Predictors of Time to COVID-19 Infection in the National Basketball Association: A Retrospective Case-Control Study

Raphael E. Cuomo, MPH, PhD[1,2], Zhuoran Li, MS[2,3,4], Vidya Purushothaman, MBBS, MAS, MPH,[2,3] Chenna Basavapatna-Shankar, BS,[2] Matthew Nali, BS,[1,2,4] Tim K. Mackey, MAS, PhD[2,3,4,5]

[1] Department of Anesthesiology, University of California, San Diego School of Medicine, San Diego, CA, USA
[2] Global Health Policy and Data Institute, San Diego, CA, USA
[3] San Diego Supercomputer Center, San Diego, CA, USA
[4] S-3 Research LLC, San Diego, CA, USA
[5] Global Health Program, Department of Anthropology, University of California, San Diego, CA, USA

Address for Correspondence:
Raphael E. Cuomo, PhD
School of Medicine
University of California San Diego
8950 Villa La Jolla Drive, A203
San Diego, CA 92037
Email: racuomo@ucsd.edu

Running Head: COVID-19 Infection in the NBA

Abstract

A case-control study was conducted between 12/01/2021–01/31/2022 to identify factors which increase risk for COVID-19 among athletes in the National Basketball Association (NBA). Behavioral factors and stadium attendance significantly decreased time to COVID-19 infection, but local COVID-19 rates were not associated in a multivariable model.

Key Words: COVID-19, infectious disease, epidemiology, survival analysis

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a virus globally accounting for at least 601 million cases of coronavirus disease 2019 (COVID-19) as of August 2022, with a high number of cases that have been detected among professional sports athletes.[1] The closely monitored, publicized, and high-stakes economic pressures faced by many professional sports organizations, such as the U.S. National Basketball Association (NBA), provides the means for robust analysis of individuals placed in different risk-modifying circumstances, including travel to geographic areas with different COVID-19 burden, time spent in densely-packed arenas, and time spent in close contact with other athletes. Previous studies have examined COVID-19 NBA-related risk characteristics including a retrospective cohort study examining case characteristics of NBA players who participated in the 2020 closed campus occupational health and safety program (i.e., "NBA Bubble" that utilized isolation protocols in Orlando, Florida[2]), a study using PCR results from NBA players to assess infectivity for the Omicron variant,[3] and a 2022 study examining infection rates among NBA players and staff who were fully boosted.[4] This study builds on this prior research by specifically analyzing NBA player-level activity-related risk factors that may significantly influence risk for time to COVID-19 infection with an emphasis on high-infectivity periods of the 2021-2022 NBA season when the Omicron variant became the dominant strain in the US.

Methods

This retrospective observational case-control study included all players in the 2021-2022 NBA season that were on an active team roster during the study period. Outcome data consisted of probable COVID-19 infection, estimated by proxy as those players placed on indefinite leave (IL) due to entering the NBA health and safety protocols. NBA health and safety protocols require that players are placed on IL if they receive a positive or inconclusive result from a reverse transcription polymerase chain reaction (RT-PCR) test for COVID-19.[5] Fully vaccinated players (with a booster) in the 2021-2022 NBA season were only required to test if symptomatic or exposed to an individual with COVID-19, and player vaccinations were not mandated. Other players, including those without a booster, were subject to daily testing during the study time period.

Athletes with a positive test would be placed on IL until one of two scenarios occur. The first scenario requires two negative RT-PCR tests at least 24 hours apart. The second scenario requires 6 total days to pass, over 24 hours after a fever without medication, and a cycle threshold greater than 30. Vaccinated players with an inconclusive test would require two negative RT-PCR tests on consecutive days, whereas unvaccinated players would require five negative RT-PCR tests on consecutive days. Unvaccinated players would also be required to quarantine if they were flagged via contact tracing as being potentially exposed to a person who is

positive for COVID-19. Players may also be placed on indefinite leave under NBA health and safety protocols for other reasons, such as hip surgery.[6] Though no specific reason is published for a player being placed on IL due to the NBA's health and safety protocols for privacy reasons, news reports from the study time period reported that much of the variability was due to infection with COVID-19,[7,8] possibly due to the perception of relative rarity for other reasons that may be related to the NBA health and safety protocol.

IL data were collected from the sports archive website Pro Sports Transactions Archive.[9] Data for NBA player-level activity-related risk factors were available from the Application Programming Interface (API) for the nba.com website (games played, home/away games, minutes played, stadium attendance).[10] COVID-19 county-level infection rates were collected from Johns Hopkins University.[1] Dates for data collection and analysis spanned from the start of December 2021 to the end of January 2022, representing sixty days during the early 2021-2022 NBA season. These dates were selected to optimally influence the impact of a single variant on time to event modeling.

Cox proportional hazard models were computed to assess for bivariate and multivariable associations between NBA player-level activity-related risk factors and time to COVID-19 infection. The outcome is conceptualized as time to first event, and therefore reinfection was not modeled as part of this study. Throughout the study period, games played was treated as an accumulating tally, percentage away games was calculated as a moving average, and minutes played on a given day was computed as a sum of minutes played during the study period. Non-behavioral risk factors (stadium attendance and county-level COVID-19 rates for areas where games were played) were not transformed prior to modeling. For visualization with Kaplan-Meier plots, risk factors were computed as player means and then players were separated into quartiles, with the exception of games played in which quartiles were computed from player maxima. Analysis and visualization was conducted R version 4.1.2.

Results

Data were available for 621 athletes in the study period. Approximately half (50.7%) of athletes were placed on the NBA IL COVID-19 protocol and were likely infected with COVID-19 during the sixty-day period, with the probability of avoiding infection falling precipitously in the second half of the study period (month of January) (**Fig1A**). All five risk factors were individually significantly associated with time to COVID-19 infection, with athletes in the lowest quartiles of behavioral risk factors (**Fig1B, Fig1E, Fig1F**) appearing to have better protection from COVID-19 infection when compared to athletes in lower quartiles of environmental risk factors (**Fig1C, Fig1D**). Assuming proportional hazards, the hazard ratio for COVID-19 infection was 11.51 (p<0.001) per unit increase in the average county-level COVID rate per 100,000 population. Also, with each additional game played, the risk of COVID-19 infection increased by 4.4% (HR=1.04,

p<0.001) and with each additional game played "away", the risk of COVID-19 infection increased by 23.3% (HR=3.33, *p*<0.001). For the average stadium attendance, the lowest quartile had the least risk for contracting COVID-19 and the hazard ratio between the lowest quartile and the fourth quartile was the highest (HR=1.31, *p*<0.001). Multivariable Cox proportional hazards modeling with all risk factors revealed that the average COVID-19 rate for counties where games were played was no longer statistically significant when accounting for effects from the other four risk factors (**Appendix Table 1**).

Discussion

Results from this study suggest that NBA player-level activity-related behaviors, particularly those related to the amount of time played on the court and travel to away games, may impact athlete risk for COVID-19 infection. Specifically, NBA players with more game activity may have higher exposure to staff, opposing players, fans, and other vectors of transmission, particularly as they may be at higher risk of exposure when playing unmasked or engaged in other activities (e.g., media interviews, etc.) despite consistent testing. Similarly, travel dynamics of teams playing home and away games and the corresponding COVID-19 restrictions for each state may influence risk both on and outside the court where players may be susceptible to different levels of exposure. Our findings suggest that the influence of these player-level behavioral factors may outweigh that of environmental factors, such as local population COVID-19 infection rates. Athletes with more minutes played or greater game-related travel may have similar non-sporting behaviors that may influence non-NBA activity exposure to COVID-19 infection (e.g., more interactions with media, fans, or public activities during away games), and these risk-influencing behaviors may not be as common in athletes with fewer minutes played.

Results have the potential to inform clinicians and public health surveillance efforts, particularly as relates to assessing risk characteristics among a defined population of young, healthy, and highly vaccinated adults when compared to the general population. Specifically, higher infectivity among NBA players may indicate that certain behavioral risk factors have the potential to translate to elevated risk in similarly situated individuals with analogous sociobehavioral characteristics (i.e., frequent travel, group performances, etc.). Additionally, higher infection rates in the NBA cohort may be an early warning sign of greater community spread, as the general population has lower vaccination coverage, less testing and quarantine, and is generally older. Hence, the application of modeling approaches that take into account multimodal factors such as those explored in this study has the potential to enhance traditional surveillance methods and also generate evidence for more targeted public health interventions among at-risk populations.

A major limitation of this study is lack of validation of the endpoint, COVID-19 infection, measured by proxy from being placed on IL. Though the proportion of NBA athletes placed on IL appears to coincide with COVID-19 infection rates in the US population,[11] and other studies have found high rates of infection in this population during this same time period,[4] future studies addressing related research questions should seek to use endpoint data from diagnostic testing. An additional limitation was that data were not available on the vaccination status of players at different time periods as the season progressed (as these data were not publicly available, though the NBA reported vaccination rates above 90% in September 2021). Further research should be conducted to determine potential sociobiological mechanisms underlying associations observed in this study, as well as applicability of study results to broader attempts to improve syndromic surveillance of novel and emerging infectious diseases

Acknowledgements

Author's Contributions: RC, MN and TM conceptualized the study. ZL and CB conducted data collection. RC and VP analyzed the data. RC, VN, and TK worked on writing the manuscript. All authors approved the final manuscript.

Ethics Approval: Not applicable

Data Availability: The datasets used and/or analyzed for the current study are available from the authors upon reasonable request.

Funding: Authors have no funding sources to report.

Competing Interests: ZL, TM and MN are employees of the startup company S-3 Research LLC. S-3 Research is a startup funded and currently supported by the National Institutes of Health – National Institute on Drug Abuse through a Small Business Innovation and Research contract for social media research and technology commercialization. Authors reports no other conflict of interest associated with this manuscript and have not been asked by any organization to be named on or to submit this manuscript.

References

1. CSSE JHU. Novel coronavirus (covid-19) cases. *GitHub Repository, https://github. com/CSSEGISandData/COVID-19, retrieved April.* 2022;5:2020.

2. Mack CD, DiFiori J, Tai CG, et al. SARS-CoV-2 Transmission Risk Among National Basketball Association Players, Staff, and Vendors Exposed to Individuals With Positive Test Results After COVID-19 Recovery During the 2020 Regular and Postseason. *JAMA Internal Medicine.* 2021;181(7):960-966.

3. Hay J, Kissler S, Fauver JR, et al. Viral dynamics and duration of PCR positivity of the SARS-CoV-2 Omicron variant. *Pre-Print.* 2022.

4. Tai CG, Maragakis LL, Connolly S, et al. Association Between COVID-19 Booster Vaccination and Omicron Infection in a Highly Vaccinated Cohort of Players and Staff in the National Basketball Association. *JAMA.* 2022;328(2):209-211.

5. Herbert J. NBA, NBPA agree to allow some players to return six days after positive COVID test, per report. 2021; https://www.cbssports.com/nba/news/nba-nbpa-agree-to-allow-some-players-to-return-six-days-after-positive-covid-test-per-report/. Accessed 25 August 2022.

6. Boylan-Pett L. Bucks' Jason Kidd taking indefinite leave to undergo hip surgery. 2015; https://www.sbnation.com/nba/2015/12/20/10631580/jason-kidd-milwaukee-bucks-hip-surgery-indefinite-leave. Accessed 25 August 2022.

7. Maloney J. NBA COVID surge: Adam Silver says league has no plans to pause season, 90 percent of cases are Omicron. 2021; https://www.cbssports.com/nba/news/nba-covid-surge-adam-silver-says-league-has-no-plans-to-pause-season-90-percent-of-cases-are-omicron/. Accessed 25 August 2022.

8. McGregor G. NBA COVID-19 tracker: Updated team-by-team list of players in health and safety protocols. 2022; https://www.sportingnews.com/us/nba/news/nba-covid-19-tracker-players-list/txmmkuyhtfko1d1gttq5g4kb2. Accessed 25 August 2022.

9. Marousek F. Pro Sports Transactions Archive. 2022; https://www.prosportstransactions.com/.

10. NBA Media Ventures LLC. The official site of the National Basketball Association. 2022; http://www.nba.com/.

11. Kazemba C, Morar N. NBA COVID-19 Dashboard. 2022; https://public.tableau.com/views/NBACOVID-19Dashboard/NBACOVID-19?:showVizHome=no.

Figure 1. Kaplan Meier plots for the probability of avoiding infection overall (**A**), by quartiles of average percent away games (**B**), quartiles of average local COVID-19 rates (**C**), quartiles of average stadium attendance (**D**), quartiles of average minutes played (**E**), and quartiles of total games played (**F**).

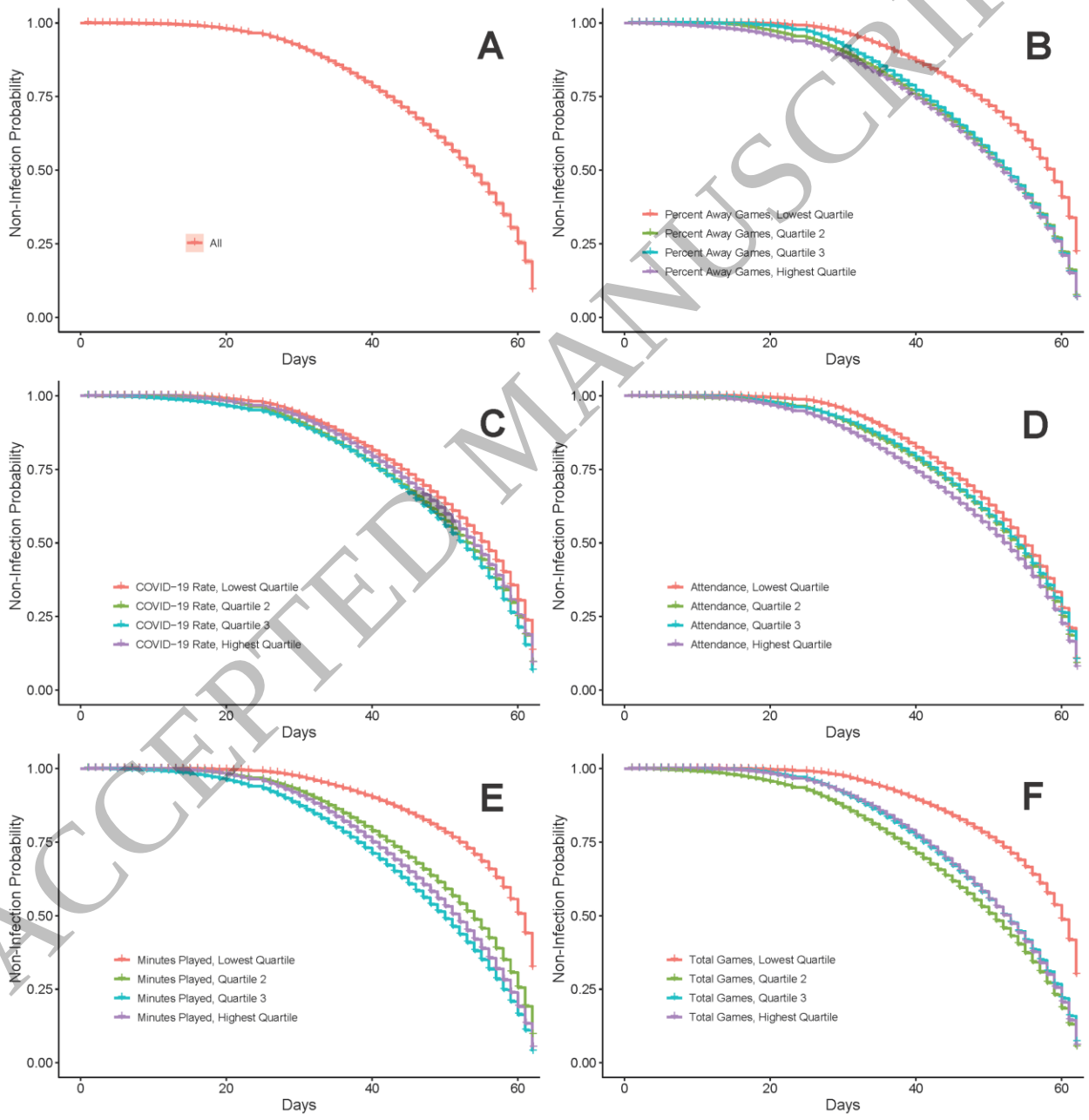

Figure 1
165x170 mm (x DPI)