the three-point (3PT) line in the 1979–1980 season. Recently a popular conception claims that NBA is passing through a 3PT revolution; however, few works have discussed the evolution of shot patterns in the NBA. Thus, in this article NBA shot data per 100 possessions for each player from all seasons since implementation of the 3PT line were gathered to compare 2PT and 3PT shot statistics, aiming to understand how the shot pattern evolved throughout the NBA history. The results show that the main differences in shot patterns happened due to modifications in the 3PT line distance. The only exception was the statistically significant increase of 3PT attempts (3PTA) in the 1986–1987 season, a likely result of the success of the first 3PT contest in the previous season, which probably led most players to attempt this kind of shot. Also, the results did not show any season-by-season statistically significant change in shot patterns after the 3PT line distance was returned to its original distance in the 1997–1998 season. Thus, the actual popularity and numbers of 3PTA gradually increased throughout the seasons.

Keywords

Basketball · 3 point shot · 2 point shot · All-star weekend · 3 point contest

pattern changes according the 3PT line distance.

Most people would expect a statistically significant increase in the mean of 3PT% between seasons 1993–1994 and 1994–1995 due to the decrease in the 3PT line distance, making it easier for players to convert this kind of shot; however, the comparison of these seasons was not statistically significant (adjusted $p = 0.1008$). Although the mean of 3PT% decreased between seasons 1996–1997 (last season with the shorter 3PT line)

Table 1 Summary of statistically significant differences between two consecutive seasons

Seasons	Shot statistics	Mean of 1st season	Mean of 2nd season	t-value	Degrees of freedom	Cohen's d	p-value	Adjusted p
1993–1994/1994–1995	3PTA	2.2592	3.6562	−4.6765	324.2321	0.4968	4.288×10^{-6}	0.0007
1996–1997/1997–1998	2PT%	0.4839	0.4688	3.6495	364.0976	0.3772	3.0117×10^{-4}	0.0235
1985–1986/1986–1987	3PTA	0.6169	1.02	−3.2287	253.5371	0.373	0.0014	0.0732

3PTA three-point field goal attempts, 2PT% two-point shot percentage

and 1997–1998 (first season after the return to the 3PT line original distance), this difference was also not statistically significant (adjusted $p = 0.7$), indicating that players became better 3PT shooters, even shooting at a longer distance. An unexpected pattern was the statistically significant decrease in the mean of 2PT% between seasons 1996–1997 and 1997–1998 (adjusted $p = 0.0235$); however, it could be explained since the low percentage shots between 6.7 m (22 feet) and 7.24 m (23.75 feet) were assigned as 2PT shots again.

Another unexpected pattern found here was the statistical difference in 3PTA between seasons 1985–1986 and 1986–1987. There is no apparent reason for this since there were no changes in NBA rules or in the 3PT line distance. Strikingly, a likely explanation may reside in the All-Star Weekend of the 1985–1986 season where the first 3PT contest happened. The success of this event may have led to other players starting to attempt this kind of shot, increasing the mean number of 3PTA in the following season.

Conclusion

The results presented here show that the only statistically significant difference in shot pattern not related with changes in the 3PT line distance was the increase in 3PTA in the 1986–1987 season. The most plausible explanation is that the first 3PT contest in the previous season led to most players attempting this kind of shot. Furthermore, these results also did not show any season-by-season statistically significant change in shot patterns after the return of the 3PT line to its original distance. Thus, the ongoing 3PT revolution in NBA did not happen abruptly, with statistically significant differences in shot patterns between two consecutive

seasons, but they are result of a gradually increase in 3PTA throughout the seasons.

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Acknowledgements. The author would like to thank you Dr. Mariana Nery for her comments on an earlier version of the manuscript.

Compliance with ethical guidelines

Conflict of interest. L. Freitas declares that he has no competing interests.

For this article no studies with human participants or animals were performed by any of the authors. All studies performed were in accordance with the ethical standards indicated in each case.

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