Prevalence of Inadequate Immunity to Measles, Mumps, Rubella, and Varicella in MLB and NBA Athletes

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Background: Multiple outbreaks of vaccine-preventable viral diseases have occurred in professional sports in recent years. Currently, there is no established protocol for vaccination or immunity screening for professional athletes.

Hypothesis: There are significant differences in the prevalence of inadequate immunity dependent on age, sport, country of birth, and participation in collegiate sports.

Study Design: Cross-sectional cohort study.

Level of Evidence: Level 4.

Methods: A sample of Major League Baseball (MLB) and National Basketball Association (NBA) players were screened for serologic evidence of immunity to measles, mumps, rubella, and varicella prior to the 2015 and 2016 seasons. The results were designated as adequate (immune) or inadequate (equivocal or nonimmune) based on laboratory criteria. Comparison with an age-matched control group was performed using data from the National Health and Nutrition Examination Survey (NHANES).

Results: A total of 98 athletes (62 MLB, 36 NBA) were screened. The prevalence of inadequate immunity for any virus was 35.5% in MLB players and 33.3% in NBA players. There was a significantly greater risk of inadequate immunity to rubella (risk ratio, 6.38; $P < 0.01$) and varicella (risk ratio, 4.21; $P < 0.01$) in athletes compared with the age-matched NHANES population. Our analysis did not reveal differences in rates of immunity based on sport, country of birth (US born vs international), or participation in college athletics. There was a lower rate of inadequate immunity to varicella with increasing age (odds ratio, 0.72; $P = 0.05$).

Conclusion: One-third of athletes studied had inadequate immunity to 1 of the 4 viruses tested. Younger players had a significantly greater risk of inadequate immunity to varicella. Birth outside the US and lack of participation in college athletics were not found to influence immunity rates.

Clinical Relevance: These results can inform the development of future screening programs to prevent outbreaks of viral infections in professional athletes.

Keywords: preparticipation screening; vaccination; immunity; infectious disease

Outbreaks of vaccine-preventable viral infections have been reported recently in professional athletes. In the National Hockey League (NHL), an outbreak of mumps affected at least 14 athletes across 5 teams in 2014, followed by another mumps outbreak affecting at least 3 athletes on 1 team in 2017.[3] Similarly, an outbreak of chickenpox in Major League Baseball (MLB) in 2015, although limited to 2 athletes on 1 team, prompted increased attention to the risk of vaccine-preventable viral infections among professional athletes.[19,26] Awareness of such diseases has also increased as a result of numerous recent outbreaks of measles and mumps across the United States in a variety of settings, including both rural and urban communities, college campuses, and popular amusement parks.[5,12,13,22]

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Table 1. Demographics

	Total	MLB	NBA
n (%)	98	62 (63)	36 (37)
Mean age (SD), y	27 (4)	27 (4)	27 (5)
US born, n (%)	71 (72)	46 (74)	25 (69)
College sports participation, n (%)	57 (58)	33 (53)	24 (67)

MLB, Major League Baseball; NBA, National Basketball Association.

A number of contributing factors have been hypothesized as to why elite athletes are susceptible to communicable infections. Proposed risk factors include training and competition in close proximity to other athletes and frequent international travel that may include areas at increased risk for infectious disease outbreak.[10] Additionally, although moderate exercise has been shown to enhance immunity, prolonged high-intensity exercise likely impairs immune function and may increase susceptibility to infection.[10,11,17,20] Elite athletes are also often subject to more severe consequences of infection than the general population, as even minor sickness may negatively affect their performance and result in time missed from practice and competition.[10]

Many professional teams now routinely screen their players for measles, mumps, rubella, and varicella with the goal of preventing future outbreaks. Particular attention is often paid to those athletes considered to be at high risk for inadequate immunity. This includes athletes born outside the United States because of a perception of low rates of routine childhood vaccination in many international settings.[26] Athletes who did not attend college in the United States have also been perceived as higher risk because proof of childhood immunization is often required by universities prior to matriculation.[19] In addition, older athletes may be at increased risk due to waning immunity with age. Despite these assumptions, no published studies to date have specifically evaluated the prevalence of inadequate immunity to vaccine-preventable illnesses among professional athletes and definitively established high-risk groups.

This study examined serologic evidence of immunity to measles, mumps, rubella, and varicella among MLB and National Basketball Association (NBA) athletes during the 2015 and 2016 seasons. The primary objective was to determine the prevalence of inadequate immunity among the athletes studied. Secondary objectives included determining relative risks of inadequate immunity based on age, sport, participation in collegiate sports, and country of birth.

METHODS

This was a cross-sectional cohort study with institutional review board approval. A sample of MLB and NBA players was screened for serologic evidence of immunity to measles, mumps, rubella, and varicella prior to the 2015 and 2016 seasons. Antibody levels were measured by enzyme immune assay per standard protocol. The results were designated as adequate (immune) or inadequate (equivocal or nonimmune) based on the following standard laboratory criteria: <0.90 (nonimmune), 0.90 to 1.09 (equivocal), and >1.09 (immune). Demographic data were also collected, including age, country of birth, and collegiate sports participation. Serologic immunity to measles, mumps, rubella, and varicella from the National Health and Nutrition Examination Survey (NHANES), 2009-2010, age group 20 to 29 years, was used to compare our findings with a nationally representative sample of similar age.[14]

Age and serologic screening results from each participant were deidentified and recorded in a password-protected Excel spreadsheet (Microsoft). Additional demographic data, including birth country and participation in collegiate sports, were obtained from publicly available player biographies. Rates of inadequate immunity between sports and the NHANES population were calculated and compared using descriptive statistics. Demographic risk factors for inadequate immunity were evaluated in a multivariable model while adjusting for all other factors simultaneously. Results are reported as odds ratios (ORs) with 95% confidence intervals. Statistical significance was defined as $P \leq 0.05$.

RESULTS

A total of 98 athletes (62 MLB, 36 NBA; mean age, 27 years; age range, 19-41 years) were screened during the 2015 and 2016 seasons; 72% of athletes were born in the United States and 58% participated in collegiate sports (Table 1). The prevalence of inadequate immunity for any virus was 35.5% in MLB athletes and 33.3% in NBA athletes. The largest differences in immunity by sport were a higher prevalence of inadequate immunity to rubella among MLB players, with 32.3% compared with 25.0% in NBA players (risk ratio [RR], 2.7; $P = 0.07$), and a higher prevalence of inadequate immunity to varicella among NBA players, with 17.4% compared with 6.7% in MLB players (RR, 2.6; $P = 0.14$) (Figure 1).

Rates of inadequate immunity to measles and mumps among our study population were similar to 2009-2010 NHANES data from the 20 to 29 years age group (Table 2). There was a significantly greater risk of inadequate immunity to rubella in

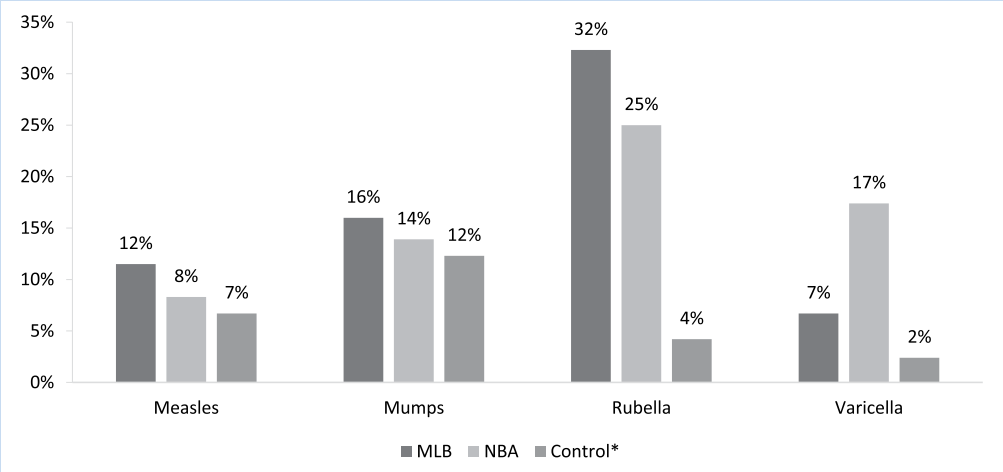

Figure 1. Prevalence of inadequate immunity. MLB, Major League Baseball; NBA, National Basketball Association. *National Health and Nutrition Examination Survey (age 20-29 years).

Table 2. Prevalence of inadequate immunity compared with age-matched controls

	Measles, n (%)	Mumps, n (%)	Rubella, n (%)	Varicella, n (%)
Total: MLB + NBA (n = 98)	10 (10.3)	15 (15.2)	29 (29.6)*	10 (10.6)*
Control (n = 950)[a]	64 (6.7)	117 (12.3)	40 (4.2)	23 (2.4)

MLB, Major League Baseball; NBA, National Basketball Association.
[a]National Health and Nutrition Examination Survey (age 20-29 years).
*$P < 0.01$.

Table 3. Risk factors for inadequate immunity: multivariable analysis[a]

	Measles (n = 97)	Mumps (n = 86)	Rubella (n = 98)	Varicella (n = 83)	Any Virus (n = 98)
Age (continuous)	1.04 (0.89-1.20)	0.93 (0.79-1.09)	1.02 (0.88-1.18)	0.72 (0.51-1.00)*	0.97 (0.87-1.08)
US born	1.52 (0.30-7.69)	1.19 (0.22-6.35)	1.73 (0.27-11.08)	0.39 (0.04-4.05)	0.92 (0.28-3.08)
College sports	1.06 (0.28-4.02)	0.77 (0.17-3.60)	2.55 (0.59-10.92)	1.96 (0.17-22.68)	1.34 (0.45-3.99)
MLB (vs NBA)	1.43 (0.34-5.90)	1.16 (0.33-4.05)	3.64 (0.93-14.24)	0.46 (0.09-2.46)	1.17 (0.48-2.84)

MLB, Major League Baseball; NBA, National Basketball Association.
[a]Data presented as odds ratios (95% CI).
*$P = 0.05$.

athletes studied compared with the NHANES population (RR, 6.38; $P < 0.01$). Inadequate immunity to varicella was also more common in this population compared with the NHANES group (RR, 4.21; $P < 0.01$).

Multivariable regression analyses of demographic risk factors for inadequate immunity demonstrated no difference in rates of immunity based on sport, country of birth (US born vs international), or participation in college athletics (Table 3). The only significant variable identified was lower rates of inadequate immunity to varicella with increasing age (OR, 0.72; $P = 0.05$).

DISCUSSION

More than one-third of MLB and NBA athletes had inadequate immunity to measles, mumps, rubella, and/or varicella. When compared with a control group of similar age, rates of immunity

for rubella and varicella were significantly lower for these players. The elevated risk of inadequate immunity found in the professional athletes in this study is likely multifactorial, with potential reasons including fragmented primary health care and immunomodulatory effects of excessive exercise and overtraining, though this requires further study.[11,24]

Our findings do not support the assumption that athletes who attended college in the United States are more likely to have adequate immunity to vaccine-preventable illness. This may be due to many universities not requiring or confirming proof of immunity from their students. In the case of varicella, for example, a survey of US colleges during the 2014-2015 academic year found that only 27% of schools required proof of immunity for matriculation, and only 68% of schools consistently enforced this requirement.[15] Thus, the role of colleges as a site of screening for immunity status may not reflect current practice.

The percentage of international athletes in our study population (28.6%) is consistent with estimates of the number of foreign-born players on NBA (24.0%) and MLB (29.8%) rosters prior to the 2017 season.[9,18] This is in stark contrast to the National Football League, where historically just 2.6% of players are foreign-born, and the NHL, where in 2015, more than 75% players were born outside the United States—with the majority of international players coming from Canada and Eastern Europe.[1,8] Among the players included in this study, we found that athletes born outside the United States were not at increased risk for inadequate immunity to measles, mumps, rubella, and varicella compared with athletes born in the United States. This is consistent with recent research that found that the rates of inadequate immunity to measles and rubella were no different among US-born and foreign-born individuals and were in fact higher in US-born individuals for mumps (86.6% vs 92.3%; $P < 0.01$).[14] Prior findings that varicella immunity is lower in foreign-born vs US-born populations were not demonstrated in our study.[14,21]

Our findings may be influenced by the development of widespread, well-coordinated childhood vaccination programs in many international countries. This is particularly relevant to the many MLB athletes from Latin America and the Caribbean, where more than 50% of countries in the region have robust mandatory immunization programs in place.[25] Notably, this does not include the United States, where currently childhood vaccination is not universally required and thus may decrease rates of immunity compared with many foreign countries.

Despite the tendency of immune titers to wane over time, increasing age was not a risk factor for inadequate immunity in this population. In fact, in the case of varicella, younger athletes actually had a greater rate of inadequate immunity compared with their older teammates. This somewhat counterintuitive finding may be related to the introduction of the varicella vaccine in the United States in 1995. After 10 years of implementation, recognition of waning immunity and limited efficacy of the 1-dose varicella vaccine prompted the Centers for Disease Control and Prevention to formally recommend a second varicella booster in 2006.[2,4] Thus, the increased rate of inadequate immunity to varicella in younger athletes may be a result of waning immunity from the varicella vaccine they received as a child and a more sustained immunologic response among older athletes who had chickenpox. These findings are consistent with a recent study of Air Force recruits, which demonstrated shorter-lived seropositivity after varicella vaccination compared with those who contracted chickenpox after wild-type exposure, and raises concerns about the risk of an increased rate of chickenpox in adult athletes as our population becomes more reliant on the vaccine alone for protection.[6]

Although this study is limited to professional athletes of only basketball and baseball, many of the same risk factors for outbreaks of viral diseases exist among athletes from other sports at all levels of competition. With that in mind, vaccination history and screening in the prevention of potentially severe viral diseases should be considered as part of the preparticipation evaluation of any athlete. Common strategies for athlete immunization programs include universal vaccination and screening plus targeted vaccination. With increased risk of vaccine-preventable diseases in elite athletes and the potential consequences of infection, universal vaccination programs are often implemented in this setting.[11] An example of this approach can be found in the US military services, which in 1991 implemented universal immunization in recruits with a single dose of the MMR (measles, mumps, rubella) vaccine, regardless of prior vaccination history.[7] On the other hand, a more targeted program is supported by a cost analysis of MMR immunity screening in adults, which found that testing for serologic immunity via blood sampling and selective immunization of those who are nonimmune is more cost-effective than universal vaccination.[23] However, in the absence of additional data, the appropriate method for ensuring immunity among professional athletes is not clear and may best be determined by team physicians and medical staff in the context of the specific setting and available resources.

Finally, as shown in several recent mumps outbreaks in US colleges, the presence of antibodies to a given disease, even when meeting the laboratory threshold for immunity, does not always confer complete protection to that individual.[16] Thus, regardless of vaccination history or titer levels, athletes and medical staff should regularly review strategies for disease prevention, such as hygiene, sleep, and nutrition, and early recognition of potentially contagious illness to minimize the risk and impact of outbreaks.

Limitations

This was a pilot study on a limited population restricted to a small convenience sample of male athletes from only 2 professional sports. Demographic factors, including age and country of origin, vary between professional and amateur sports, and thus, the findings here may be skewed by factors specific to NBA and MLB athletes. This limits generalizability of the results. We also did not differentiate countries or regions

outside the United States from one another when determining risk for inadequate immunity for international athletes, which may hide variations in vaccination adherence around the world.

Another key limitation is that personal vaccine and medical history of individual athletes were not collected, so we were unable to differentiate between immunity conferred by vaccination or prior infection. Though it is difficult to obtain reliable vaccination histories in many cases, this information, when available, would offer more insight into the causes of inadequate immunity. In turn, more clarity on whether inadequate immunity was due to lack of childhood vaccines or waning immunity would aid in the design of properly targeted intervention efforts.

Although our study was limited to professional athletes only, team personnel, including coaches, trainers, and other support staff, are also an important potential source for communicable viral infection among professional athletes. They also may be at greater risk for severe disease given the older age and higher likelihood of medical comorbidities in coaches and other staff compared with players.

CONCLUSION

This study demonstrates a high prevalence of inadequate immunity to measles, mumps, rubella, and varicella among MLB and NBA athletes, with a particular risk of inadequate immunity to varicella in younger players. Birth outside the United States and lack of participation in college athletics were not found to influence immunity rates. The results can inform the development of future screening programs to prevent outbreaks of viral infections in professional athletes.

Clinical Recommendations

SORT: Strength of Recommendation Taxonomy Grade
A: consistent, good-quality patient-oriented evidence
B: inconsistent or limited-quality patient-oriented evidence
C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

Clinical Recommendation	SORT Evidence Rating
Screening athletes for serologic evidence of immunity should be considered by team physicians as part of the preparticipation evaluation.	C
Athletes who are found to have inadequate immunity to measles, mumps, rubella, or varicella should be offered appropriate vaccination.	C
Athletes and medical staff should regularly review strategies for disease prevention and early recognition of potentially contagious illness to minimize the risk and impact of outbreaks.	C

REFERENCES

1. Borchers C. The NFL has the most protests. It is also the most American sports league. *The Washington Post*. https://www.washingtonpost.com/news/the-fix/wp/2017/10/13/the-nfl-has-the-most-protests-it-is-also-the-most-american-sports-league/?utm_term=.60dbc3f34293. Accessed February 8, 2018.
2. Chaves SS, Gargiullo P, Zhang JX, et al. Loss of vaccine-induced immunity to varicella over time. *N Engl J Med*. 2007;356:1121-1129.
3. Clarke M. Mumps virus returns to the NHL with cases confirmed on the Wild, Canucks. *SBNation.com*. https://www.sbnation.com/nhl/2017/2/24/14731468/vancouver-canucks-minnesota-wild-mumps-nhl-troy-stecher-parise-pominville. Accessed September 5, 2017.
4. Committee on Infectious Diseases. Prevention of varicella: recommendations for use of varicella vaccines in children, including a recommendation for a routine 2-dose varicella immunization schedule. *Pediatrics*. 2007;120:221-223.
5. Dayan GH, Quinlisk MP, Parker AA, et al. Recent resurgence of mumps in the United States. *N Engl J Med*. 2008;358:1580-1589.
6. Duncan JR, Witkop CT, Webber BJ, Costello AA. Varicella seroepidemiology in United States Air Force recruits: a retrospective cohort study comparing immunogenicity of varicella vaccination and natural infection. *Vaccine*. 2017;35:2351-2357.
7. Eick AA, Hu Z, Wang Z, Nevin RL. Incidence of mumps and immunity to measles, mumps and rubella among US military recruits, 2000-2004. *Vaccine*. 2008;26:494-501.
8. Gaines C. CHART: nationalities of NHL players. *Business Insider*. http://www.businessinsider.com/nhl-player-nationalities-2015-10. Accessed February 8, 2018.
9. Gamble JR. The changing face of Major League Baseball. *TSL*. https://www.theshadowleague.com/story/the-changing-face-of-major-league-baseball. Accessed February 8, 2018.
10. Gärtner BC, Meyer T. Vaccination in elite athletes. *Sports Med*. 2014;44:1361-1376.
11. Gleeson M. Immune function in sport and exercise. *J Appl Physiol*. 2007;103:693-699.
12. Hall V, Banerjee E, Kenyon C, et al. Measles outbreak—Minnesota April-May 2017. *MMWR Morb Mortal Wkly Rep*. 2017;66:713-717.
13. Halsey NA, Salmon DA. Measles at Disneyland, a problem for all ages. *Ann Intern Med*. 2015;162:655-656.
14. Lebo EJ, Kruszon-Moran DM, Marin M, et al. Seroprevalence of measles, mumps, rubella and varicella antibodies in the United States population, 2009-2010. *Open Forum Infect Dis*. 2015;2(1):ofv006.
15. Leung J, Marin M, Leino V, Even S, Bialek SR. Varicella immunization requirements for US colleges: 2014-2015 academic year. *J Am Coll Health*. 2016;64:490-495.
16. McLean HQ, Fiebelkorn AP, Temte JL, Wallace GS. Centers for Disease Control and Prevention. Prevention of measles, rubella, congenital rubella syndrome, and mumps, 2013: summary recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep*. 2013;62(RR-04):1-34.
17. Moreira A, Delgado L, Moreira P, Haahtela T. Does exercise increase the risk of upper respiratory tract infections? *Br Med Bull*. 2009;90:111-131.
18. NBA Official Release. NBA rosters feature 108 international players from record 42 countries and territories. NBA.com: NBA Communications. http://pr.nba.com/nba-international-players-2017-18/. Accessed February 8, 2018.
19. NFL Infectious Disease News—September 2015. Chickenpox in athletes: a basic review and assessment of the risk of chickenpox transmission in NFL teams. Introduction. Duke Infection Control Outreach Network (DICON). 2015;6(1):2010-2012.
20. Nieman DC. Exercise, upper respiratory tract infection, and the immune system. *Med Sci Sports Exerc*. 1994;26:128-139.

21. Reynolds MA, Kruszon-Moran D, Jumaan A, Schmid DS, McQuillan GM. Varicella seroprevalence in the U.S.: data from the National Health and Nutrition Examination Survey, 1999-2004. *Public Health Rep*. 2010;125:860-869.
22. Shah M, Quinlisk P, Weigel A, et al. Mumps outbreak in a highly vaccinated university-affiliated setting before and after a measles-mumps-rubella (MMR) vaccination campaign—Iowa, July 2015–May 2016. *Clin Infect Dis*. 2018;66:81-88.
23. Shirts BH, Welch RJ, Couturiera MR. Seropositivity rates for measles, mumps, and rubella IgG and costs associated with testing and revaccination. *Clin Vaccine Immunol*. 2013;20:443-445.
24. Smith L. Overtraining, excessive exercise, and altered immunity. *Sport Med*. 2003;33:347-364.
25. Trumbo SP, Janusz CB, Jauregui B, et al. Vaccination legislation in Latin America and the Caribbean. *J Public Health Policy*. 2013;34:82-99.
26. Welch A. Chicken pox outbreak hits Kansas City Royals. *CBS News*. https://www.cbsnews.com /news/chicken-pox-outbreak-hits-kansas-city-royals/. Accessed September 5, 2017.