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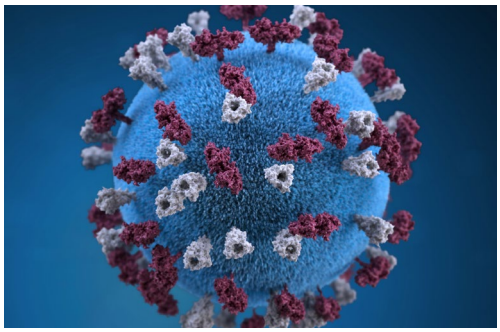
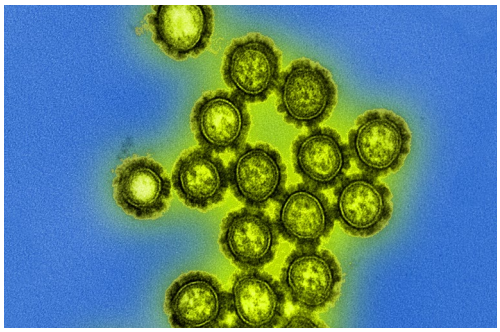
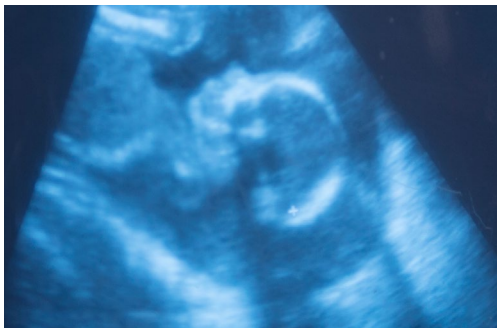
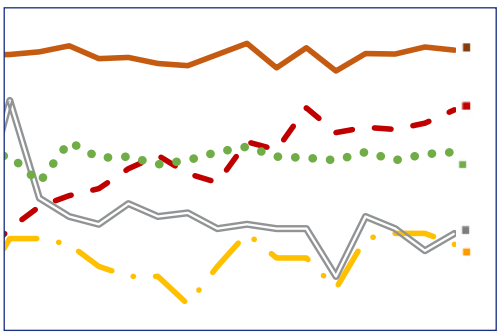








Update

Measles, Mumps, Rubella and Varicella Among Service Members and Other Beneficiaries of the Military Health System, 2019–2024

Sithembile L. Mabila, PhD, MSc; Michael T. Fan, PhD; Shauna L. Stahlman, PhD, MPH

Measles, mumps, rubella, and varicella (MMR/V) cases have decreased in the U.S. Military Health System (MHS) overall, but in recent years, increasing numbers of MMR/V outbreaks in the U.S. have led to a rise in reported cases among the civilian population. Data were queried from the Defense Medical Surveillance System to identify total number of confirmed and possible MMR/V cases among all MHS beneficiaries from 2019 through 2024. The total numbers of confirmed and possible cases among MHS beneficiaries included 8 confirmed and 71 possible cases of measles, 18 confirmed and 193 possible cases of mumps, 13 confirmed and 265 possible cases of rubella, and 251 confirmed and 4,554 possible cases of varicella. During the surveillance period the numbers of all confirmed and possible cases decreased. Among service members, most cases were either partially vaccinated, or vaccination records were not available.

What are the new findings?

In this 6-year surveillance period, cases of MMR/V decreased over time. No cases of measles were observed among U.S. service members during the surveillance period.

What is the impact on readiness and force health protection?

This report emphasizes the importance of continued vaccination against MMR/V to limit morbidity among U.S. service members, as evidenced by the lower number of cases among service members, who are required to be vaccinated, when compared to non-service members.

Although the numbers of measles, mumps, rubella, and varicella (MMR/V) cases have drastically declined in the U.S. after vaccine implementation, outbreaks of these diseases still occur sporadically.[1,2] Fourteen measles outbreaks occurred in the U.S. between January 1 and May 8, 2025, accounting for 1,001 confirmed measles cases reported by 31 U.S. jurisdictions, 126 (12.6%) hospitalizations, and 3 deaths. Mumps outbreaks also continue to occur across the U.S., with cases drastically increasing in 2016 (n=6,366 cases) compared to the previous 5 years, during which cases ranged from 200 to 1,329 annually.[4] Even though the number of total cases of mumps has decreased since 2016, with cases dropping below 500 cases per year, from 2021 through 2025, mumps cases are still reported annually, with 357 cases reported in 2024.[4] Varicella cases have also drastically decreased since the introduction of the 2-dose vaccine in 2007, from an average rate of 215 cases per 100,000 population, 1994–1995, to 33 cases per 100,000 population.[5] The median number of rubella cases reported annually, 2001–2004, was 14 (range 7-23), and rubella was declared eliminated in the U.S. in 2004.[6] Rubella is no longer endemic to the U.S., with its annual 2005–2022 incidence remaining less than 1 case per 10 million population, with most reported cases in the recent past acquired while traveling or living outside the U.S.[6] It remains important to monitor MMR/V cases in the U.S. Military Health System (MHS), as service members deploy to other countries where MMR/V is endemic, and viral outbreaks continue to occur within the U.S.

The Standing Order for Administering MMR/V vaccine among adults outlines the U.S. Department of Defense (DOD) policy for MMR/V vaccination.[7] Military environments such as recruit training locations, barracks, and ships are conducive to the spread of MMR/V because service members live in close quarters. Military personnel are required to receive the MMR/V vaccine and provide documentation of 2 lifetime doses of MMR/V-containing vaccines, or serological evidence of immunity. If no documentation is available, 1 dose of MMR/V-containing vaccine is administered within the first 2 weeks of initial training, and the second dose is administered at least 4 weeks later. *MSMR* has previously reported on MMR/V cases among MHS beneficiaries, describing trends from 2010 through 2016 and 2016 through 2019.[8,9] From 2016 through June 2019, the total number of MMR/V cases were relatively low among MHS beneficiaries, with 5 confirmed cases of measles and 64 confirmed cases of mumps. None of the measles cases were among service members.[9]

This analysis provides an update on MMR/V cases from 2019 through 2024 to describe temporal trends among MHS beneficiaries. Additionally, this analysis stratifies cases by MMR/V immunization status to evaluate waning immunity and breakthrough infections among service members.

Methods

This retrospective cohort study included all MHS beneficiaries from 2019 through 2024. Demographic, immunization, and medical encounter data were obtained from the Defense Medical Surveillance System (DMSS). Because MMR/V are considered reportable medical events (RMEs), RME data for confirmed and possible cases were evaluated, in addition to International Classification of Diseases, 9th and 10th Revisions, Clinical Modification (ICD-9/10-CM) diagnostic codes from medical encounter data.

The Armed Forces Health Surveillance Division surveillance case definitions for MMR/V were used for this analysis. In summary, a 'confirmed' case was defined as an individual identified through an RME of MMR/V that was described as confirmed according to laboratory and epidemiological criteria.[10-13] A 'possible' case was defined as 1) a suspect, probable, unknown, or pending RME of MMR/V or 2) a record of an inpatient or outpatient medical encounter with a diagnosis of measles, mumps, rubella, or varicella in the primary diagnostic position.

For measles, mumps, and rubella cases, a disease-associated symptom in any other diagnosis position was also required in addition to the aforementioned RME or medical encounter requirement for possible cases.[10-13] Encounters with a record of MMR/V immunization or positive test for serological immunity to MMR/V within 7 days of the encounter date, or an ICD-10-CM diagnosis or a Current Procedural Terminology (CPT) code indicating MMR/V vaccination on the same day as the MMR/V diagnosis were excluded. [10-13]

Vaccination status for service member cases was determined using the immunization data from the immunization table in DMSS. Immunization types for measles (03, 04, 05, 94), mumps (03, 07, 038, 94), rubella (03, 04, 06, 38, 94) and varicella (21, 36, 117, 94) were queried. A fully vaccinated case was an individual who had received 2 MMR/V vaccine doses at least 28 days apart, while any cases with 1 dose were considered partially vaccinated. Individuals without any vaccination information, or those with vaccination information after an incident case, were considered unvaccinated. Immunization exemption data were queried to determine cases that were exempt from the MMR/V vaccine. MHS beneficiaries were stratified by component and service. Due to the limited number of cases among service members, incident rates and any further analysis were not performed. The immunization table in DMSS does not have immunization data for non-service members; thus, the vaccination status of non-service members was not determined. All analyses were conducted using SAS-Enterprise Guide (version 8.3).

Results

Measles

This retrospective study identified a total of 8 confirmed and 71 possible cases of measles among all MHS beneficiaries during the surveillance period **(Table 1)**. No confirmed measles cases were among U.S. service members. Of the 71 possible measles cases, the majority (n=69, 97.2%) were among non-service member beneficiaries. Overall, both confirmed and possible cases of measles decreased during the surveillance period **(Figure 1)**. Half of confirmed

TABLE 1. Confirmed and Possible Cases of Measles, Mumps, Rubella and Varicella, All Military Health System Beneficiaries, 2019–2024

	Measles		Mumps		Rubella		Varicella	
	Confirmed	Possible	Confirmed	Possible	Confirmed	Possible	Confirmed	Possible
	No.	No.	No.	No.	No.	No.	No.	No.
Total	8	71	18	193	13	265	251	4,554
Component								
Active component	0	1	7	61	6	22	68	359
Reserve component, National Guard	0	1	2	2	0	2	4	124
Non-service member beneficiaries	8	69	9	130	7	241	179	4,071
Sex								
Male	5	38	13	117	4	123	139	2,158
Female	3	33	5	76	9	142	112	2,396
Service branch[a]								
Army	0	0	3	33	2	9	18	198
Navy	0	1	5	12	3	6	24	85
Air Force	0	1	1	6	1	6	21	132
Marine Corps	0	0	0	11	0	3	8	51
Space Force	0	0	0	0	0	0	1	2
Coast Guard	0	0	0	1	0	0	0	15

Abbreviation: No., number.
[a]Among active component, reserve component, and National Guard service members.

measles cases (n=4, 50.0%) and over half of possible measles cases (n=41, 57.7%) were among children ages 5 years or younger **(Figure 2)**.

Mumps

A total of 18 confirmed and 193 possible mumps cases were identified among all MHS beneficiaries during the surveillance period. Half of confirmed mumps cases (n=9) occurred among service members. Among the 193 possible cases, a majority (n=130, 67.4%) were among non-service member beneficiaries **(Table 1)**. The greatest annual number of confirmed cases (n=14) for all MHS beneficiaries occurred in 2019 **(Figure 3)**. Cases were sporadically distributed among age categories **(Figure 4)**. Of the 9 confirmed mumps cases among service members, 4 had been fully vaccinated, 2 partially vaccinated, and 3 had not been vaccinated **(Table 2)**.

Rubella

A total of 13 confirmed and 265 possible rubella cases were identified among all MHS beneficiaries during the surveillance period. Six of the confirmed rubella cases occurred among active component service members. Among the 265 possible cases, a majority (n=241, 90.9%) were among non-service member beneficiaries **(Table 1)**. Confirmed rubella cases peaked in 2022 (n=6), subsequently declining to 0 cases in 2024 **(Figure 5)**. All confirmed rubella cases were among those aged 21 years and older **(Figure 6)**. Among the confirmed service member cases, 3 had been partially vaccinated, and 3 cases had received an exemption from vaccination **(Table 2)**.

Varicella

A total of 251 confirmed and 4,554 possible varicella cases were identified among all MHS beneficiaries during the surveillance period. The majority of confirmed varicella cases (n=179, 71.3%) and possible varicella cases (n=4,071, 89.4%) were among non-service member beneficiaries **(Table 1)**. The overall trend in possible varicella cases declined by approximately 37% during the surveillance period (from 1,049 cases in 2019 to 666 cases in 2024).

FIGURE 1. Annual Measles Cases, All Military Health System Beneficiaries, 2019–2024

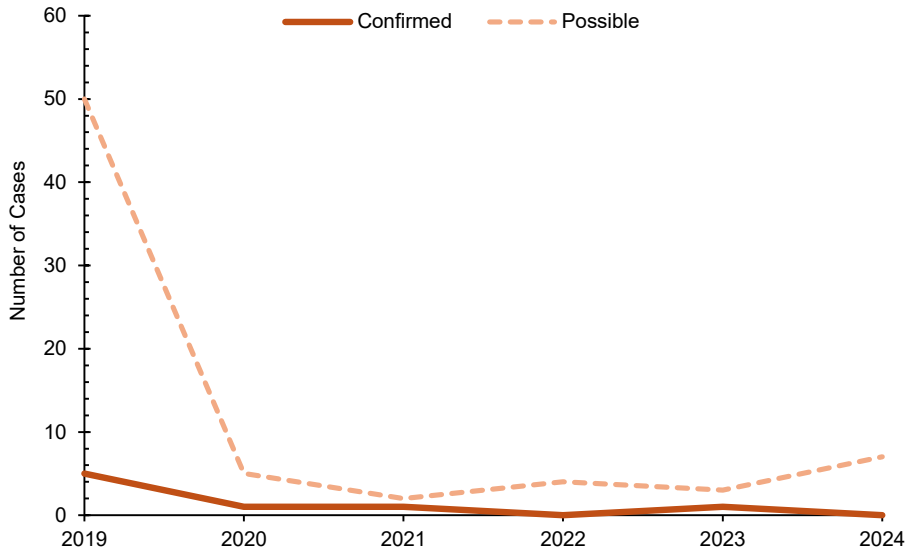
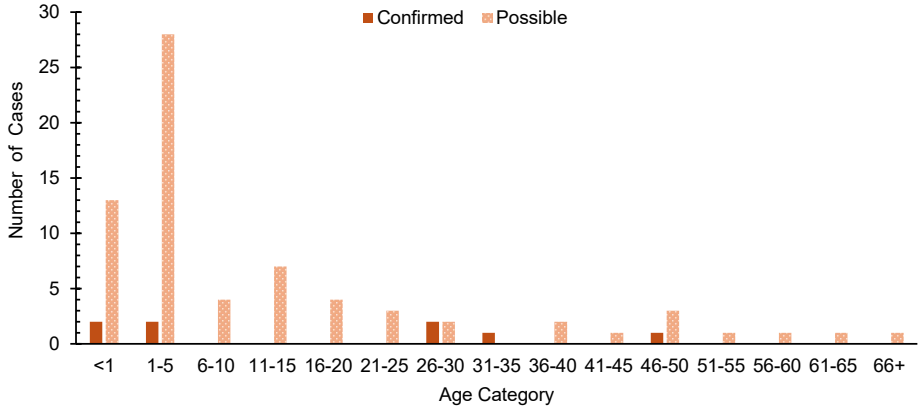


FIGURE 2. Age Distribution of Confirmed and Possible Measles Cases, All Military Health System Beneficiaries, 2019–2024



While the number of confirmed varicella cases remained relatively stable from 2020 through 2023, the subsequent increase to 51 confirmed cases in 2024 does not indicate a general decline over the surveillance period, as demonstrated by possible varicella case data **(Figure 7)**. Nearly 23% (n=57) of confirmed cases were among children ages 5 years and younger **(Figure 8)**. Among the 72 confirmed cases of varicella among service members, only 7 cases had been fully vaccinated, 48 cases had received an exemption from immunization, and 12 cases had not been vaccinated **(Table 2)**.

Discussion

In this retrospective analysis from 2019 to 2024, no measles cases were identified among service members. The previous MMR/V report also demonstrated no confirmed measles cases among service members from 2016 to 2019.[9] For non-service member beneficiaries, measles primarily affected children ages 5 years or younger, with 50% of confirmed cases and over 57% of possible cases occurring in this age group. A similar trend was observed

TABLE 2. Vaccination Status of Confirmed Mumps, Rubella and Varicella Cases, U.S. Service Members, by Year, 2019–2024

	Status of Vaccination	2019	2020	2021	2022	2023	2024	Total
		No.	No.	No.	No.	No.	No.	No.
Mumps	Fully vaccinated	3	1	0	0	0	0	4
	Partially vaccinated	2	0	0	0	0	0	2
	Not vaccinated	2	1	0	0	0	0	3
	Exempt	0	0	0	0	0	0	0
Rubella	Fully vaccinated	0	0	0	0	0	0	0
	Partially vaccinated	0	0	1	1	1	0	3
	Not vaccinated	0	0	0	0	0	0	0
	Exempt	0	0	1	1	1	0	3
Varicella	Fully vaccinated	0	1	1	3	0	2	7
	Partially vaccinated	0	2	1	1	1	0	5
	Not vaccinated	3	2	0	4	1	2	12
	Exempt	11	7	11	7	7	5	48

Abbreviation: No., number.

in the general U.S. population, with 42% of all cases among children under age 5 years in 2024.[3] This is especially of concern, as measles can cause serious health complications in children younger than age 5 years.[14] It is important to note, however, that measles continued to decrease among all MHS beneficiaries throughout the surveillance period.

During the 6-year surveillance period, there were over double the number of confirmed cases of mumps compared to measles (n=18, n=8, respectively). In the last *MSMR* report of MMR/V cases among MHS beneficiaries, confirmed mumps cases were 12 times higher than measles cases.[9] The increased number of mumps cases is consistent with continued mumps outbreaks across the U.S., particularly among fully vaccinated young adults.[15] This may be attributed to the fact that the 2-dose MMR vaccine is less effective against mumps (86%) compared to the measles (97%).[15-17] This is evident in this study, with 22% (n=4) breakthrough mumps cases that were fully vaccinated during the surveillance period. In 2017, the Advisory Committee of Immunization practices recommended a third dose of MMR (MMR3) during mumps outbreaks; and it has been proposed that MMR3 be administered in late adolescence or prior to college to help improve mumps vaccine efficacy.[18]

FIGURE 3. Annual Mumps Cases, All Military Health System Beneficiaries, 2019–2024

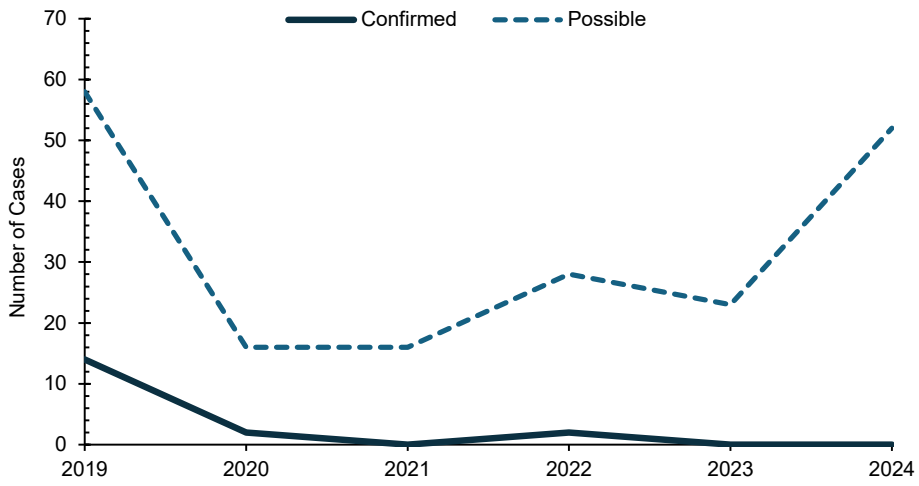
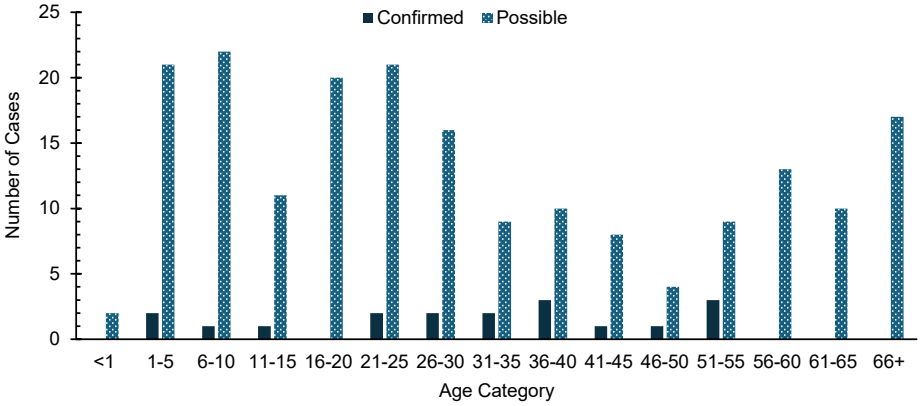


FIGURE 4. Age Distribution of Confirmed and Possible Mumps Cases, All Military Health System Beneficiaries, 2019–2024



Distribution of confirmed rubella cases was relatively similar in service members and non-service members. No confirmed rubella cases were among children or young adults (younger than age 20 years); most rubella cases were among adults aged 21-35 years. A larger number of possible rubella cases were identified among non-service members than service members, which may be attributed to the vaccination requirement for military service. Since rubella is no longer endemic to the U.S., cases among MHS beneficiaries were most likely acquired outside the U.S.; however, this analysis did not discern country of MMR/V acquisition.

Varicella afforded the most confirmed cases in both service members (n=72) and non-service members (n=179), and 90% (n=65) of all confirmed cases among service members were not fully vaccinated. Full vaccination against varicella among service members might decrease the number of cases among all MHS beneficiaries.

All MMR/V cases decreased from 2019 to 2020, coincident with the COVID-19 pandemic during which most people were socially distancing and taking extra hygiene precautions, such as wearing masks and frequently washing hands. The same is observed in the general U.S. population, from 1,274 cases of measles in 2019 that drastically dropped to 13 cases in 2020. There were also multiple mumps outbreaks in 2019 within the U.S. military, such as the outbreak aboard USS Fort McHenry in early 2019 and an outbreak in July 2019 among Army troopers in Italy.[9] Such outbreaks are contributing factors to the high number of observed cases in 2019 compared to the rest of the surveillance period. Cases of mumps and rubella started increasing, however, again in 2023 and 2022, respectively. Similar to previous reports of MMR/V among all MHS beneficiaries,[8,9] a substantially higher number of possible cases were identified than confirmed cases. Since a diagnosis of an MMR/V in this study was considered a case if reported as a confirmed RME notification, cases identified from inpatient and outpatient records that were not reported as RMEs are not counted as confirmed cases, but as possible cases. This potentially led to under-estimating confirmed MMR/V cases within the MHS.

FIGURE 5. Annual Rubella Cases, All Military Health System Beneficiaries, 2019–2024

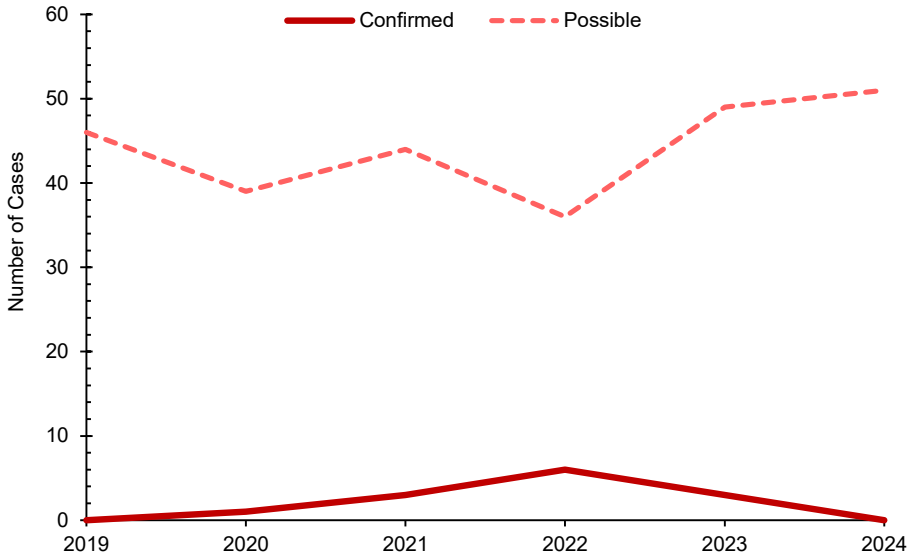


FIGURE 6. Age Distribution of Confirmed and Possible Rubella Cases, All Military Health System Beneficiaries, 2019–2024

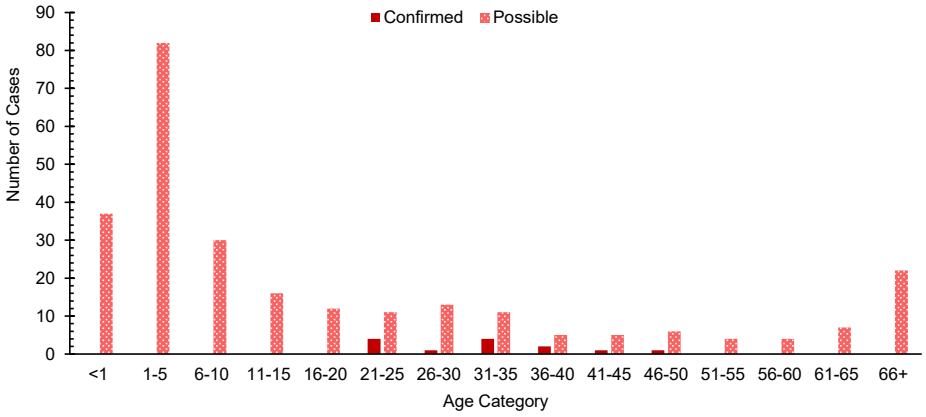


FIGURE 7. Annual Varicella Cases, All Military Health System Beneficiaries, 2019–2024

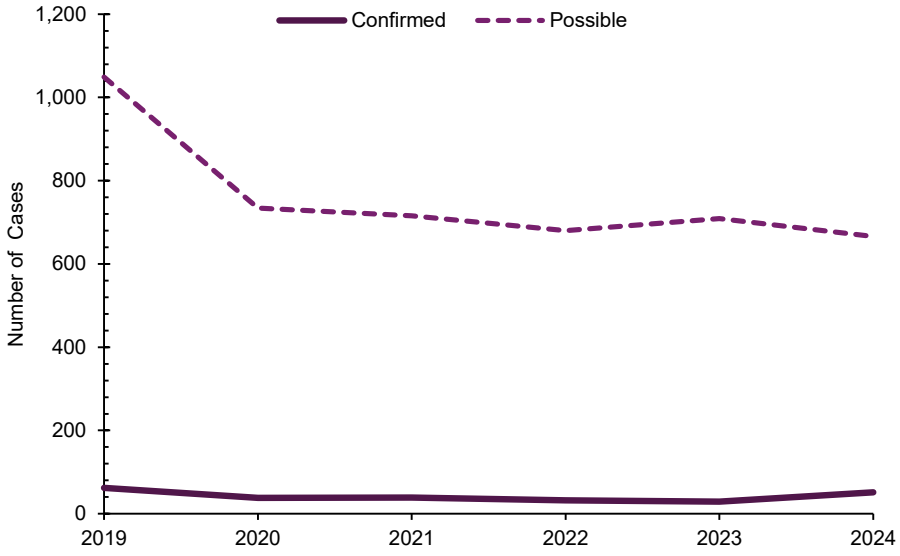
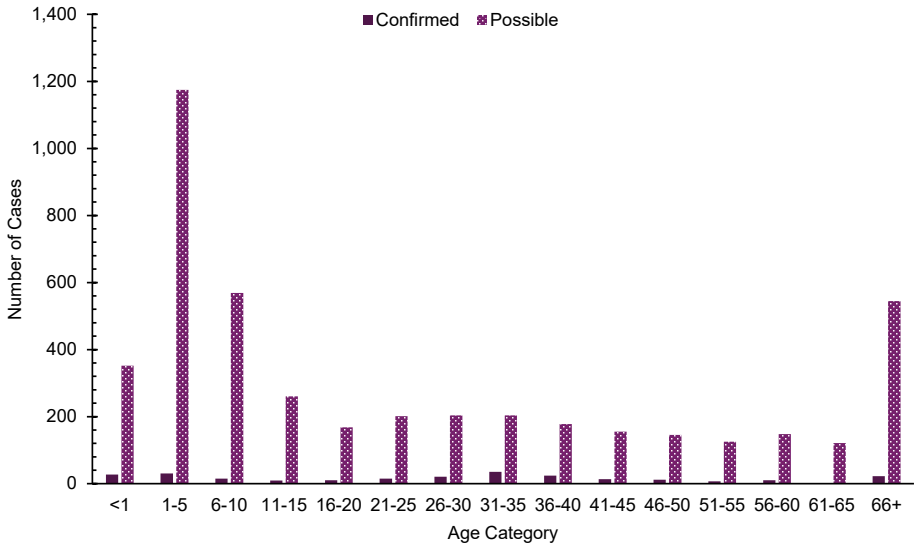


FIGURE 8. Age Distribution of Confirmed and Possible Varicella Cases, All Military Health System Beneficiaries, 2019–2024



Note: 4 'possible' cases with unknown ages.

This analysis also included MMR/V vaccination status among service members, which was not considered in previous updates. This addition is useful for determining numbers of breakthrough cases and identifying cases that were unvaccinated, providing indication of the importance of MMR/V vaccination.

The results presented may, however, be subject to data limitations. A few confirmed mumps and varicella cases among service members had no evidence of either a vaccine record or immunization exemption. It is, therefore, probable that immunization information may be missing or subject to data entry errors for some service members, as MMR/V vaccination is a requirement for military service.

Overall, the number of all MMR/V cases were higher among non-service member MHS beneficiaries compared to service members. This finding is not surprising, since evidence of immunity for MMR/V is required for service members. As MMR/V outbreaks continue to occur in the U.S. continued monitoring of MMR/V cases within the MHS is essential to ensure a healthy force and military readiness.

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Seasonal Influenza Hospitalization Incidence Rates Among U.S. Active Component Service Members, 2010–2024

David R. Sayers, MD, MTM&H; Saixia Ying, PhD; Angelia A. Eick-Cost, PhD

Despite a longstanding U.S. Department of Defense (DOD) requirement for seasonal influenza vaccination of active component service members (ACSMs), quantifying the impact of the DOD immunization program is challenging. To measure the burden of severe influenza among this highly immunized ACSM population, this study evaluated seasonal and cumulative seasonal influenza hospitalization rates among ACSMs from 2010 through 2024, stratifying by sex, age group, race and ethnicity, service branch, recruit site, and location (U.S. vs. non-U.S.). In contrast to Centers for Disease Control and Prevention (CDC) U.S. population data, the highest ACSM cumulative seasonal influenza hospitalization rate was in the age group under 25 years (9.3 per 100,000 person-years [p-yrs]) and recruits (70.1 per 100,000 p-yrs). Non-U.S.-based ACSMs had lower influenza hospitalization rates (4.8 per 100,000 p-yrs) compared to ACSMs in the U.S. (8.0 per 100,000 p-yrs). Within the DOD, cumulative seasonal influenza hospitalization rates were highest in the youngest age group, particularly among recruits. This may influence DOD influenza vaccine distribution priority considerations in the future.

What are the new findings?

Compared to U.S. national data, in which adult seasonal influenza hospitalization rates increase with age, the highest cumulative hospitalization rate among active component service members occurred in the youngest age group, those younger than age 25 years, especially in recruit settings.

What is the impact on readiness and force health protection?

Lower cumulative rates of seasonal influenza hospitalization in older age groups of active component service members help quantify the impacts of the longstanding DOD vaccination requirement for influenza. The higher burden of hospitalization among recruits offers DOD vaccine distribution priority considerations in the future.

Influenza vaccines have been employed by the U.S. Department of Defense (DOD) since the 1940s and have been required annually since the 1950s for active component service members (ACSMs).[1] Each year, the DOD's goal is to reach greater than 90% influenza vaccine compliance rates by January 15, a goal that is typically achieved, especially for ACSMs.[2] The DOD influenza program is challenged with shipping vaccine across the world in a timely manner. Differences in compliance groups are influenced by how quickly vaccines can be sent and used. Historically, non-U.S. locations have been prioritized for distribution first, while U.S. locations (including training sites) are hierarchized as lower in importance.

Quantifying the impact of the DOD influenza program is challenging, as vaccine effectiveness (VE) calculations through traditional, observational test-negative case control studies typically demonstrate lower VE compared to national data.[3] Multiple factors may influence this observed lower VE with the DOD, including diminished antibody response to serial annual vaccinations, waning immunity during the influenza season, and study design limitations (i.e., adequate statistical power).[4] Evaluating the burden of severe influenza illness among this highly vaccinated population may serve as a surrogate for vaccine performance.

The U.S. Centers for Disease Control and Prevention (CDC) Influenza Hospitalization Surveillance Network (FluSurv-NET) generates cumulative seasonal influenza hospitalization rates, stratified by age group, to define the national burden of influenza disease. Typically, the highest rates of influenza hospitalizations occur in older adults (≥50 years) and young children (0-4 years).[5] Cumulative seasonal influenza hospitalization rates help quantify the burden of severe illness, but this has not been summarized previously for U.S. ACSMs. Analyzing DOD cumulative seasonal influenza hospitalization rates allows identification of higher risk ACSM groups and comparisons of the highly immunized military population to national trends.

The objectives of this study were to evaluate the cumulative seasonal influenza hospitalization rates of ACSMs by sex, age group, race and ethnicity, service branch, recruit site, and location (U.S. vs. non-U.S.). ACSM seasonal influenza hospitalization rates were also compared to CDC age group rates.

Methods

The population included all U.S. ACSMs during each influenza season, defined as September 1 through April 30, from the 2010-2011 through

2023-2024 seasons. Data from the Defense Medical Surveillance System (DMSS) and standardized laboratory data provided by the Defense Centers for Public Health–Portsmouth were utilized for the analysis.

Influenza hospitalizations were defined as 1 hospitalization with any of the defining diagnoses of influenza in the first or second diagnostic position (International Classification of Diseases, 10th Revision [ICD-10] codes J09-J11, International Classification of Diseases, 9th Revision [ICD-9] codes 487-488) or laboratory-confirmed influenza-positive result (rapid antigen, RT-PCR, or culture influenza assay) with an indication that the individual was hospitalized. All hospitalizations meeting the inclusion criteria were included in the analysis. There were no exclusions. The incidence date was defined as the first date of hospitalization. An individual could be an incident case only once per influenza season.

For each influenza season, individual person-time began on September 1 or entry into active component service (whichever came last) and ended either April 30, last date in active component service, or incidence date for the hospitalization (whichever came first). Seasonal influenza hospitalization incidence rates (IRs) were calculated as the number of incident influenza hospitalizations divided by the number of person-years (p-yrs) for the season multiplied by 100,000. Incidence rates were calculated overall and stratified by sex, age group, race and ethnicity, service branch, recruit status, and location. Cumulative IRs were also calculated by combining data for the entire surveillance period. Comparisons were made to general U.S. age-stratified influenza hospitalization rates using the CDC Influenza Hospitalization Surveillance Network (FluSurv-NET) data.[5]

Results

Table 1 describes the total cumulative seasonal influenza hospitalizations among ACSMs from 2010 through 2024, stratified by sex, age group, race and ethnicity, service branch, recruit status and location (U.S. vs. non-U.S.). The overall cumulative influenza hospitalization rate was 7.4 per 100,000 p-yrs, with the highest rate among recruits (70.1 per 100,000 p-yrs). Higher hospitalization rates were observed in the youngest age group (<25 years; 9.3 per 100,000 p-yrs), women (9.7 per 100,000 p-yrs), Marine Corps members (13.9 per 100,000 p-yrs), and individuals located in the U.S. (8.0 per 100,000 p-yrs).

Seasonal counts and incidence rates of influenza hospitalizations with stratification by recruit status are shown in **Figure 1**. Overall counts varied by annual influenza season, with the largest number of influenza hospitalizations (n=145) during the 2019-2020 season. Counts and rates dropped significantly during the 2020-2021 season, coinciding with the COVID-19 pandemic. The largest number (41) of recruit influenza hospitalizations occurred during the 2023-2024 influenza season. Except for the seasons affected by the COVID-19 pandemic, incidence rates of influenza hospitalizations among recruits trended upwards during the surveillance period, with the highest rate (IR 218.5 per 100,000 p-yrs) observed during the 2023-2024 season.

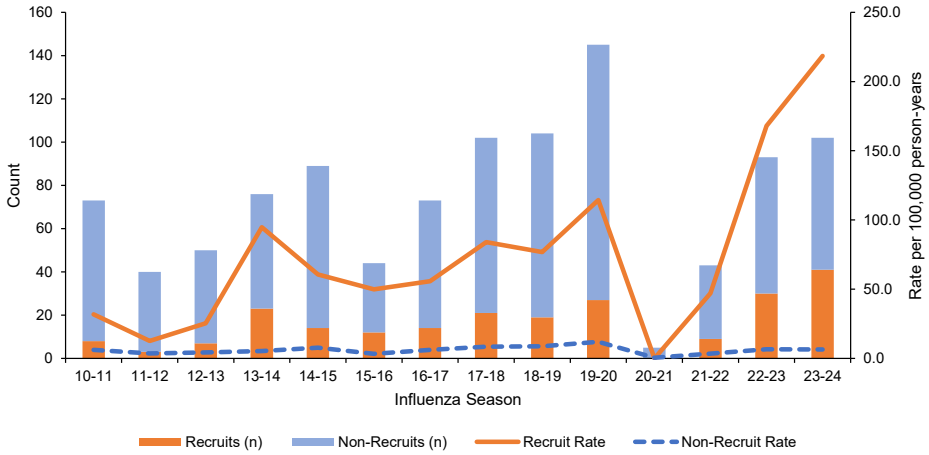
Table 2 shows the influenza hospitalization counts and rates for recruits, stratified by age group, sex, race and ethnicity, and service branch. Among recruits, higher cumulative seasonal influenza hospitalization rates occurred in ages younger than 25 years (71.9 per 100,000 p-yrs), men (76.3 per 100,000 p-yrs), and Marine Corps members (178.7 per 100,000 p-yrs).

TABLE 1. Cumulative Seasonal Incidence of Influenza Hospitalizations, by Demographic Characteristics, U.S. Active Component Service Members, 2010–2024

Characteristics	Cases	Person-Time	Incidence Rate[a]
	No.	Person-Years	
All	1,039	14,066,193	7.4
Sex			
Male	820	11,812,456	6.9
Female	219	2,253,737	9.7
Age, *y*			
<25	499	5,348,026	9.3
25–29	170	3,337,557	5.1
30–39	242	3,930,877	6.2
40+	128	1,449,733	8.8
Race and ethnicity			
White, non-Hispanic	542	8,044,365	6.7
Black, non-Hispanic	195	2,210,087	8.8
Hispanic	176	2,165,838	8.1
Other, unknown	126	1,645,903	7.7
Service branch			
Army	418	5,064,269	8.3
Navy	171	3,351,236	5.1
Air Force	163	3,328,304	4.9
Marine Corps	265	1,907,678	13.9
Coast Guard	22	414,706	5.3
Recruit			
No	811	13,741,025	5.9
Yes	228	325,168	70.1
Location			
U.S.	901	11,210,960	8.0
Outside U.S.	138	2,855,233	4.8

Abbreviations: No., number; *y*, years.
[a] Rate per 100,000 person-years

FIGURE 1. Counts and Incidence Rates of Influenza Hospitalizations, by Recruit Status and Influenza Season[a], U.S. Active Component Service Members, 2010–2024



Abbreviation: n, number.
[a] Influenza seasons defined as Sep. 1–Apr. 30.

TABLE 2. Cumulative Seasonal Incidence of Influenza Hospitalizations Among Recruits, by Demographic Characteristics, U.S. Active Component Service Members, 2010–2024

Characteristics	Cases	Person-Time	Incidence Rate[a]
	No.	Person-Years	
All	228	325,168	70.1
Sex			
Male	206	270,075	76.3
Female	22	55,093	39.9
Age, *y*			
<25	209	290,650	71.9
25–29	17	26,754	63.5
30–39	2	7,620	26.2
40+	0	145	0.0
Race and ethnicity			
White, non-Hispanic	129	171,255	75.3
Black, non-Hispanic	33	56,567	58.3
Hispanic	41	64,248	63.8
Other, unknown	25	33,098	75.5
Service branch			
Army	60	123,773	48.5
Navy	4	61,729	6.5
Air Force	15	54,548	27.5
Marine Corps	143	80,022	178.7
Coast Guard	6	5,096	117.7

Abbreviations: No., number; *y*, years.
[a] Rate per 100,000 person-years

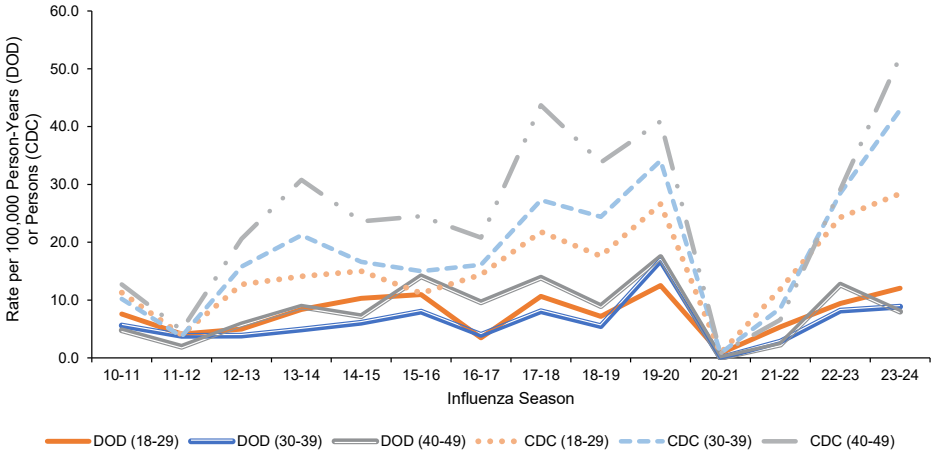
Figure 2 compares seasonal influenza hospitalization rates for ACSMs to CDC age groups. Seasonal influenza hospitalization rates were lower among ACSMs for all age groups compared to CDC age groups. Whereas CDC hospitalization rates increase with older age groups, the ACSM age groups were more comparable throughout each influenza season. When ACSMs younger than age 30 years were further stratified into younger than age 25 years and ages 25-29 years, the younger than age 25 years group had the highest influenza hospitalization rate among all age groups for over half the annual influenza seasons reported (data not shown).

Discussion

Cumulative seasonal influenza hospitalization rates help quantify the burden of severe illness in a population. In this study, cumulative seasonal influenza hospitalization rates from 2010 through 2024 reveal higher hospitalization rates among the youngest age group (<25 years) of ACSMs. This is counter to CDC national data in which adult influenza hospitalization rates increase with each age group. Hospitalizations within recruit populations drive this increased risk in the youngest DOD age group and in the Marine Corps. Military trainees have historically been vulnerable to acute respiratory disease due to relative immune compromise from physical, environmental, and psychological stress.[6] Multiple studies have reported that recruits have a higher incidence of influenza-like illnesses compared to non-recruits.[7,8]

Age-stratified influenza hospitalization rates from CDC national data were higher than the age-stratified ACSM rates. Influenza immunization has been a requirement for the DOD since the 1950s, with goals to reach at least 90% coverage each season.[1,2] Influenza vaccine coverage among individuals ages 18-49 years in the general U.S. population ranged from 26.9% to 38.4%, depending on the influenza season, from the 2010-2011 through 2023-2024 seasons.[9] This differential vaccine coverage is likely a factor in why influenza hospitalization incidence rates among ACSMs were lower than CDC national data rates and do not increase incrementally with each older age group.

FIGURE 2. Comparison of U.S. Department of Defense and U.S. Centers for Disease Control and Prevention[a] Data for Incidence Rates of Influenza Hospitalizations, by Influenza Season, 2010–2024



Abbreviations: DOD, Department of Defense; CDC, Centers for Disease Control and Prevention.
[a] CDC age stratified rates for the 2020-21 influenza season were not available. Therefore, the overall rate (0.8 per 100,000 persons) was used for all age groups to make the trend line continuous.

Locations outside the continental U.S. are the priority areas for DOD influenza vaccine distribution; however, the non-U.S. influenza hospitalization rate was lower than the rate for U.S. locations. This may be complicated by service members seeking care outside oversees DOD facilities. Future studies could examine influenza vaccination in DOD locations outside the continental U.S. versus U.S. populations. Regardless, the high influenza hospitalization rates in recruits should influence vaccine priority distribution strategies in the future. Areas of additional study need to evaluate factors associated with hospitalizations in the recruit setting and within the Marine Corps.

This study has several limitations. First, influenza hospitalizations were identified using ICD-10-CM (International Classification of Diseases, 10th Revision, Clinical Modification) billing code data, which is dependent on correct coding during inpatient stay and completeness. Inpatient diagnostic coding is entered by nosologists, however, which should ensure higher coding accuracy. The DMSS also has near-complete capture of all ACSM data, including outsourced data in addition to military hospitals and clinics.

Another limitation is the completeness of the laboratory data. Only laboratory testing requested by a military medical facility is captured in these data. This limitation could lead to an under-estimation of hospitalization rates; however, inclusion of ICD-10-CM hospitalization data should cover this gap. The laboratory data also do not indicate if a hospitalization was specifically for influenza, only that the individual testing positive for influenza was hospitalized, which could over-estimate the number of hospitalizations due to influenza. Data evaluating the influenza vaccine performance could not be determined against type or lineage of circulating virus. The incidence of hospitalization was low, along with a small unvaccinated population; thus, this study did not have adequate power to calculate valid vaccine effectiveness estimates.

Although influenza hospitalizations are relatively rare in this population, likely due to the influenza vaccine requirements for service members, these results identify subpopulations within ACSMs at higher risk for severe influenza infections. DOD policies and vaccine distribution should consider these findings to ensure the health and readiness of U.S. service members.

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The Association Between Body Mass Index, Physical Fitness and COVID-19 Hospitalization Among Male Active Duty U.S. Army Soldiers, May 2020–November 2021

Jacob D. Smith, MPH; Joseph R. Pierce, PhD; Anthony Marquez, MPH; Ryan Steelman, MPH; Markku A. Malmi, PhD; Michelle Canham-Chervak, PhD; John F. Ambrose, PhD

Few studies have investigated body mass index (BMI) and physical fitness factors related to coronavirus disease (COVID)-19 hospitalizations among U.S. active duty service members. This investigation examined associations between measures of physical fitness, BMI, and Army physical fitness test (APFT) performance with COVID-19 hospitalizations of U.S. Army active duty soldiers. From May 2020 through November 2021, 13,074 male soldiers were diagnosed with COVID-19 (90 hospitalized, 12,984 non-hospitalized) who also had an APFT and BMI record no more than 9 months from the COVID-19 diagnosis date. Female soldiers were excluded due to insufficient numbers of COVID-19 hospitalizations. In adjusted logistic regression models controlling for race and ethnicity as well as comorbidities, and including age, BMI, and their interactions, both BMI (adjusted odds ratio [aOR] 1.07; 95% CI 1.01, 1.14; p=0.021), and the age and BMI interaction were statistically significant (aOR 1.01; 95% CI 1.00, 1.02; p=0.004). Each additional year of age amplified the odds of hospitalization by an additional 1% for every 1 unit increase in BMI. Development and maintenance of a healthy body weight may reduce likelihood of COVID-19 hospitalization and sustain individual and unit health and medical readiness.

What are the new findings?

For male U.S. Army active duty soldiers, the association between having a higher BMI and COVID-19 hospitalization was amplified by age, indicating about a 1% increase in the odds of hospitalization per BMI unit for each additional year of age.

What is the impact on readiness and force health protection?

Maintaining a healthy body weight may reduce the risk of COVID-19 related hospitalization for military personnel. The U.S. Army's Holistic Health and Fitness Program is one example of a comprehensive health program established to simultaneously enhance several facets of military health and fitness.

Although the U.S. Centers for Disease Control and Prevention (CDC) has identified well-established risk factors—such as age, sex, race, comorbidities, vaccination status—for coronavirus disease (COVID)-19 hospitalization within the general U.S. population, limited research has explored the contributing factors specific to U.S. active duty service members.[1,2]

Obesity (BMI ≥ 30 kg/m^2) is perhaps the most common comorbidity associated with COVID-19 severity, but obesity is related to several other chronic conditions including hypertension, type 2 diabetes, cardiovascular disease, lung disease, and sleep apnea, all of which have been independently associated with severe COVID-19 disease.[3-7] Additionally, overweight (BMI 25.0–29.9 kg/m^2) or obesity increase risk of respiratory symptoms, such as shortness of breath, often associated with severe COVID-19 outcomes.[4,6,8] Service members are estimated to have higher overweight prevalence and lower obesity prevalence compared to the general U.S. population, with similar trends of higher overweight prevalence with older age.[9]

A 2021 CDC *Morbidity and Mortality Weekly Report* added further evidence that a higher BMI increases risk of severe COVID-19 outcomes (e.g., hospitalization, intensive care unit hospitalization, or death) in the general public.[4] Epsi et al. (2021) reported that obesity was correlated with COVID-19 severity in a study of Military Health System (MHS) beneficiaries, in which active duty service members comprised over 50% of the study population.[3] Early in the pandemic, studies described comorbidities associated with positive COVID-19 cases in the U.S. Army active duty population, and included obesity diagnosis codes in the medical records. Studies have yet to examine associations with BMI values obtained from periodic body composition assessments, such as the Army's Digital Training Management System (DTMS) or vital records associated with medical encounters.[1,2]

The active duty military population tends to be more physically fit, younger, and healthier (i.e., 'the healthy soldier effect' or 'healthy worker effect') compared to the general U.S. population due to accession requirements for health, ready access to medical care, and stringent standards of physical fitness and body composition.[10-12] The current U.S. Army *Field Manual*, volume 7-22, *Holistic Health and Fitness*, describes the Holistic Health and Fitness (H2F) Program that prescribes physical readiness training at least 5 to 6 times per week for a total of 5 to 7.5 hours in addition to rigorous fitness standards.[13]

Physical activity is 1 of 4 main modifiable risk factors identified by the CDC

to reduce risk of some chronic diseases, which have been associated with severe COVID-19 outcomes.[6,14] Regular physical activity is generally associated with improved immune response, reduction in comorbid conditions, and reduction in systemic inflammation.[15,16] Regular physical activity has also been shown to reduce susceptibility to viral infection; however, this is dependent on meeting guidelines for exercise volume and intensity.[17] Greater cardiorespiratory fitness may provide improved pro-inflammatory responses and increased antiviral host responses post-infection.[15,16] A meta-analysis of almost 2 million medical records demonstrated a reduction in risk of COVID-19 infection, hospitalization, and mortality for individuals who participated in regular physical activity (e.g., 500 metabolic equivalent [MET]-minutes per week, where 1 MET equals resting energy expenditure and MET-minutes is the product of METs achieved and task duration) compared to individuals who were inactive (0 MET-minutes per week).[18]

While prior studies have compared pre- and post-pandemic impacts on physical activity and BMI, few studies have described how physical fitness and BMI, prior to COVID-19 diagnosis, affected COVID-19 hospitalizations.[18-21] One large retrospective study in 2020 found that physically inactive patients diagnosed with COVID-19 were significantly more likely to experience severe COVID-19 outcomes including hospitalization, intensive care unit (ICU) admission, or death.[21] This report describes associations between prior BMI and prior physical fitness performance with COVID-19 hospitalization while adjusting for age, race and ethnicity, vaccination status, and comorbidities.

Methods

Study population

The population for this retrospective cohort study included U.S. Army active duty soldiers with measured heights and weights and either 1) documented history of initial COVID-19 or 2) history of initial COVID-19 hospitalization from May 1, 2020 through November 30, 2021. (See **Figure 1** for analysis population exclusions.) The beginning of the period was selected to capture the widespread use of the ICD-10-CM (International Classification of Diseases, 10th Revision, Clinical Modification) U07.1 diagnosis code for COVID-19. The end of the period was selected to capture cases before the initial wave of the Omicron variant, in December 2021.

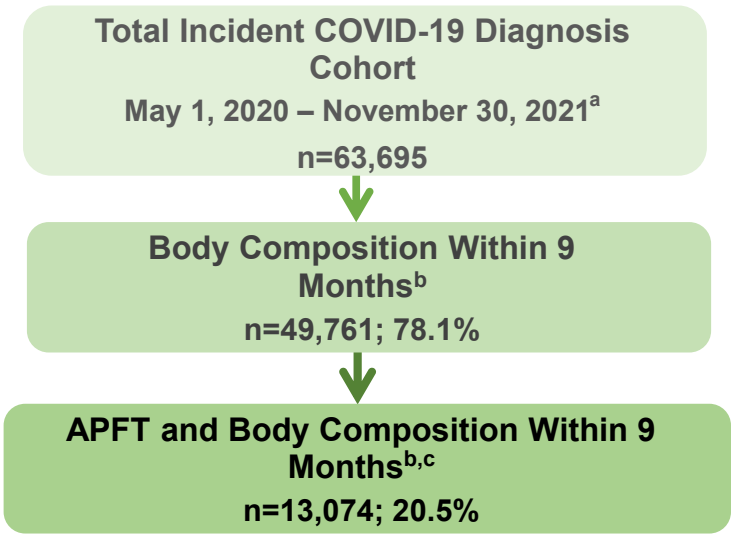
Administrative medical data were obtained in December 2022 from electronic health records in the Military Health System Data Repository (MDR), and reportable medical event data were obtained from the Disease Reporting System internet (DRSi). The MDR is one of the most robust centralized sources of Department of Defense (DOD) health care data. MDR data utilized for this report included inpatient and outpatient medical encounters, immunizations, laboratory results, and pharmacy records.

COVID-19 hospitalizations were included if the first 2 positions of the diagnostic codes in the inpatient medical records contained 1 of the COVID-19 ICD-10-CM diagnosis codes **(Table 1)** and occurred within 30 days of the initial COVID-19 diagnosis or positive SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) polymerase chain reaction (PCR) laboratory result or DRSi medical event report.[2,22-25] Non-hospitalized COVID-19 encounters were defined by a COVID-19 ICD-10-CM diagnosis code **(Table 1)** in the first 2 diagnostic positions, a positive SARS-CoV-2 PCR laboratory result, or a confirmed DRSi case without a related inpatient record.

Vaccination status at the date of COVID-19 diagnosis was obtained from MDR immunization, outpatient, and pharmacy data using 'CVX', 'CPT', and 'NDC' codes. Soldiers completing a primary COVID-19 vaccination series were defined as those who had received the second dose of a 2-dose primary vaccination series or a single dose of a 1-dose primary vaccine product 14 days or more prior to a COVID-19 encounter. Soldiers with 1 dose of a 2-dose primary vaccination series were categorized as 'partially vaccinated', and others were categorized as 'unvaccinated'.

A soldier was considered to have a comorbidity if a medical encounter contained an ICD-10-CM diagnosis code for that condition in any diagnosis position

FIGURE 1. Analysis Population Exclusions, Male Active Duty U.S. Army Soldiers with Incident COVID-19 Diagnosis, BMI and APFT, May 2020–November 2021



[a] Females excluded due to low number of hospitalizations (n=10), after obstetric-related hospitalizations removed.
[b] BMI>9 months of COVID-19 event.
[c] Excludes APFT>9 months of COVID-19 event.

TABLE 1. ICD-10-CM Diagnosis Codes Utilized to Identify COVID-19 Hospitalizations

Description	ICD-10-CM
Coronavirus, unspecified	B34.2
SARS-associated coronavirus as the cause of disease classified elsewhere	B97.21
Other coronavirus as the cause of diseases classified elsewhere	B97.29
Acute nasopharyngitis; common cold	J00
Acute upper respiratory infection; unspecified	J06.9
Pneumonia due to SARS-associated coronavirus	J12.81
Pneumonia due to coronavirus disease 2019	J12.82
Other viral pneumonia	J12.89
Viral pneumonia unspecified	J12.9
Pneumonia due to other specified infectious organism	J16.8
Pneumonia in diseases classified elsewhere	J17
Bronchopneumonia, unspecific organism	J18.0
Lobar pneumonia, unspecified organism	J18.1
Other pneumonia, unspecified organism	J18.8
Pneumonia, unspecified organism	J18.9
Acute bronchitis due to other specified organisms	J20.8
Acute bronchitis, unspecified	J20.9
Unspecified acute lower respiratory infection	J22
Bronchitis, not specified as acute or chronic	J40
Acute respiratory distress syndrome	J80
Idiopathic interstitial pneumonia not otherwise specified	J84.111
Acute respiratory failure	J96.0
Cough	R05
Dyspnea	R06.0
Dyspnea, unspecified	R06.00
Shortness of breath	R06.02
Acute respiratory distress	R06.03
Other forms of dyspnea	R06.09
Anosmia	R43.0
Aguesia	R43.2
Fever, unspecified	R50.9
2019-nCoV acute respiratory disease, COVID-19, virus identified	U07.1

Abbreviations: ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification; COVID-19, coronavirus disease 2019; SARS, severe acute respiratory syndrome; 2019-nCoV, 2019 novel coronavirus.

from January 1, 2019 and the date of the initial positive COVID-19 diagnosis. Comorbidities were selected using Clinical Classifications Software Refined (CCSR) categories from diagnostic codes similar to other research by the CDC, with a retrospective review period through January 1, 2019.[4,26,27] CCSR categories used included hypertension (CIR007, CIR008), coronary atherosclerosis and other heart disease (CIR011), chronic kidney disease (GEN003), diabetes (END002, END003), neoplasms (CIR categories beginning with 'NEO'), chronic obstructive pulmonary disease and bronchiectasis (RSP008), and sleep wake disorders (NVS016).[4,26,27]

Active duty soldier demographics (i.e., service, component, age, sex, race and ethnicity) were obtained in December 2022 from Defense Manpower Data Center (DMDC) personnel rosters. Age was calculated at the COVID-19 encounter date by date of birth. Race and ethnicity were categorized, based on data available in DMDC, as 1) non-Hispanic White—the reference population—2) non-Hispanic Black, 3) Hispanic, or 4) 'other' including those of Asian, Native Hawaiian/Pacific Islander, American Indian / Alaskan Native, or other race or ethnicity. BMI (displayed as kg/m^2) was calculated using height (inches) and weight (pounds) closest to the initial COVID-19 encounter date using the formula (weight [lb] / height $[in]^2$) x 703). Measurements were recorded during periodic height and weight checks by unit personnel in Defense Training Management System (DTMS) body composition records, supplemented by MDR vital records recorded during medical encounters when no DTMS record was available. Records were included if the BMI measurement was no more than 9 months prior to the documented COVID-19 diagnosis date.

DTMS data for the Army physical fitness test (APFT) were used because those data were more readily available during the investigation period; the Army combat fitness test (ACFT) was not yet the U.S. Army fitness test of record. The APFT assessed physical fitness through performance on 3 timed events: 1) 2-minute push-ups, 2) 2-minute sit-ups, and 3) a 2-mile run. APFT event data were retained if the record occurred no more than 9 months prior to the initial COVID-19 diagnosis date, were considered 'for record', and each of the 3 events contained plausible values recorded (e.g., push-ups and sit-ups of 1-150 repetitions, 2-mile run times of 9.5–30 minutes). Implausible values accounted for less than 0.1% of all records.

Exclusions

Records were excluded if a soldier had a history of COVID-19 prior to the investigation start date, as identified via DRSi or the medical record, or were non-active duty (including activated National Guard or reserve). Female service members were excluded from the analysis due to an insufficient number (n=10) of hospitalizations after obstetric-related admissions were removed.

Statistical analysis

Differences in COVID-19 hospitalization by categorical variables were explored with chi-square tests; continuous variables were explored using univariate logistic regression. Crude and adjusted logistic regression models were fit to estimate odds ratios (ORs) and associated 95% confidence intervals (CIs). Adjusted logistic regression models used the outcome of COVID-19 hospitalization and age and BMI as main predictors, controlling for covariates that included race and ethnicity, vaccination status, comorbidities, and physical fitness characteristics. An interaction term between age and BMI was also included in the model.

Non-linearity was assessed using empirical logistic plots and the functional form with cumulative residual plots. When non-linearity was detected, models were fit as a linear term, polynomial degree, and restricted cubic splines, and the fit (i.e., AIC) of the linear term with the non-linear term was compared. Initial covariate selection was *a priori*, considering both linear and non-linear terms for each variable, as appropriate. Variables were excluded if the non-linear term did not improve the model fit compared to the linear term. Variables with less than 15 observations per category were excluded. There was strong evidence of non-linearity among the 3 APFT variables. Even after fitting different models with various functional forms of the 3 APFT variables, the model fit did not improve, and the APFT variables were omitted from the adjusted model. The final adjusted models included racial and ethnic group, age, BMI, comorbidities, and an interaction between age and BMI. Alpha levels were set to 0.05. Analyses were conducted using SAS, version 9.4 (SAS Institute Inc., Cary, NC).

Results

From May 1, 2020 through November 30, 2021, a total of 13,074 unique male Army active duty soldiers were identified as incident COVID-19 cases with a documented BMI and complete 3-event APFT no more than 9 months prior to the COVID-19 encounter date **(Figure 1)**. Women were excluded from the analysis because only 10 hospitalizations of female soldiers for COVID-19 occurred, which was below the minimum required for analysis.

Table 2 summarizes the baseline demographic, physical fitness, and body composition characteristics of this cohort. The average male soldier was 26.5 years old (standard deviation [SD] 6.0) with a BMI of 26.6 (SD 3.4). Those male soldiers performed an average of 63.6 push-ups

TABLE 2. Characteristics of COVID-19-Hospitalized Versus Non-Hospitalized Male Active Duty U.S. Soldiers, May 2020–November 2021

			COVID-19-related Outcome				
	Total		Hospitalized		Non-Hospitalized		*p*-value
Total, *n*	13,074		90		12,984		
Continuous Variables							
Age, *y*							0.004
Mean ± SD	26.5 ± 6.0		28.3 ± 7.1		26.5 ± 6.0		
Median (IQR)	25.0 (22.0, 29.0)		27.0 (22.0, 34.0)		25.0 (22.0, 29.0)		
BMI (kg/m^2)							<0.001
Mean ± SD	26.6 ± 3.4		27.9 ± 4.0		26.6 ± 3.4		
Median (IQR)	26.3 (24.3, 28.7)		28.0 (25.0, 30.9)		26.3 (24.3, 28.7)		
APFT push-ups (repetitions)							0.189
Mean ± SD	63.6 ± 12.9		61.8 ± 12.2		63.6 ± 12.9		
Median (IQR)	65.0 (54.0, 74.0)		62.5 (55.0, 71.0)		65.0 (54.0, 74.0)		
APFT sit-ups (repetitions)							0.003
Mean ± SD	67.3 ± 10.9		63.9 ± 9.8		67.3 ± 10.9		
Median (IQR)	67.0 (60.0, 76.0)		64.0 (57.0, 71.0)		67.0 (60.0, 76.0)		
APFT 2-mile run (minutes)							0.060
Mean ± SD	14.9 ± 1.5		15.2 ± 1.3		14.9 ± 1.5		
Median (IQR)	14.8 (14.0, 15.7)		15.4 (14.3, 16.1)		14.8 (13.9, 15.7)		
Categorical Variables							
	No.	%	No.	%	No.	%	
Race and ethnicity							0.066
White, non-Hispanic	6,714	51.4	41	45.6	6,673	51.4	
Black, non-Hispanic	2,826	21.6	27	30.0	2,799	21.6	
Hispanic	2,707	20.7	13	14.4	2,694	20.7	
Other	827	6.3	9	10.0	818	6.3	
Vaccination status							0.981
Unvaccinated	12,541	95.9	86	95.6	12,455	95.9	
Partial	124	0.9	1	1.1	123	0.9	
Full	409	3.1	3	3.3	406	3.1	
Comorbidities							0.006
No history	11,952	91.4	75	83.3	11,877	91.5	
History	1,122	8.6	15	16.7	1,107	8.5	

Abbreviations: *n*, number; *y*, years; SD, standard deviation; IQR, interquartile range; No., number; kg, kilogram; m, meter; APFT, Army physical fitness test.

(SD 12.9), 67.3 sit-ups (SD 10.9), and completed the 2-mile-run in 14.9 minutes (SD 1.5) on the APFT **(Table 2)**. The cohort was primarily non-Hispanic White (51.4%), unvaccinated (95.9%), with no histories of the selected comorbidities (91.4%) **(Table 2)**. Compared with soldiers who were hospitalized, those not hospitalized were younger, with lower BMI, performed more sit-ups, and had a lower proportion of comorbidities **(Table 2)**. Only 3% of soldiers were fully vaccinated during the study period, and just 4 of those were hospitalized; consequently, vaccination status was not incorporated in the adjusted model.

In unadjusted analyses, BMI (OR 1.11; 95% CI 1.05, 1.17), age (OR 1.04; 95% CI 1.01, 1.08), sit-ups (OR 0.97; 95% CI 0.95, 0.99), and comorbidities (OR 2.15; 95% CI 1.23, 3.75) were each significantly associated with COVID-19-related hospitalization **(Table 3)**.

The final adjusted model included race and ethnicity, age, BMI, comorbidities, and the interaction term for age (mean-centered at 26.5 years old) and BMI (mean-centered at 26.6 kg/m^2). In the adjusted model, the main effect of age was not statistically significant (aOR 1.01; 95% CI 0.98, 1.05), whereas the main effect of BMI was significant, with an additional 7% increase in the adjusted odds (aOR 1.07; 95% CI 1.01, 1.14) **(Table 4)**. The age and BMI interaction was significant, for each additional year of age, the adjusted odds with a 1-unit increase in BMI is amplified by an additional 1%, and conversely each additional BMI unit amplifies the age effect by an additional 1% **(Table 4, Figure 2)**.

TABLE 3. Unadjusted Association Between BMI, APFT and COVID-19 Hospitalization, Male Active Duty U.S. Army Soldiers, May 2020–November 2021

	No.	OR	95% CI Lower Limit	95% CI Upper Limit	*p*-value
Total	13,074				
Continuous variables[a]					
BMI (kg/m^2)	13,074	1.11	1.05	1.17	<0.001
Age, *y*	13,074	1.04	1.01	1.08	0.004
APFT push-ups, *n*	13,074	0.99	0.97	1.01	0.189
APFT sit-ups, *n*	13,074	0.97	0.95	0.99	0.003
APFT 2-mile run (min)	13,074	1.12	1.00	1.26	0.060
Race and ethnicity					
White, non-Hispanic	6,714	Reference	—	—	—
Black, non-Hispanic	2,826	1.57	0.96	2.56	0.070
Hispanic	2,707	0.79	0.42	1.47	0.449
Other	827	1.79	0.87	3.7	0.115
Comorbidities					
History	1,122	2.15	1.23	3.75	<0.001
No history	11,952	Reference	—	—	—
Vaccination status					
Unvaccinated	12,541	Reference	—	—	—
Partial	124	1.18	0.16	8.52	0.871
Full	409	1.07	0.34	3.4	0.908

Abbreviations: BMI, body mass index; APFT, Army physical fitness test; COVID-19, coronavirus disease 2019; No., number; OR, odds ratio; CI, confidence interval; kg, kilogram; m, meter; *y*, years; *n*, number; min, minute.
[a] Continuous variables were modeled per 1 unit increase unless otherwise specified.

Discussion

This study investigated the association between BMI, physical fitness, and COVID-19 hospitalizations in a subset of U.S. Army active duty soldiers with an APFT and body composition measures no more than 9 months prior to a COVID-19 medical encounter, either hospitalized or non-hospitalized. Prior physical fitness, as measured by APFT performance, in this cohort was not associated with COVID-19 hospitalization. In the adjusted logistic regression model, at the average age, each 1 unit increase in BMI increased odds of hospitalization by 7%. Additionally, there was significant interaction between BMI and age, with an additional 1% increase in odds of hospitalization for each unit increase in either BMI or age.

The lack of association between prior physical fitness and COVID-19 hospitalization found in this study is inconsistent with some studies which suggested that higher levels of prior physical fitness could lessen likelihood of COVID-19 hospitalization.[18,28-30] Differences in the methods that defined and measured physical fitness, along with the study populations, complicate direct comparisons between these results and those prior reports. Other papers have evaluated self-reported physical fitness or self-reported physical activity, which may introduce self-reporting and recall bias.[21,29] One report evaluating maximal exercise capacity, via peak METs, used fitness tests up to 2 years prior to SARS-CoV-2 infection and included a population unrepresentative of the U.S. population with a significantly higher hospitalization rate compared to other reports.[30]

At least 1 study of U.S. service members identified self-reported fitness and exercise capacity decrements following SARS-CoV-2 infection.[31] A specific threshold of physical fitness could potentially reduce hospitalization duration or intensity. Alternatively, physical fitness may reduce symptom duration or intensity during a non-hospitalized infection, which this report did not assess. This could also be due to the multifactorial nature of COVID-19 severity, in which other factors such as pre-existing health conditions, age, immune response, and genetic predispositions play critical roles. Additionally, the 'healthy warrior effect', attributed to rigorous physical and medical screening processes required for military service, health care access, and employment,

may also positively affect clinical outcomes.[10] Active duty soldiers who are generally healthier and more physically fit may experience lower morbidity, which could have influenced this study's observed associations. Soldiers participate in regular physical activity to maintain required physical fitness standards, and several studies and a meta-analysis found that regular physical activity was associated with lower risk of COVID-19 infection, hospitalization, severe illness, and death.[18-21]

The significant interaction found in this study between BMI and age underscores the compounded risk that higher BMI and increasing age pose for hospitalization. This finding aligns with existing literature that has identified obesity as a major risk factor for hospitalization, likely due to the association and interaction of COVID-19 with comorbidities such as hypertension, diabetes, and cardiovascular diseases.[2,4,32,33] Other reports that examined changes in service member BMI during the same period observed a significant increase in obesity, although the increases tended to be largest among service members younger than age 20 years.[34] The additional 1% increase in hospitalization risk per unit increase in BMI with age in this study suggests that some older individuals with higher BMI are particularly vulnerable, highlighting the need for targeted interventions in this group. This report differed from other studies that primarily relied on an ICD-10-CM diagnosis code to indicate obesity rather than measured heights and weights to calculate BMI.[1,2] This approach enabled us to better understand the relationship between BMI, age, and COVID-19-related hospitalization observed in our models.

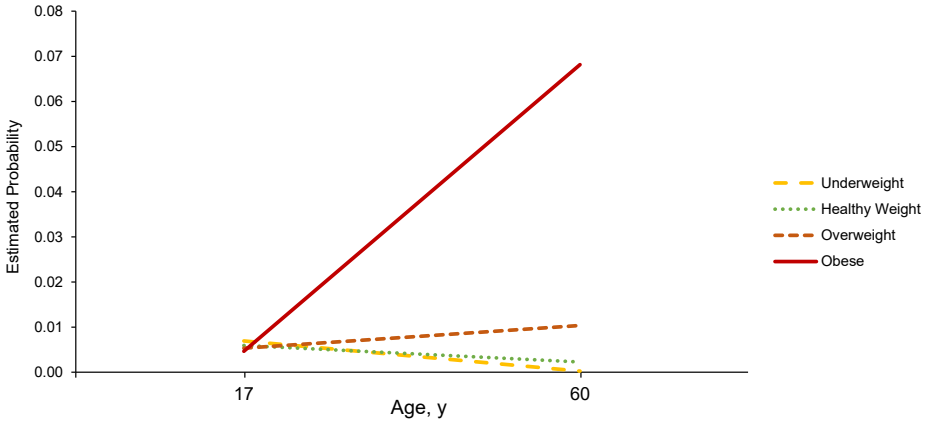
This study has several limitations. Soldiers with a BMI and APFT record no more than 9 months from the COVID-19 diagnosis date limited the sample size to 20.5% of the original population, which could affect the generalizability of the results **(Figure 1)**. The sample size available for soldiers with an APFT was considerably lower during this period, primarily due to fitness testing pauses during the initial stages of the COVID-19 pandemic (i.e., "lockdowns"). As the pandemic continued, the ACFT was gradually phased in, until established as the fitness test of record on October 1, 2022, resulting in fewer available APFT results. The ACFT data were incomplete and unavailable for use during the reporting period. It is also possible that ACFT performance may demonstrate different associations with COVID-19 hospitalizations than the APFT, given that it assesses additional physical fitness components (e.g., anaerobic fitness, muscular strength and power); ACFT results were not widely available during the period investigated, however. Because soldiers are automatically enrolled in TRICARE, the number of cases and related characteristics may have been under-estimated if soldiers sought care outside of the MHS TRICARE network or were unreported in DRSi. Vaccination

TABLE 4. Adjusted Association Between BMI and COVID-19 Hospitalization, Male Active Duty U.S. Army Soldiers, May 2020–November 2021

	No.	aOR	95% CI Lower Limit	95% CI Upper Limit	*p*-value
Total	13,074				
Continuous variables[a]					
Age[b], *y*	13,074	1.01	0.98	1.05	0.451
BMI[b] (kg/m^2)	13,074	1.07	1.01	1.14	0.021
BMI x age[b]	13,074	1.01	1.00	1.02	0.004
Race and ethnicity					
White, non-Hispanic	6,714	Reference	—	—	—
Black, non-Hispanic	2,826	1.50	0.92	2.45	0.108
Hispanic	2,707	0.73	0.39	1.37	0.330
Other	827	1.63	0.79	3.4	0.187
Comorbidities					
History	1,122	1.32	0.69	2.5	0.401
No history	11,952	Reference	—	—	—

Abbreviations: BMI, body mass index; COVID-19, coronavirus disease 2019; No., number; aOR, adjusted odds ratio; CI, confidence interval; *y*, years; kg, kilogram; m, meter.
[a] Continuous variables were modeled per 1 unit increase unless otherwise specified.
[b] BMI x age results are mean-centered (mean BMI 26.6, mean age 26.5).

FIGURE 2. BMI and Age Interaction-Adjusted Probabilities for COVID-19 Hospitalization, Male Active Duty U.S. Army Soldiers, May 2020–November 2021



[a] Presented values for each weight category contain the middle value for each commonly reference BMI category from CDC to illustrate interaction between age and BMI
[b] Adjusted model included racial and ethnic group, age (mean-centered at 26.5 years), BMI (mean-centered at 26.6), comorbidity history, and interaction of age and BMI
[c] Adjusted model reference category (not hospitalized)

status may have been under-estimated due to the accessibility of vaccinations at out-of-network facilities, such as pharmacies or mass vaccination sites.

COVID-19 hospitalizations may not be entirely preventable, but the results of this analysis suggest that risk is higher among military personnel with higher BMI and greater age. Resources available to soldiers such as H2F and Armed Forces Wellness Centers can provide individual guidance to maintain or improve BMI.

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Adverse Pregnancy Outcomes Following COVID-19 Infection or Vaccination in Active Component U.S. Military Service Women, 2021–2023

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Prior studies have found a higher risk of adverse pregnancy outcomes due to COVID-19 infection; however, recent literature documents few adverse impacts to younger and otherwise healthy populations, but with limited information about military members. The study population comprised active component service women with a singleton delivery between 2021 and 2023. Adverse pregnancy outcomes were evaluated by COVID-19 infection and vaccination history, as well as by demographics and pre-existing co-morbidities. During the surveillance period, 39,355 active component U.S. service women had a singleton delivery. After controlling for potential confounders in the adjusted logistic regression analysis, COVID-19 infection during pregnancy was associated with eclampsia (OR 2.18, $p<0.05$) and antepartum hemorrhage (OR 1.11, $p<0.05$), and COVID-19 infection prior to the start of pregnancy was associated with antepartum hemorrhage (OR 1.18, $p<0.05$). In comparison, after adjustment, COVID-19 vaccination during pregnancy and prior to start of pregnancy was not associated with increased odds of any adverse pregnancy outcome in active component service women. COVID-19 vaccines are recommended for pregnant women by the American College of Obstetricians and Gynecologists and, previously, the U.S. Centers for Disease Control and Prevention.

What are the new findings?

This analysis found no significant difference in adverse pregnancy outcomes among those who received a COVID-19 vaccine prior to delivery compared to women who did not, between 2021 and 2023. COVID-19 infection prior to start of pregnancy was associated with antepartum hemorrhage whereas COVID-19 infection during pregnancy was associated with eclampsia and antepartum hemorrhage.

What is the impact on readiness and force health protection?

The findings from this analysis suggest there is a benefit to vaccinating pregnant active component service women against COVID-19. There was no increased risk of these adverse pregnancy outcomes associated with receipt of a COVID-19 vaccine in this study population. In contrast, COVID-19 infection may be associated with increased occurrence of some adverse pregnancy events.

COVID-19 infection during pregnancy has been associated with an increased risk of certain pregnancy complications such as pre-eclampsia and pre-term birth.[1,2] Severity of COVID infection may also play a role, as more severe infections have been more strongly linked to pre-term premature rupture of membranes. [3] The increased risk for stillbirth and pre-eclampsia could be due to inflammatory changes affecting the placenta, and the need for intensive care associated with severe disease could result in the increased rates of pre-term delivery.[4]

In 1 cohort study of electronic health care records in southeastern Texas, COVID-19 infection before and during pregnancy were associated with spontaneous abortion.[5] Other studies, however, found no association between COVID-19 infection and risk of miscarriage.[6] One matched retrospective cohort study of over 170,000 pregnancies found a 12% higher risk for gestational diabetes following COVID-19 infection during the first 21 weeks of pregnancy.[7] This association could be due to inflammation increasing insulin resistance, damage to the pancreas, or shared risk factors for more severe COVID-19 infection.[8,9]

In contrast, studies of COVID-19 vaccination in pregnant women have not revealed increased risk of adverse maternal or neonatal outcomes including stillbirth, pre-term birth, hypertensive disorders, congenital malformations, or other conditions due to vaccination.[10-12] In fact, some studies have indicated that COVID-19 vaccination during pregnancy can reduce risk of stillbirth and pre-term birth.[13,14] Consequently, during the pandemic the U.S. Centers for Disease Control and Prevention (CDC) recommended that all pregnant patients remain up-to-date with COVID-19 vaccines before and during pregnancy.[15] The American College of Obstetricians and Gynecologists also recommends that patients receive an updated COVID-19 vaccine or 'booster' at any point during pregnancy.[16]

Healthy women infected with COVID-19 during pregnancy primarily experience mild illness with limited or no significant adverse effects on the mother or neonate.[4,17] Women in active duty military service must maintain physical fitness standards and represent a relatively young and healthy population; as a result, it would be

expected that COVID-19 infection would not increase risk of adverse pregnancy outcomes, in most situations. The objective of this study was to evaluate associations between COVID-19 infection during pregnancy and certain adverse pregnancy outcomes in active component U.S. service women who had a delivery between 2021 and 2023, with a review of any change in this association for women who received a COVID-19 vaccine during or prior to their pregnancy start dates. This study focused on adverse conditions that would be coded in the maternal record, since data from neonatal medical records were not available.

Methods

Study population

This cross-sectional study used inpatient and outpatient direct and purchased care medical encounter records from the Defense Medical Surveillance System (DMSS). The study population included U.S. active component service women who had a singleton delivery, either live or still birth outcome, from January 1, 2021 through December 31, 2023. International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) codes were used to determine singleton live (Z370) or still births (Z371). The first birth event in this surveillance period was used if a woman had multiple delivery events during the period. Deliveries were included if a woman was on active component duty during the 280 days preceding the delivery date. The pregnancy start date was calculated as the date 280 days prior to the delivery event.

Outcomes

The outcomes for this study were specific adverse pregnancy events diagnosed within 280 days preceding the first singleton delivery event during the surveillance period. Outcomes included antepartum hemorrhage or threatened abortion (ICD-10: O20* or O46*), gestational diabetes (O24.4*), eclampsia (O15*), pre-eclampsia (O14*), pre-term labor or delivery (O60*), premature rupture of membranes (O42*), and stillbirth (Z37.1). For the gestational diabetes analysis, individuals were excluded from the study population if they had an inpatient or outpatient diagnosis of ICD-10: E10* (type 1 diabetes), E11* (type 2 diabetes), O24.4* (gestational diabetes), or O24.9* (unspecified diabetes) prior to the start of pregnancy.

Exposures of interest

The exposures of interest in this study were COVID-19 infection before or during pregnancy and COVID-19 vaccination before or during pregnancy. The Armed Forces Health Surveillance Division (AFHSD) maintains a master list of COVID-19 cases for active component service members. These COVID-19 cases were identified from reports of positive antigen, polymerase chain reaction (PCR), and confirmed or probable tests that were entered into the Disease Reporting System internet (DRSi) prior to January 2023, and Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENSE) positive antigen and PCR tests that occurred on or after January 2023.

Anyone with multiple positive COVID-19 tests or reports was counted as 1 infection if both tests were within a 90-day period, consistent with guidelines from the CDC.[18] A woman was categorized as having a COVID-19 infection during pregnancy if there was a documented COVID-19 infection within 280 days prior to her delivery event, and categorized as having COVID-19 infection prior to pregnancy if it occurred more than 280 days prior to the delivery event.

DMSS immunization data were utilized to determine COVID-19 vaccination status. A single dose of any of the following CVX codes met criteria for receiving a COVID-19 vaccination: 207, 208, 212, 221, 217, 211, 229, 300, 309, 312, 313, 510, 511, 502, or 210.[19] These data are provided to DMSS from the MHS Information Platform (MIP) Immunizations Tracking System. DMSS only receives immunizations data for U.S. military service members.

Covariates

Covariates for this study included age, race and ethnicity, service branch, number of prior deliveries, and comorbidities diagnosed prior to the start of the pregnancy. Electronic Periodic Health Assessment (PHA) data were reviewed to determine a service member's self-reported smoking status within the 2 years prior the start of the associated pregnancy. Smoking was used as a covariate for its documented link to adverse maternal health outcomes.[13] Other lifestyle factors were not readily available from the PHA and thus were not included for covariate analysis. Pre-existing comorbidities were identified by having a diagnosis of that condition in any diagnostic position of an inpatient or outpatient encounter within 2 years prior to the delivery date **(Table 1)**. For assessment of the number of prior deliveries, 1 delivery was counted every 280 days (ICD-10 codes Z37*, O80, O82). All births were classified as vaginal or cesarian section (ICD-10: O82* or inpatient procedure codes 10D00; outpatient CPT codes 59510, 59515, 59514, 00850, 00857, 01961, 01963, 01968, 01969; diagnostic group codes 370, 371). Age, race and ethnicity, and service branch were assigned based on demographic data for the member at the time of the delivery event.

Statistical analysis

Pearson chi-square tests were used to assess the relationship between exposures of interest and covariates with the adverse pregnancy outcomes. Adjusted logistic regression models were used to further explore the associations between the exposures of interest and study outcomes that were significant in the crude (unadjusted) analysis. These models adjusted for COVID-19 infection prior to the start of pregnancy, COVID-19 infection during pregnancy, COVID-19 vaccination prior to the start of pregnancy, COVID-19 vaccination during pregnancy, age, race and ethnicity, number of prior deliveries, and any previously diagnosed comorbidity. Covariates were selected for inclusion in the adjusted models based on being exposures of interest or significant potential confounders.

Results

A total of 39,355 active component service women experienced a singleton delivery between January 1, 2021 and December 31, 2023 **(Table 2)**. Of those service women, 29,927 (76.0%) had vaginal deliveries, and 9,428 (24.0%) had cesarean sections. A total of 5,190 (13.2%) of these women had a documented COVID-19 infection during pregnancy, and 6,491 (16.5%) had a COVID-19 infection prior to pregnancy. Among women with an infection prior to the start of pregnancy, the first infection was a median of 233 days (IQR 110-402 days) prior.

A total of 9,236 (23.5%) active component service women received at least 1 COVID-19 vaccine dose during pregnancy, and 22,056 (56.0%) received a dose prior to start of pregnancy. There were 27,685 (70.3%) women who received a vaccine dose on or prior to the delivery event, less than the sum of women (n=31,292) who received at least 1 dose during and prior to start of pregnancy, because some women received a dose both prior to and during pregnancy. The percentage of women who received at least 1 dose by their delivery date increased each calendar year: 30% for deliveries in 2021, 91% for deliveries in 2022, 99% for deliveries in 2023.

Most service women had no documented prior deliveries (69.1%). Most service women were ages 20–34 years (86.9%), while non-Hispanic White service women comprised the largest racial and ethnic group (41.6%). Obesity (11.7%), immune-compromising conditions (11.2%), and metabolic disease (11.1%) were the most commonly diagnosed comorbidities within the 2 years prior to pregnancy.

Without adjusting for any potential confounders, antepartum hemorrhage was the most common adverse pregnancy outcome (20.9%), followed by premature rupture of membranes (15.0%), gestational diabetes (8.3%), pre-eclampsia (8.2%), preterm labor or delivery (7.2%), stillbirth (0.8%), and eclampsia (0.1%) **(Table 3)**. Black, non-Hispanic service women had the highest percentage of pre-eclampsia, eclampsia, antepartum hemorrhage, and stillbirth. Generally, prevalence of adverse pregnancy outcomes tended to be higher among service women with certain pre-existing comorbidities. For example, pre-eclampsia and antepartum hemorrhage were more prevalent among service women with cardiovascular disease. Pre-eclampsia, gestational diabetes, antepartum hemorrhage, and stillbirth were more common among service women with obesity.

In many cases, there was not a significant (p<0.05) difference in prevalence of adverse pregnancy outcomes in service women according to COVID-19 infection or vaccination status, with a few notable exceptions **(Table 3)**. COVID-19 infection during pregnancy was associated with a higher percentage of eclampsia and antepartum hemorrhage; COVID-19 infection prior to start of pregnancy was associated with a higher percentage of antepartum hemorrhage and premature rupture of members; COVID-19 vaccination during pregnancy was associated with lower percentage of antepartum hemorrhage; and COVID-19 vaccination prior to the start of pregnancy was associated with a higher percentage of premature rupture of membranes and a lower percentage of pre-term labor or delivery.

After controlling for potential confounders in the adjusted logistic regression analysis, COVID-19 infection during pregnancy remained significantly and positively associated with eclampsia (OR 2.18, p<0.05) and antepartum hemorrhage (OR 1.11, p<0.05), and COVID-19 infection prior to start of pregnancy remained significantly and positively associated with antepartum hemorrhage (OR 1.18, p<0.05) **(Table 4)**. After adjustment, COVID-19 vaccination prior to start of pregnancy was no longer associated with premature rupture of membranes. COVID-19 vaccination prior to start of pregnancy was, however, inversely associated (OR 0.86, p<0.05) with pre-term labor or delivery.

TABLE 1. ICD-10-CM Codes Utilized to Define COVID-19 Comorbidities

COVID-19 Comorbidities	ICD-10 Codes
Any lung disease	J40*–J99*
Any cardiovascular disease	I05*–I89*, Z95*
Asthma	J45*
Chronic kidney disease	N03*–N16*, N18*–N19*
Chronic liver disease	K70*–K77*, B18*
Chronic lower respiratory disease	J40*–J44*
Chronic neurological disorders	G10*–G40*
Immune-compromising conditions	B20, D55*-D77*, D80*–D89*, Z94*, Z795*, L40*, M04*–M08*, K50*–K52*
Metabolic disease	E08*–E13*, O24*, Z794*, E00*–E07*, E50*–E64*, E84*, E88.81
Mood disorders, depression, schizophrenia	F20*, F30*-F39*
Neoplasms	C00*–D49*
Obesity	E66.0*, E66.1, E66.2, E66.3, E66.8, E66.9, Z68.3*, Z68.4*, O9921*
Substance use disorders including nicotine dependence	F10*–F16*, F17*, F18*–F19*
Tuberculosis	A15*

Abbreviations: ICD-10-CM, International Classification of Diseases, 10th Edition, Clinical Modification; COVID-19, coronavirus disease 2019.
* Indicates all child codes included.

TABLE 2. Demographics of Active Component U.S. Service Women with Singleton Births, 2021–2023

Demographics	Total	
	No.	%
Total	39,355	100
COVID-19 infection during pregnancy		
Yes	5,190	13.2
No	34,165	86.8
COVID-19 infection prior to start of pregnancy		
Yes	6,491	16.5
No	32,864	83.5
COVID-19 vaccination during pregnancy		
Yes	9,263	23.5
No	30,092	76.5
COVID-19 vaccination prior to start of pregnancy		
Yes	22,056	56.0
No	17,299	44.0
Age, *y*		
<20	655	1.7
20–24	13,868	35.2
25–29	12,087	30.7
30–34	8,239	20.9
35–39	3,862	9.8
40+	644	1.6
Race and ethnicity		
White, non-Hispanic	16,351	41.6
Black, non-Hispanic	8,953	22.8
Hispanic	8,784	22.3
Other	4,509	11.5
Unknown	758	1.9
Service branch		
Army	13,522	34.4
Navy	11,183	28.4
Air Force, Space Force	11,020	28.0
Marine Corps	2,777	7.1
Coast Guard	853	2.2
Comorbidities prior to pregnancy start date		
Cardiovascular disease	2,144	5.5
Chronic lower respiratory disease	318	0.8
Asthma	910	2.3
Lung disease	1,621	4.1
Metabolic disease	4,360	11.1
Immune compromising conditions	4,414	11.2
Substance use disorders (including nicotine dependence)	2,025	5.2
Chronic liver disease	217	0.6
Chronic kidney disease	1,003	2.6
Chronic neurological disorders	318	0.8
Neoplasms	3,749	9.5
Obesity	4,613	11.2
Tuberculosis	19	0.1
Mood disorders, depression, schizophrenia	3,891	9.9
Tobacco use (reported on PHA)	4,727	12.0
Prior deliveries, *n*		
0	27,189	69.1
1	9,023	22.9
2+	3,143	8.0

Abbreviations: No., number; COVID-19, coronavirus disease 2019; *y*, years; PHA, Periodic Health Assessment; *n*, number.

Discussion

This study found increased odds of eclampsia and antepartum hemorrhage, which includes threatened abortion or any bleeding during pregnancy, among active component service women with a documented COVID-19 infection during pregnancy. In contrast, COVID-19 vaccination during or prior to start of a pregnancy was not associated with increased odds of any adverse pregnancy outcome, after adjustment for potentially confounding factors. It is important to note that these findings cannot be generalized to the U.S. population, nor to earlier periods during the COVID-19 pandemic when vaccines were not widely available, and pre-existing immunity was low or non-existent. It is possible that by the period of analysis for this study, members of the study population may have already had COVID-19 illness and thereby developed natural immunity, which could not be identified. It is estimated that by June 2021 74% of active component service members had been exposed to COVID-19, either by prior infection or vaccination.[20]

A mandate issued by the U.S. Department of Defense (DOD) on August 24, 2021 required service members to receive a COVID-19 vaccination by December 31, 2021. That requirement was rescinded in January 2023, however, by Section 525 of the National Defense Authorization Act.[21,22] This study concurs with prior research that reveals that receipt of a COVID-19 vaccine prior to or during pregnancy was not associated with any change in adverse pregnancy outcomes, including antepartum hemorrhage and stillbirth.[10-12] The results of this study are also consistent with a recently published article from the DOD's Birth and Infant Health Registry, which found that COVID-19 vaccination was not associated with increased risk for pre-term birth, small size for gestational age, low birth weight, or neonatal intensive care unit admission among active duty service women who gave birth in 2021.[23]

The highest percentage of adverse pregnancy outcomes occurred in Black, non-Hispanic service women, consistent with other research that reveals elevated levels of adverse pregnancy outcomes in this population.[24] This study population differs

TABLE 3. Pregnancy Outcomes, Singleton Births, Active Component U.S. Service Women 2021–2023

Demographics	Gestational Diabetes			Pre-Eclampsia			Eclampsia			Premature Rupture of Membrane		
	No.	%	*p*-value	No.	%	*p*-value	No.	%	*p*-value	No.	%	*p*-value
Total	3,259	8.3		3,230	8.2		53	0.13		5,895	15.0	
COVID-19 infection during pregnancy												
Yes	418	8.1	0.5597	424	8.2	0.9152	13	0.25	0.0146	808	15.6	0.2016
No	2,841	8.3		2,806	8.2		40	0.12		5,087	14.89	
COVID-19 infection prior to start of pregnancy												
Yes	540	8.4	0.8917	554	8.5	0.2927	8	0.12	0.7836	1,036	16.0	0.0153
No	2,719	8.3		2,676	8.1		45	0.14		4,859	14.8	
COVID-19 vaccination during pregnancy												
Yes	810	8.8	0.0589	742	8.0	0.4296	11	0.12	0.6328	1,384	14.9	0.9070
No	2,449	8.2		2,488	8.3		42	0.14		4,511	15.0	
COVID-19 vaccination prior to start of pregnancy												
Yes	1,845	8.4	0.4441	1,798	8.2	0.6514	29	0.13	0.8456	3,405	15.4	0.0040
No	1,414	8.2		1,432	8.3		24	0.14		2,490	14.4	
Age, *y*												
< 20	20	3.1	<.0001	62	9.5	<.0001	3	0.46	0.0547	128	19.5	<.0001
20–24	796	5.8		1,318	9.5		20	0.14		2,146	15.5	
25–29	971	8.1		951	7.9		14	0.12		1,875	15.5	
30–34	845	10.3		553	6.7		6	0.07		1,197	14.5	
35–39	530	13.8		277	7.2		8	0.21		484	12.5	
40 +	97	15.3		69	10.7		2	0.31		65	10.1	
Race and ethnicity												
White, non-Hispanic	1,205	7.4	<.0001	1,290	7.9	<.0001	22	0.13	0.0278	2,310	14.1	<.0001
Black, non-Hispanic	658	7.4		869	9.7		20	0.22		1,297	14.5	
Hispanic	769	8.8		661	7.5		7	0.08		1,446	16.5	
Other	561	12.5		353	7.8		2	0.04		748	16.6	
Unknown	66	8.7		57	7.5		2	0.26		94	12.4	
Service branch												
Army	1,082	8.0	<.0001	1,140	8.4	0.0005	29	0.21	0.0058	2,252	16.6	<.0001
Navy	1,059	9.5		992	8.9		5	0.04		1,548	13.8	
Air Force, Space Force	889	8.1		850	7.7		16	0.15		1,572	14.3	
Marine Corps	151	5.5		191	6.9		3	0.11		392	14.1	
Coast Guard	78	9.2		57	6.7		0	0.00		131	15.4	
Comorbidities prior to pregnancy start date												
Cardiovascular disease												
Yes	192	9.1	0.1730	237	11.0	<.0001	4	0.19	0.5004	261	12.2	0.0002
No	3,067	8.3		2,993	8.0		49	0.13		5,634	15.1	
Chronic lower respiratory disease												
Yes	34	10.9	0.1006	25	7.9	0.8216	1	0.31	0.3800	47	14.8	0.9204
No	3,225	8.3		3,205	8.2		52	0.13		5,848	15.0	
Asthma												
Yes	89	9.9	0.0868	85	9.3	0.2076	1	0.11	0.8366	119	13.1	0.1038
No	3,170	8.3		3,145	8.2		52	0.14		5,776	15.0	
Lung disease												
Yes	162	10.1	0.0083	146	9.0	0.2311	3	0.19	0.5720	217	13.4	0.0666
No	3,097	8.2		3,084	8.2		50	0.13		5,678	15.1	
Metabolic disease												
Yes	490	11.6	<.0001	374	8.6	0.3444	8	0.18	0.3513	583	13.4	0.0016
No	2,769	7.9		2,856	8.2		45	0.13		5,312	15.2	
Immune compromising conditions												
Yes	333	7.6	0.0694	355	8.0	0.6721	7	0.16	0.6457	583	13.2	0.0005
No	2,926	8.4		2,875	8.2		46	0.13		5,312	15.2	
Substance use disorders (including nicotine dependence)												
Yes	196	9.7	0.0192	197	9.7	0.0105	2	0.10	0.6510	330	16.3	0.0881
No	3,063	8.2		3,033	8.1		51	0.14		5,565	14.9	
Chronic liver disease												
Yes	23	10.9	0.1719	15	6.9	0.4859	1	0.46	0.1889	33	15.2	0.9247
No	3,236	8.3		3,215	8.2		52	0.13		5,862	15.0	
Chronic kidney disease												
Yes	93	9.4	0.2307	89	8.9	0.4363	4	0.40	0.0209	145	14.5	0.6386
No	3,166	8.3		3,141	8.2		49	0.13		5,750	15.0	
Chronic neurological disorders												
Yes	37	11.6	0.0311	32	10.1	0.2261	1	0.31	0.3800	47	14.8	0.9204
No	3,222	8.3		3,198	8.2		52	0.13		5,848	15.0	
Neoplasms												
Yes	334	9.0	0.1347	299	8.0	0.5866	4	0.11	0.6234	494	13.2	0.0012
No	2,925	8.2		2,931	8.2		49	0.14		5,401	15.2	
Obesity												
Yes	625	13.7	<.0001	448	9.7	<.0001	7	0.15	0.7365	641	13.9	0.0282
No	2,634	7.6		2,782	8.0		46	0.13		5,254	15.1	
Tuberculosis												
Yes	3	16.7	0.1990	2	10.5	0.7126	0	0.00	0.8728	3	15.8	0.9211
No	3,256	8.3		3,228	8.2		53	0.13		5,892	15.0	
Mood disorders, depression, schizophrenia												
Yes	394	10.2	<.0001	353	9.1	0.0384	10	0.26	0.0284	545	14.0	0.0734
No	2,865	8.1		2,877	8.1		43	0.12		5,350	15.1	
Tobacco use (reported on PHA)												
Yes	446	9.5	0.0021	450	9.5	0.0005	8	0.17	0.4896	735	15.6	0.2418
No	2,813	8.2		2,780	8.0		45	0.13		5,160	14.9	
Prior deliveries, *n*												
0	2,120	7.8	<.0001	2,631	9.7	<.0001	39	0.14	0.0076	4,560	16.8	<.0001
1	802	9.0		430	4.8		5	0.06		1,014	11.2	
2 +	337	10.8		169	5.4		9	0.29		321	10.2	

Note: These findings not adjusted for any potential confounders.
Abbreviations: No., number; COVID-19, coronavirus disease 2019; *y*, years; PHA, Periodic Health Assessment; *n*, number.

TABLE 3 cont. Pregnancy Outcomes, Singleton Births, Active Component U.S. Service Women 2021–2023

Demographics	Pre-Term Labor or Delivery			Antepartum Hemorrhage			Stillbirth		
	No.	%	*p*-value	No.	%	*p*-value	No.	%	*p*-value
Total	2,830	7.2		8,210	20.86		323	0.8	
COVID-19 infection during pregnancy									
Yes	401	7.7	0.1090	1161	22.37	0.0041	45	0.9	0.6914
No	2,429	7.1		7,049	20.63		278	0.8	
COVID-19 infection prior to start of pregnancy									
Yes	442	6.8	0.1929	1,533	23.62	<.0001	56	0.9	0.6815
No	2,388	7.3		6,677	20.32		267	0.8	
COVID-19 vaccination during pregnancy									
Yes	702	7.9	0.0987	1,860	20.08	0.0343	88	1.0	0.1148
No	2,128	7.1		6,350	21.10		235	0.8	
COVID-19 vaccination prior to start of pregnancy									
Yes	1,463	6.6	<.0001	4,606	20.88	0.9043	181	0.8	0.9981
No	1,367	7.9		3,604	20.83		142	0.8	
Age, *y*									
<20	72	11.0	<.0001	163	24.89	<.0001	6	0.9	0.0001
20–24	1,062	7.7		3,127	22.55		106	0.8	
25–29	824	6.8		2,393	19.80		83	0.7	
30–34	522	6.3		1,582	19.20		65	0.8	
35–39	296	7.7		803	20.79		50	1.3	
40+	54	8.4		142	22.05		13	2.0	
Race and ethnicity									
White, non-Hispanic	1,076	6.6	<.0001	2,835	17.34	<.0001	111	0.7	0.0007
Black, non-Hispanic	796	8.9		2,360	26.36		105	1.2	
Hispanic	588	6.7		1,988	22.63		71	0.8	
Other	310	6.9		882	19.56		32	0.7	
Unknown	60	7.9		145	19.13		4	0.5	
Service branch									
Army	1,093	8.1	<.0001	2,918	21.58	0.0468	117	0.9	0.6473
Navy	776	6.9		2,317	20.72		82	0.7	
Air Force, Space Force	718	6.5		2,257	20.48		93	0.8	
Marine Corps	201	7.2		563	20.27		26	0.9	
Coast Guard	42	4.9		155	18.17		5	0.6	
Comorbidities Prior to Pregnancy Start Date									
Cardiovascular disease									
Yes	181	8.4	0.0211	534	24.91	<.0001	24	1.1	0.1149
No	2,649	7.1		7,676	20.63		299	0.8	
Chronic lower respiratory disease									
Yes	27	8.5	0.3677	90	28.30	0.0010	5	1.6	0.1358
No	2,803	7.2		8,120	20.80		318	0.8	
Asthma									
Yes	59	6.5	0.4033	226	24.84	0.0028	8	0.9	0.8434
No	2,771	7.2		7,984	20.77		315	0.8	
Lung disease									
Yes	131	8.1	0.1564	423	26.10	<.0001	13	0.8	0.9319
No	2,699	7.2		7,787	20.64		310	0.8	
Metabolic disease									
Yes	360	8.3	0.0039	1,087	24.93	<.0001	44	1.0	0.1436
No	2,470	7.1		7,123	20.35		279	0.8	
Immune compromising conditions									
Yes	397	9.0	<.0001	1,069	24.22	<.0001	42	1.0	0.3067
No	2,433	7.0		7,141	20.44		281	0.8	
Substance use disorders (including nicotine dependence)									
Yes	173	8.5	0.0156	502	24.79	<.0001	20	1.0	0.3926
No	2,657	7.1		7,708	20.65		303	0.8	
Chronic liver disease									
Yes	18	8.3	0.5279	60	27.65	0.0136	2	0.9	0.8688
No	2,812	7.2		8,150	20.82		321	0.8	
Chronic kidney disease									
Yes	80	8.0	0.3296	229	22.83	0.1198	8	0.8	0.9345
No	2,750	7.2		7,981	20.81		315	0.8	
Chronic neurological disorders									
Yes	31	9.8	0.0763	86	27.04	0.0064	2	0.6	0.7035
No	2,799	7.2		8,124	20.81		321	0.8	
Neoplasms									
Yes	270	7.2	0.9782	844	22.51	0.0089	43	1.2	0.0199
No	2,560	7.2		7,366	20.69		280	0.8	
Obesity									
Yes	347	7.5	0.3540	1,113	24.13	<.0001	62	1.3	<.0001
No	2,483	7.2		7,097	20.43		261	0.8	
Tuberculosis									
Yes	2	10.5	0.5735	4	21.05	0.9836	0	0.0	0.6916
No	2,828	7.2		8,206	20.86		323	0.8	
Mood disorders, depression, schizophrenia									
Yes	360	9.3	<.0001	969	24.90	<.0001	40	1.0	0.1311
No	2,470	7.0		7,241	20.42		283	0.8	
Tobacco use (reported on PHA)									
Yes	366	7.7	0.1174	1,061	22.45	0.0043	39	0.8	0.9720
No	2,464	7.1		7,149	20.65		284	0.8	
Prior deliveries, *n*									
0	1,883	6.9	0.0068	5,888	21.66	<.0001	215	0.8	0.0015
1	692	7.7		1,701	18.85		65	0.7	
2+	255	8.1		621	19.76		43	1.4	

Abbreviations: No., number; COVID-19, coronavirus disease 2019; *y*, years; PHA, Periodic Health Assessment; *n*, number.
Note: These findings are not adjusted for any potential confounders

TABLE 4. Adjusted[a] Odds of Pregnancy Outcomes, Singleton Births, Active Component U.S. Service Women, 2021–2023

Exposure	Eclampsia			Premature Rupture of Membrane			Pre-Term Labor or Delivery			Antepartum Hemorrhage		
	OR	95% CI Lower Limit	95% CI Upper Limit	OR	95% CI Lower Limit	95% CI Upper Limit	OR	95% CI Lower Limit	95% CI Upper Limit	OR	95% CI Lower Limit	95% CI Upper Limit
COVID-19 infection during pregnancy												
Yes	2.18	1.16	4.10	1.06	0.98	1.15	1.09	0.98	1.22	1.11	1.03	1.19
No	Reference	—	—	Reference	—	—	Reference	—	—	Reference	—	—
COVID-19 infection prior to start of pregnancy												
Yes	0.95	0.43	2.07	1.06	0.98	1.14	0.98	0.88	1.10	1.18	1.10	1.26
No	Reference	—	—	Reference	—	—	Reference	—	—	Reference	—	—
COVID-19 vaccination prior to start of pregnancy												
Yes	0.92	0.52	1.63	1.03	0.97	1.09	0.86	0.79	0.93	0.96	0.91	1.01
No	Reference	—	—	Reference	—	—	Reference	—	—	Reference	—	—
COVID-19 vaccination during pregnancy												
Yes	0.85	0.43	1.68	1.05	0.98	1.12	1.06	0.97	1.16	0.98	0.92	1.04
No	Reference	—	—	Reference	—	—	Reference	—	—	Reference	—	—

Abbreviations: OR, odds ratio; CI, confidence interval; COVID-19, coronavirus disease 2019.
[a]Models included COVID-19 infection during pregnancy, COVID-19 infection prior to start of pregnancy, COVID-19 vaccination during pregnancy, COVID-19 vaccination prior to start of pregnancy, age, race and ethnicity, number of prior deliveries, and any previously diagnosed comorbidity

from most other studies, however, because military service women have access to robust medical care and surveillance during their pregnancies, which eliminates access to care as a potential confounder for the association between race and pregnancy outcome. Consequently, the findings in this study support the possibility of other factors besides access to care that contribute to the increased risk of adverse pregnancy outcomes in non-Hispanic Black service women.[25]

Consistent with prior studies, preexisting comorbidities were associated with different types of adverse pregnancy outcomes.[26-28] Further studies should be conducted to validate the finding of potential associations between COVID-19 infection and eclampsia and antepartum hemorrhage, since it was not possible in this study to determine whether COVID-19 infection was the cause of those adverse outcomes.

Some limitations to this study are important to note. First, in this cross-sectional study design, temporality between COVID-19 infection or COVID-19 vaccination that occurred during pregnancy cannot be inferred with these adverse pregnancy outcomes. It is possible that some adverse pregnancy outcomes occurred prior to the documented COVID-19 infection. COVID-19 infection and vaccination prior to the start of pregnancy does infer temporality, however, which adds to the robustness of these findings.

Selection bias could have occurred in this study because pregnancies that ended in abortion, spontaneous or otherwise, were not included. If COVID-19 infection and adverse pregnancy outcomes are associated with spontaneous abortions, this would result in a negative bias, or an attenuation of the true association between COVID-19 infection and an adverse pregnancy outcome.

It is also unlikely that all COVID-19 infections during pregnancy were identified in this study, as at-home COVID test kits were rapidly deployed during the surveillance period. In addition, service women had the ability to test outside of the military's medical system, resulting possible in misclassification for some categorized as without COVID-19 infection when they were potentially infected during their pregnancy. Similarly, women with no or mild COVID-19 symptoms may not have realized they were infected and, therefore, would not have tested.

This study considered women with any dose of any COVID-19 vaccine as vaccinated. As such, a misclassification bias is possible if these women were not fully vaccinated. Remaining up-to-date with COVID-19 vaccines was believed to provide the most benefit in the prevention of both severe adverse pregnancy outcomes and COVID-19 disease.[15]

Lastly, it should be noted that 52% (n=4,298) of the cases of antepartum hemorrhage had a diagnosis of O20.0 for "threatened abortion," which can also be used to code bleeding during pregnancy. This coding could result in an over-estimate of antepartum hemorrhage cases, since bleeding during pregnancy is a more common and less severe outcome. Similarly, premature rupture of membranes may be overestimated because 52% (n=3,079) of those cases had a diagnosis of O42.02, "Full-term premature rupture of membranes, onset of labor within 24 hours of rupture," which suggests that, for half of these cases, the rupture occurred at or after 37 completed weeks of gestation.

This study provides insight on adverse pregnancy outcomes among pregnant U.S. active component service women. These findings suggest that COVID-19 vaccination is not associated with adverse pregnancy outcomes in this population.

Future studies should review the prevalence of these outcomes in this population, refine and validate any associations with COVID-19 infection, along with the various levels of vaccination on adverse neonatal outcomes, and further investigate outcomes for pregnant active component service women of racial and ethnic minorities, to determine the reasons for these differences, given their equal access to no-cost medical care.

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Strategies for Forecasting Long COVID in the Active Component U.S. Military

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Long COVID, or post-acute coronavirus disease syndrome, represents a potentially serious threat to military readiness. Forecasts of future long COVID diagnoses could help prepare senior leaders for disruptions. Few studies predicting the incidence of long COVID have been published to date, however. Using existing COVID-19 and long COVID diagnoses, as well as demographic and outpatient encounter data, 1- to 6-month ahead and full 6-month forecasts were generated using time series and machine learning models trained on various covariate data. Forecasting models generated accurate predictions of long COVID diagnoses up to 6 months ahead of the forecasted date. Several model and covariate combinations were within 5% of the observed number of diagnoses over the full 6-month testing period, while monthly forecasts of long COVID diagnoses had median absolute percentage errors ranging from 3% to 10% for the best performing model combinations. Simple forecasting models and distribution-based forecasts that utilize existing clinical databases can provide accurate predictions of incident long COVID up to 6 months in advance and can be used to prepare for the burden of new long COVID diagnoses.

What are the new findings?

Accurate predictions of long COVID cases over a 6-month period were achieved by utilizing existing COVID-19 case and outpatient encounter data from January 1, 2020, through December 31, 2022.

What is the impact on readiness and force health protection?

Long COVID symptoms can cause disruptions to military readiness and prevent a healthy force, especially after surges in COVID-19 cases. The ability to use existing data sources to accurately predict future cases of long COVID allows senior leaders to anticipate and prepare for potential changes in the availability of service members.

Long COVID, or post-acute coronavirus disease syndrome, has been well studied in the general population, although it has not been well established in the U.S. military. Internal, not yet published Defense Medical Surveillance System (DMSS) data from active component U.S. service members diagnosed with coronavirus disease 2019 (COVID-19) from January 2020 through December 2022 indicate that symptoms of long COVID may be present in up to 20% of service members, with cardiac symptoms in approximately 8% and respiratory symptoms in approximately 5% of service members (unpublished). Another study of active duty service members with COVID-19 diagnoses from March 2020 to November 2021 found cardiac symptoms in nearly 2% of service members more than 30 days after COVID-19 diagnosis.[1] At best, mild symptoms of long COVID could disrupt force readiness by causing unplanned training limitations and absences, while more severe symptoms could result in long-term disability or even death. It is, therefore, critical for senior U.S. Department of Defense (DOD) leaders to anticipate the burden of long COVID in advance to prepare for potential disruptions and to anticipate impacts on the military health care system resources.

Infectious disease forecasting, especially for influenza, has been conducted for decades. Various mechanistic, statistical, and time series models have been used for forecasting, as well as combined ensemble models. The U.S. Centers for Disease Control and Prevention (CDC) hosts annual forecasting challenges for influenza and COVID-19 aimed at predicting short-term incidence of cases and hospitalizations.[2] The CDC has found that ensemble models tend to be more stable and accurate for multiple forecasting locations and targets than individual models, including COVID-19 forecasting.[3-4]

Long COVID is a long-term, post-infectious process of COVID-19, however, that is not contagious and requires a person to both be infected with COVID-19 and develop symptoms of long COVID after a specified period. Traditional time series methods for forecasting short-term COVID-19 and other respiratory disease activity may not be useful for forecasting long COVID cases, and little research has been published to date on efforts to predict the incident number of long COVID diagnoses utilizing existing case data, especially within the military population. Studies using clinical data in civilian populations found various models to be

reasonably accurate, with AUROC (area under a receiver operating characteristic) values between 0.74 and 0.895.[5-7] Attempts have been made to use time series models to forecast incident cases of other diseases with long follow-up periods, such as Lyme disease, using clinical data, with mean absolute percentage errors around 8%.[8]

The purpose of this study was to develop predictive models to forecast future long COVID diagnoses and to compare the predictions of each model against observed long COVID diagnoses. To achieve this aim, this study utilized a cohort of COVID-19 cases, linked demographic and medical records, and longitudinal health encounter data.

Methods

The protocol for this study was approved by both the George Washington University Committee on Human Research Institutional Review Board and the Component Office for Human Research Protections of the Defense Health Agency Office of Research Protections.

Study population

The study population included a cohort of 464,356 active component U.S. service members with a confirmed case of COVID-19 at a U.S. military hospital or clinic, from January 1, 2020 through December 31, 2022. The U.S. active component includes full-time, active duty service members but excludes reservists or National Guard members.

Data were obtained from a master list of COVID-19 cases, defined as having either a positive SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) nucleic acid or antigen test or a COVID-19 reportable medical event (RME) in the Disease Reporting System Internet (DRSi) maintained by the Armed Forces Health Surveillance Division (AFHSD). The master list includes information relevant to a service member's COVID-19 event, including vaccinations, re-infection status, and hospitalization.

Exposures and covariates

Covariates of interest in this study focused on measures of COVID-19 activity, including COVID-specific, COVID-like illness (CLI), and post-acute sequelae of COVID-19 (PASC) outpatient encounters, as well as risk factors for long COVID. Risk factors included sex, age, race and ethnicity, rank, COVID-19 hospitalization status, COVID-19 re-infection status, and COVID-19 vaccination status.

Demographic information for each COVID-19 case in the master positive list was taken from the Defense Medical Surveillance System (DMSS), a DOD-maintained database of health information that includes personnel, medical, immunization, pharmacy, health assessment, laboratory, and deployment data.[9] Monthly aggregated outpatient encounters by military hospital or clinic were downloaded from the DOD Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE).

COVID-specific encounters were defined as any outpatient encounter with a discharge diagnosis containing the ICD-10 codes U07.1 or J12.81, while PASC encounters were defined as those containing the ICD-10 code U09.9. The CLI encounter definition is provided in **Supplementary Table 1**.

Case definition

The outcome of interest, long COVID, was assessed using the PASC definition developed and validated by the Defense Centers for Public Health–Portsmouth (DCPH-P). Briefly, the definition requires a service member to have a positive SARS-CoV-2 nucleic acid test or a confirmed COVID-19 RME, and an International Classification of Diseases, 10th Revision (ICD-10) code from 1 of the mental health, neurological, cardiac, or respiratory diagnostic groups from 4 to 52 weeks after the COVID-19 event. Diagnostic groups and their ICD-10 codes are shown in **Supplementary Table 2**. A service member must not have the same diagnosis within that specific diagnosis group within 1 year prior to the COVID-19 event. Inpatient and outpatient datasets from DMSS were used to identify incidence of long COVID in this population.

Analyses

This study focused on longitudinal forecasts of long COVID in the U.S. active component population. To facilitate time series forecasting, long COVID, COVID-19, and outpatient encounter data sets were converted into time series by aggregating the monthly numbers of cases and encounters. COVID-19 cases were additionally stratified by risk factor. The number of monthly cases and encounters were plotted together to visualize the relationship between each metric and the outcome of long COVID.

The data were divided into training and testing datasets. The training dataset included data from January 1, 2020 through June 30, 2022, and the testing dataset included data from July 1, 2022 through December 31, 2022. Using the training data, 3 models were fit with long COVID diagnoses as the outcome: autoregressive integrated moving average (ARIMA), neural network, and vector autoregressive (VAR), in addition to an ensemble model that represented the average of the other 3 models. Different versions of each model were fit, with 21 in total that featured different data lags (unlagged, 3-month lag, and 6-month lag) and covariate data including PASC encounters, COVID-19 cases, COVID-specific encounters, CLI encounters, and demographics (age, sex, race and ethnicity, rank, re-infection status, hospitalization status, and vaccination status). All model and covariate combinations are shown in **Table 1**. Model fit statistics were assessed for the training period, including Akaike information criterion (AIC), sigma^2 (variance of forecast errors), root mean squared error (RMSE), and median absolute percent error (MAPE).

Models showing the best fit with the training data were selected for forecasting, including the models with all COVID-19 metrics and those with all metrics. The models using PASC encounters were also included for forecasting. Several baseline models were also created for comparison.

First, a seasonal NAÏVE was calculated using a 5-month lag of COVID-19 cases and 22% of COVID-19 cases diagnosed with long COVID in the cohort. The lag parameter represented the average time in months from the COVID-19 event date to the long COVID diagnosis date in the cohort,

TABLE 1. Median Ensemble Model Fit Statistics, by Training Covariates and Lagging

Combination	AIC[a]	Sigma[2] [b]	RMSE	MAPE
Base (no covariates)	331.5	250,962.5	491.2	10.1
PASC encounters				
	427.9	267,422.6	525.4	18.0
COVID-19 cases				
No lag	327.7	124,189.8	313.6	8.8
3-month lag	421.9	250,262.5	645.6	19.6
6-month lag	331.5	271,967.1	528.5	11.5
COVID-19 encounters				
No lag	331.4	211,062.8	445.8	11.0
3-month lag	422.7	277,948.1	643.0	20.1
6-month lag	331.6	202,544.6	441.7	9.8
CLI encounters				
No lag	331.6	217,329.0	455.5	10.5
3-month lag	421.4	258,492.6	630.0	17.9
6-month lag	420.5	254,913.9	621.4	17.3
COVID-19 cases, COVID-19 encounters and CLI encounters				
No lag	327.9	156,411.2	392.1	8.3
3-month lag	425.3	284,716.0	610.4	16.3
6-month lag	326.4	201,484.5	431.9	9.9
Demographics: age, sex, race and ethnicity, rank, re-infection status, hospitalization status				
	463.8	223,839.5	210.1	14.9
COVID-19 cases, COVID-19 encounters, CLI encounters and demographics				
No lag	470.2	350,118.4	262.6	75.8
3-month lag	494.5	856,769.3	391.9	93.3
6-month lag	485.7	623,760.2	334.1	112.3
All: PASC encounters, COVID-19 cases, COVID-19 encounters, CLI encounters and demographics				
No lag	465.1	299,529.7	231.8	56.6
3-month lag	-103.8	0.0	0.4	0.05
6-month lag	422.1	64,483.4	108.0	85.7

Abbreviations: AIC, Akaike information criterion; RMSE, root mean squared error; MAPE, median absolute percent error; PASC, post-acute sequelae of COVID-19; COVID-19, coronavirus disease 2019; CLI, COVID-like illness.
[a] Not available for neural network (NNET) model.
[b] Not available for vector autoregressive (VAR) model.

and the long COVID incidence parameter represented the percentage of COVID-19 cases diagnosed with long COVID in the sample.

Second, the distribution of the time from the COVID-19 event date to the long COVID diagnosis date in the cohort was estimated to be a Weibull distribution with a shape parameter of 1.56 and scale parameter of 5.81. A distribution of diagnosis times was calculated using the Weibull parameters, the long COVID incidence parameter described, and a minimum diagnosis time of 1 month and maximum of 12 months. The calculated distribution was applied to the time series of COVID-19 cases to create an estimate of expected long COVID diagnoses by month.

Similarly, an adjusted Weibull prediction was created using a long COVID incidence parameter that varied by risk factor. Based on factor-specific incidence of long COVID in the cohort, the parameter was estimated for sex (32% for females, 20% for males), race and ethnicity (21% for Asian, 22% for Hispanic, 27% for non-Hispanic Black, 21% for non-Hispanic White, 22% for 'other'), age group (19% for <20, 21% for 20-34, 27% for 35-39, 30% for 40-44, 31% for 45+), rank (23% for enlisted, 19% for officers), COVID-19 re-infection status (22% for first infection, 26% for re-infection), and COVID-19 hospitalization status (22% for not hospitalized, 43% for hospitalized). The average calculated distribution was applied to the time series of COVID-19 cases to create an estimate of expected long COVID diagnoses by month.

Lastly, an ensemble model was calculated as the average of all models for each covariate and lag combination as well as overall.

Two sets of forecasts were generated for each model combination. First, the number of long COVID diagnoses during the entire 6-month testing period was forecasted using the training dataset. Second, for each month during the testing period (July–December), forecasts were generated for each remaining month in the testing period (through December 2022). Models used data through the end of the previous month for training. For example, data through July 31, 2022, were used to generate forecasts for August, September, October, November, and December 2022. Data through August 31, 2022 were used to generate forecasts for September, October, November, and December 2022. This continued through the end of the testing period. Seasonal naïve and ensemble forecasts were generated in both quantile and point formats to facilitate evaluation of the complete distribution of the forecasts. Forecasts using the Weibull distribution were only generated as a point forecast.

Forecasts were scored by comparing the predicted number of long COVID diagnoses in a period to the observed number. Monthly point forecasts were scored using a MAPE, and quantile forecasts were scored using a weighted interval score (WIS). Full 6-month point forecasts were scored using percentage error. WIS has been used previously by the CDC for scoring COVID-19 forecasting hub entries.[10] All statistical analyses were conducted using R (version 4.1, R Foundation for Statistical Computing, Vienna, Austria), and an alpha (α) level of 0.05 was considered statistically significant.

Results

Table 2 shows demographic characteristics of COVID-19 cases in the training and testing datasets. Datasets were similar by age, race and ethnicity, rank, and COVID-19 hospitalization, although a larger proportion of the testing dataset was female (24.3% vs. 20.4%). COVID-19 re-infections were much more prominent in the testing dataset (19.2% vs. 5.5%), although this was expected, as the testing data were generated nearly 2 years into the COVID-19 pandemic. **Figure 1** shows the time series of observed data used for training and prediction in this study. As expected, incidence of COVID-19 was higher than PASC, with COVID-19 cases peaking between 10,000 and 20,000 monthly cases each summer, and between 25,000 and 100,000 monthly cases each winter, while PASC cases peaked between 2,500 and 6,000 monthly cases. PASC peaks tended to follow peaks in COVID-19 activity by 2 to 3 months.

Table 1 shows model fit statistics for each combination of trained models during the training period. The lowest AIC was seen for the 3-month lag model containing all covariates (-103.8). This model combination also had the lowest sigma^2 (0.0), RMSE (0.4), and MAPE (0.05%) compared to other combinations. Other model combinations with a MAPE below 10% were the unlagged COVID-19 case model (8.8%), 6-month lagged COVID-19 encounter model (9.8%), unlagged all COVID-19 metric model (8.3%), and the 6-month lag all-COVID-19 metric model (9.9%). Graphs of the median fitted predicted values for each model combination and lag compared to observed data are shown in **Supplementary Figure 1**. All models appeared to fit the observed data visually, although the models with all covariates and those with only demographic covariates appeared to fit the data best.

Table 3 shows model scoring metrics for each ensemble and baseline model and forecasting horizons. For all forecasting horizons, the ensemble model using PASC encounters had the lowest median MAPE (9.2%) and weighted interval score (WIS) (206.6), followed by the 3-month lag ensemble model using all covariates (11.3% MAPE, 291.0 WIS), and the unadjusted Weibull model (MAPE 11.5%). Model performance varied between the 1-month ahead and 6-month ahead horizons. **Figure 2** shows the observed compared to predicted values for each model and horizon. Ensemble models tended to predict a later peak than what was observed for the 1-month ahead through 3-month ahead forecasts, although this was less severe for the ensemble model using PASC encounters at the 2-month and 3-month ahead horizons. Weibull forecasts were more stable than ensemble model forecasts.

Table 4 shows the results of the full 6-month forecasts. During the forecasting period, from July through December 2022, 23,132 incident cases of PASC were observed. The 6-month lag ensemble model using all covariates had the lowest percent error over the 6-month period at -0.8% (22,960 predicted cases), followed by the unlagged ensemble model using all covariates (+4.3%, 24,174 predicted cases), adjusted Weibull model (-4.7%, 22,093 predicted cases), and the ensemble model using PASC encounters (+5%, 24,353 predicted cases). The seasonal naïve model had the highest percentage error, -71.6%, predicting only 13,479 cases during the 6-month period.

TABLE 2. Demographic Characteristics of COVID-19 Cases During Training and Testing Periods

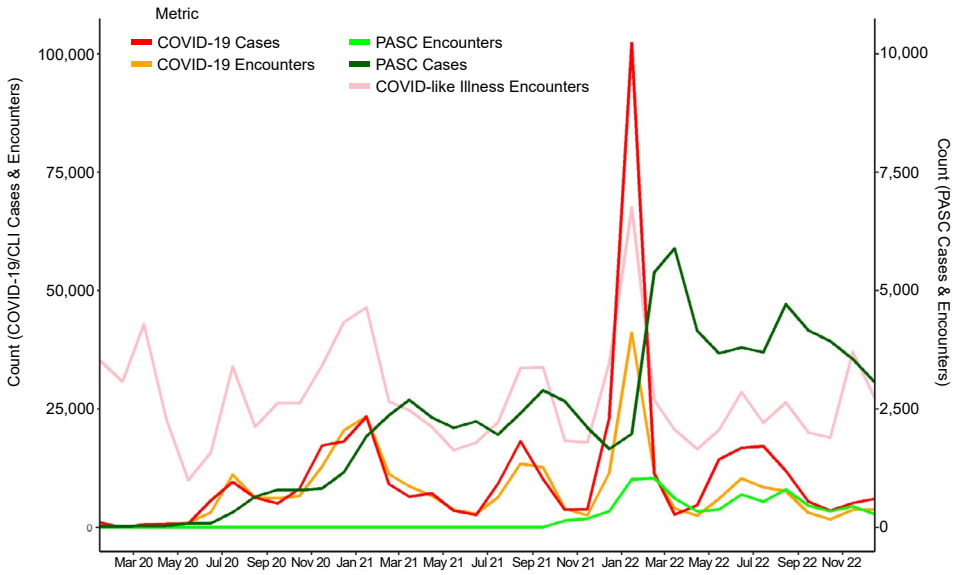
Variable	Cases			
	Training		Testing	
	No.	%	No.	%
Total	402,352		62,004	
Age, *y*				
<20	27,950	6.9	3,276	5.3
20–24	138,332	34.4	19,323	31.2
25–29	96,233	23.9	15,117	24.4
30–34	62,144	15.4	10,366	16.7
35–39	45,198	11.2	7,766	12.5
40–44	21,242	5.3	3,870	6.2
45+	11,251	2.8	2,286	3.7
Sex				
Female	82,064	20.4	15,050	24.3
Male	320,288	79.6	46,954	75.7
Race and ethnicity				
White, non-Hispanic	203,674	50.6	30,678	49.5
Black, non-Hispanic	70,954	17.6	10,547	17.0
Hispanic	80,899	20.1	12,305	19.8
Asian	15,462	3.8	2,772	4.5
Other	25,311	6.3	4,845	7.8
Unknown	6,052	1.5	857	1.4
Rank				
Enlisted	344,510	85.6	53,362	86.1
Officer	57,842	14.4	8,642	13.9
Re-infection of COVID-19				
First infection	380,256	94.5	50,121	80.8
Re-infection	22,096	5.5	11,883	19.2
Hospitalization for COVID-19				
Not hospitalized	399,367	99.3	61,611	99.4
Hospitalized	2,985	0.7	393	0.6

Abbreviations: COVID-19, coronavirus disease 2019; No., number; *y*, year.

Discussion

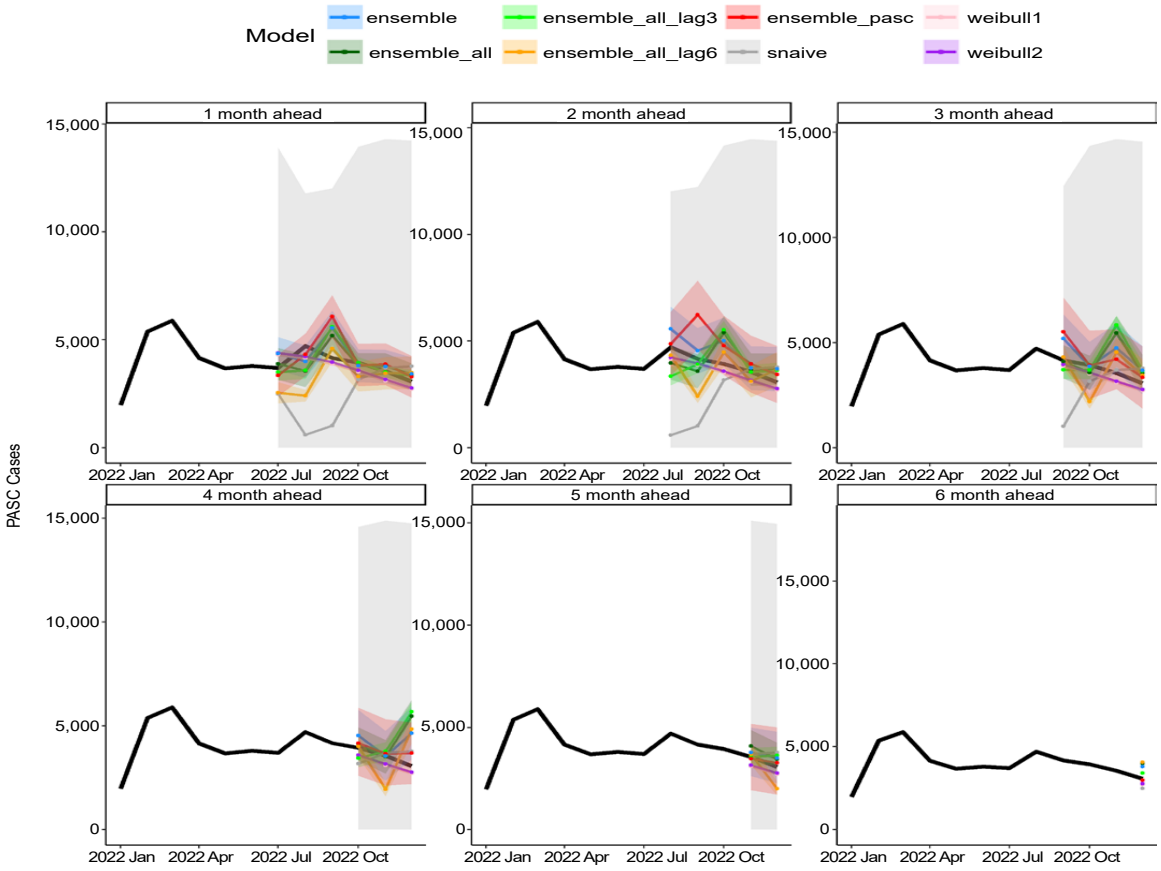
This study aimed to use various forecasting models, including time series and machine learning models, as well as simple time-based distributions, to predict the number of incident long COVID diagnoses over a 6-month period utilizing various case, outpatient encounter, and demographic data. Forecasts were generated at the beginning of the study period for the entire 6-month period, and 1- to 6-month forecasts were generated for each month in the study period. Monthly forecasts ranged in accuracy, with the PASC encounter ensemble model having the lowest WIS for all forecasting horizons and a MAPE below 10%, as did the adjusted Weibull forecasts, which can be seen in **Table 4** and **Supplementary Figure 2**. No pattern was seen for the 1- to 6-month ahead horizons, with some models performing better at earlier horizons and some performing better at later

FIGURE 1. Observed Monthly Numbers of Cases and Encounters, by Metric, 2020–2022



Note: Observed COVID-19 cases and COVID-19/CLI encounters shown via left axis; PASC cases and encounters shown via right axis.
Abbreviations: COVID-19, coronavirus disease 2019; PASC, post-acute sequelae of COVID-19; CLI, COVID-like illness.

FIGURE 2. Observed Versus Predicted Value, by Selected Ensemble and Baseline Models and Forecasting Horizon



Note: Observed cases shown in black; solid, colored lines represent the point forecast for each model, while shaded area represents 95% confidence interval (CI) in each model.
Abbreviation: PASC, post-acute sequelae of COVID-19.

horizons. This contrasts with COVID-19 forecasts, which tend to perform worse as horizons increase.[11]

Because long COVID is not an infectious process, it may not be useful to generate monthly forecasts of long COVID diagnoses, but instead generate forecasts for a specified period, to assist senior leaders and public health practitioners with planning for expected case burdens. To this end, forecasts of the entire 6-month period may be most useful. The ensemble model using all covariates and a 6-month lag was the most accurate, with a percent error of just -0.8% (-172 cases) over the study period. This is not unexpected, as the average time to a long COVID diagnosis was 5 months, so lagging covariate data by 6 months is a reasonable choice. Other models also had a percentage error within 5%, however, including the unlagged ensemble model using all covariates (+4.3%), the adjusted Weibull model (-4.7%), and the ensemble model using PASC encounters (+5.0%). These results are similar to estimates in a previous study of Lyme disease, another slow-developing disease.[8] Despite having the best model fit using the training data, the 3-month lag all-covariate ensemble model had a percentage error of -10.2%, ranking only sixth best of the 8 models tested. This was not unexpected, as the lag in the full cohort was 5 months, which is closer to the 6-month lag model. It does not explain why the model performed worse than the unlagged ensemble model, however.

This study serves as a 'proof of concept' for long COVID forecasting, demonstrating how forecasting models can be used to predict incident long COVID cases up to 6 months in advance, utilizing clinical and demographic data. The study employed existing datasets and surveillance databases to accurately predict the numbers of long COVID diagnoses over a 6-month period.

This study has several limitations. First, models were only trained on COVID-19 cases from January 1, 2020 through June 30, 2022 and, therefore, do not reflect trends in long COVID in later years. Second, the study included the entire U.S., which may not be as useful as regional or single installation forecasts, a possible goal of future studies. Lastly, longer-term horizons, such as the 5- and 6-month forecasts, were limited to just

TABLE 3. Median Model Scores, by Selected Ensemble and Baseline Models

Combination	MAPE	WIS
Ensemble	15.3	322.8
Ensemble (all covariates)	13.9	265.9
Ensemble (all covariates, 3-month lag)	11.3	291.0
Ensemble (all covariates, 6-month lag)	16.2	363.8
Ensemble (PASC encounters)	9.2	206.6
SNaïve	23.2	1,098.3
Weibull 1	11.5	N/A
Weibull 2	9.7	N/A
1 month ahead		
Ensemble	13.6	263.9
Ensemble (all covariates)	8.8	155.6
Ensemble (all covariates, 3-month lag)	6.9	132.9
Ensemble (all covariates, 6-month lag)	15.0	319.6
Ensemble (PASC encounters)	8.8	180.3
SNaïve	28.0	1,082.2
Weibull 1	11.7	N/A
Weibull 2	10.0	N/A
2 months ahead		
Ensemble	18.1	332.9
Ensemble (all covariates)	15.5	378.1
Ensemble (all covariates, 3-month lag)	18.6	438.2
Ensemble (all covariates, 6-month lag)	14.0	326.7
Ensemble (PASC encounters)	12.0	217.3
SNaïve	23.2	1,077.4
Weibull 1	11.5	N/A
Weibull 2	9.7	N/A
3 months ahead		
Ensemble	22.4	410.2
Ensemble (all covariates)	12.7	231.2
Ensemble (all covariates, 3-month lag)	15.1	364.8
Ensemble (all covariates, 6-month lag)	20.4	472.3
Ensemble (PASC encounters)	14.0	277.9
SNaïve	21.4	1,087.8
Weibull 1	11.1	N/A
Weibull 2	9.3	N/A
4 months ahead		
Ensemble	15.2	289.3
Ensemble (all covariates)	4.9	118.4
Ensemble (all covariates, 3-month lag)	12.6	327.5
Ensemble (all covariates, 6-month lag)	45.5	1,488.2
Ensemble (PASC encounters)	5.8	206.6
SNaïve	19.5	1,101.5
Weibull 1	11.5	N/A
Weibull 2	9.7	N/A
5 months ahead		
Ensemble	10.2	227.9
Ensemble (all covariates)	13.7	249.4
Ensemble (all covariates, 3-month lag)	9.2	220.4
Ensemble (all covariates, 6-month lag)	19.2	505.8
Ensemble (PASC encounters)	4.7	200.0
SNaïve	13.7	1,113.7
Weibull 1	12.2	N/A
Weibull 2	10.4	N/A
6 months ahead		
Ensemble	23.9	368.8
Ensemble (all covariates)	30.5	632.3
Ensemble (all covariates, 3-month lag)	11.3	202.2
Ensemble (all covariates, 6-month lag)	32.8	797.0
Ensemble (PASC encounters)	2.9	191.7
SNaïve	18.7	1,326.7
Weibull 1	11.5	N/A
Weibull 2	9.7	N/A

Abbreviations: MAPE, median absolute percent error; WIS, weighted interval score; PASC, post-acute sequelae of COVID-19; SNaïve, seasonal naïve; N/A, not applicable.

TABLE 4. Observed Versus Predicted Six-Month PASC Cases, by Selected Ensemble and Baseline Models

Model	Predicted Cases													
	July 2022		August 2022		September 2022		October 2022		November 2022		December 2022		July-December 2022	
	No.	% Error	No.	% Error	No.	% Error	No.	% Error	No.	% Error	No.	% Error	No.	% Error
Observed	3,702	—	4,712	—	4,163	—	3,938	—	3,553	—	3,064	—	23,132	—
Ensemble	4,368	+15.2	5,567	15.4	5,191	+19.8	4,537	+13.2	3,777	+5.9	3,797	+19.3	27,237	+15.1
Ensemble (all covariates)	3,884	+4.7	3,980	-18.4	4,097	-1.6	4,132	+4.7	4,082	+13.0	4,000	+23.4	24,174	+4.3
Ensemble (all covariates, 3 month lag)	3,510	-5.5	3,352	-40.6	3,710	-12.2	3,444	-14.4	3,557	+0.1	3,409	+10.1	20,982	-10.2
Ensemble (all covariates, 6 month lag)	2,553	-45.0	4,328	-8.9	4,307	+3.3	4,012	+1.8	3,692	+3.8	4,068	+24.7	22,960	-0.8
Ensemble (PASC encounters)	3,359	-10.2	4,874	+3.3	5,509	+24.4	4,168	+5.5	3,466	-2.5	2,976	-2.9	24,353	+5.0
SNaïve	2,491	-48.6	599	-686.3	1,029	-304.6	3,172	-24.2	3,697	+3.9	2,491	-23.0	13,479	-71.6
Weibull 1	4,311	+14.1	4,152	-13.5	3,889	-7.0	3,516	-12.0	3,096	-14.8	2,711	-13.0	21,675	-6.7
Weibull 2	4,387	+15.6	4,229	-11.4	3,964	-5.0	3,586	-9.8	3,159	-12.5	2,768	-10.7	22,093	-4.7

Abbreviations: PASC, post-acute sequelae of COVID-19; No., number; SNaïve, seasonal naïve.

1 or 2 data points for each model, potentially limiting assessment of those horizons. Future research could focus on the utility of longer-term forecasts by expanding the study period to allow additional forecasts. Additional lag periods, such as the 5-month lag used for the baseline models, can be explored for the ensemble model forecasts.

This study demonstrates that accurate forecasting of long COVID incidence is possible, utilizing clinical, laboratory, and demographic data. Further research needs to determine if results are consistent in more recent time periods, and whether additional or more complex models improve accuracy.

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SUPPLEMENTARY TABLE 1. PASC Diagnostic Categories and ICD-10 Diagnosis Codes

Mental Health	
Anxiety	F4323, F419, F411, F418, F4322
Insomnia	G4700, F51
PTSD	F4312
Major depression	F321, F329, F331, F332, F339, R45851
Neurological	
Headache	R51
Taste loss	R430, R431, R432, R438, R439
Seizure	R5600, R5601, R569, G40001, G40009, G40011, G40019, G40101, G40109, G40111, G40119, G40201, G40209, G40211, G40219, G40301, G40309, G40311, G40319, G40401, G40409, G40411, G40419, G40501, G40509, G40801, G40802, G40803, G40804, G40811, G40812, G40813, G40814, G40821, G40822, G40823, G40824, G4089, G40901, G40909, G40911, G40919, G40A01, G40A09, G40A11, G40A19, G40B01, G40B09, G40B11, G40B19
Blurred vision	H53
Fatigue	R53
Memory loss	R413
Cognitive dysfunction	R410, R411, R412
Vertigo	H8110, H8111, H8112, H8113, H8141, H8142, H8143, H8149
Respiratory	
Cough	R05
Short of breath	R0602, R0600, R0609
Pulmonary embolism	I2699
Asthma	J45909, J4520, J45901, J4530, R062
Cardiac	
Chest pain	R079, R0789, R072
Palpitations	R002
Atrial fibrillation	I4891, I480
Syncope	R55
Tachycardia	R000
Heart failure	I509, I517
Bradycardia	R001
Myocardial infarction	I21, I22
Cerebral infarction, stroke	I63
Post-exertional malaise	T733
Myocarditis	I40, I41, I514, B3322
Pericarditis	I30, I32, B3323

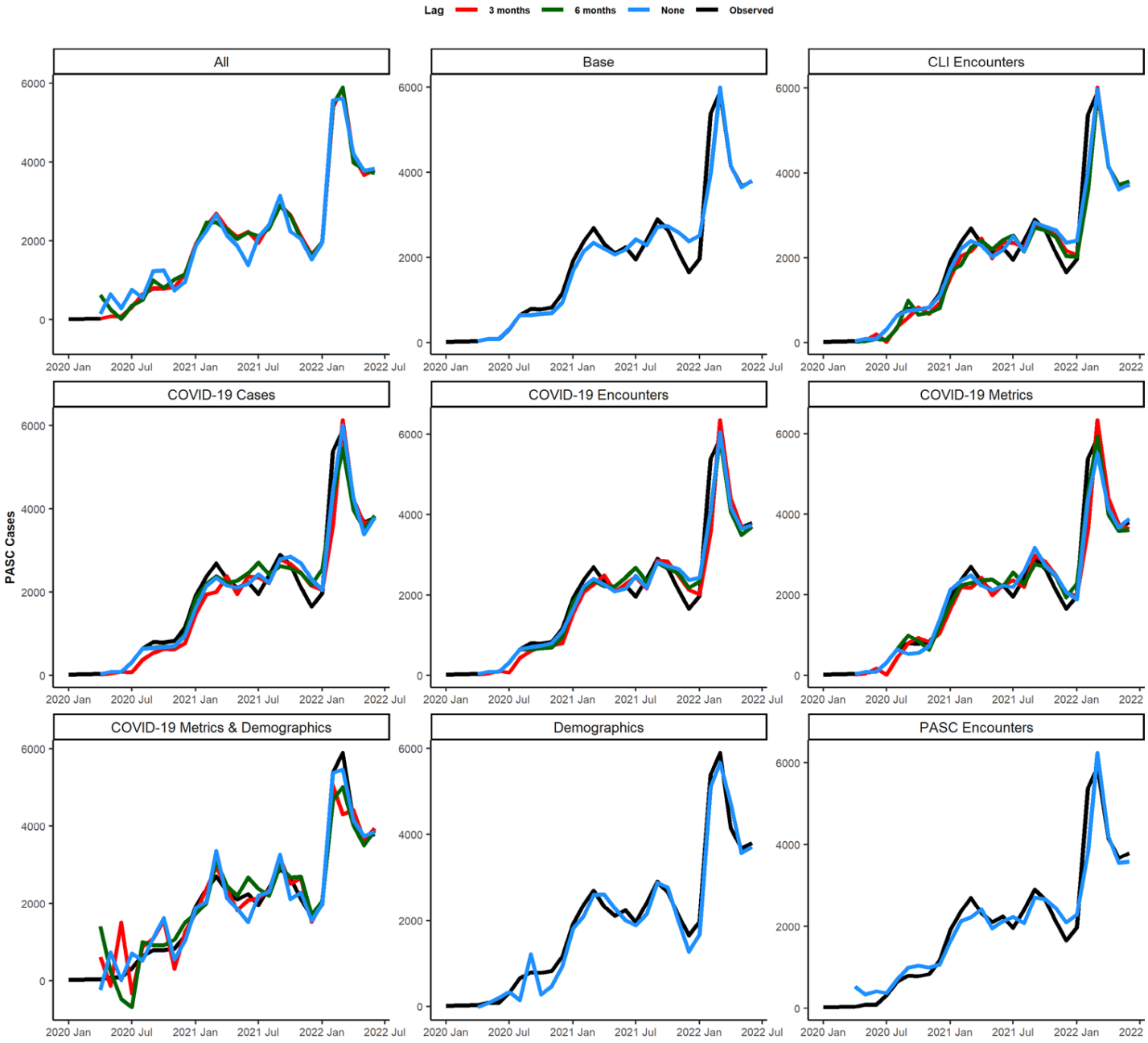
Abbreviations: PASC, Post Acute Sequelae of COVID-19; ICD-10, International Classsification of Diseases, 10th Revision; PTSD, post-traumatic stress disorder.

SUPPLEMENTARY TABLE 2. ESSENCE COVID-like Illness (CLI) Definition

Diagnosis Description	ICD-10 Code
Coronavirus, unspecified	B34.2
SARS-associated coronavirus as cause of disease classified elsewhere	B97.21
Other coronavirus as cause of disease classified elsewhere	B97.29
Acute nasopharyngitis, common cold	J00
Acute upper respiratory infection, unspecified	J06.9
Pneumonia due to SARS-associated coronavirus	J12.81
Other viral pneumonia	J12.89
Viral pneumonia unspecified	J16.8
Pneumonia in diseases classified elsewhere	J17
Bronchopneumonia, unspecified organism	J18.0
Lobar pneumonia, unspecified organism	J18.1
Other pneumonia, unspecified organism	J18.8
Pneumonia, unspecified organism	J18.9
Acute bronchitis due to other specified organisms	J20.8
Acute bronchitis, unspecified	J20.9
Unspecified acute lower respiratory infection	J22
Bronchitis, not specified as acute or chronic	J40
Acute respiratory distress syndrome	J80
Idiopathic interstitial pneumonia not otherwise specified	J84.111
Cough	R05
Dyspnea	R06.0
Dyspnea, unspecified	R06.00
Shortness of breath	R06.02
Acute respiratory distress	R06.03
Other forms of dyspnea	R06.09
Anosmia	R43.0
Ageusia	R43.2
Fever, unspecified	R50.9
2019-nCoV acute respiratory disease, COVID-19, virus identified	U07.1

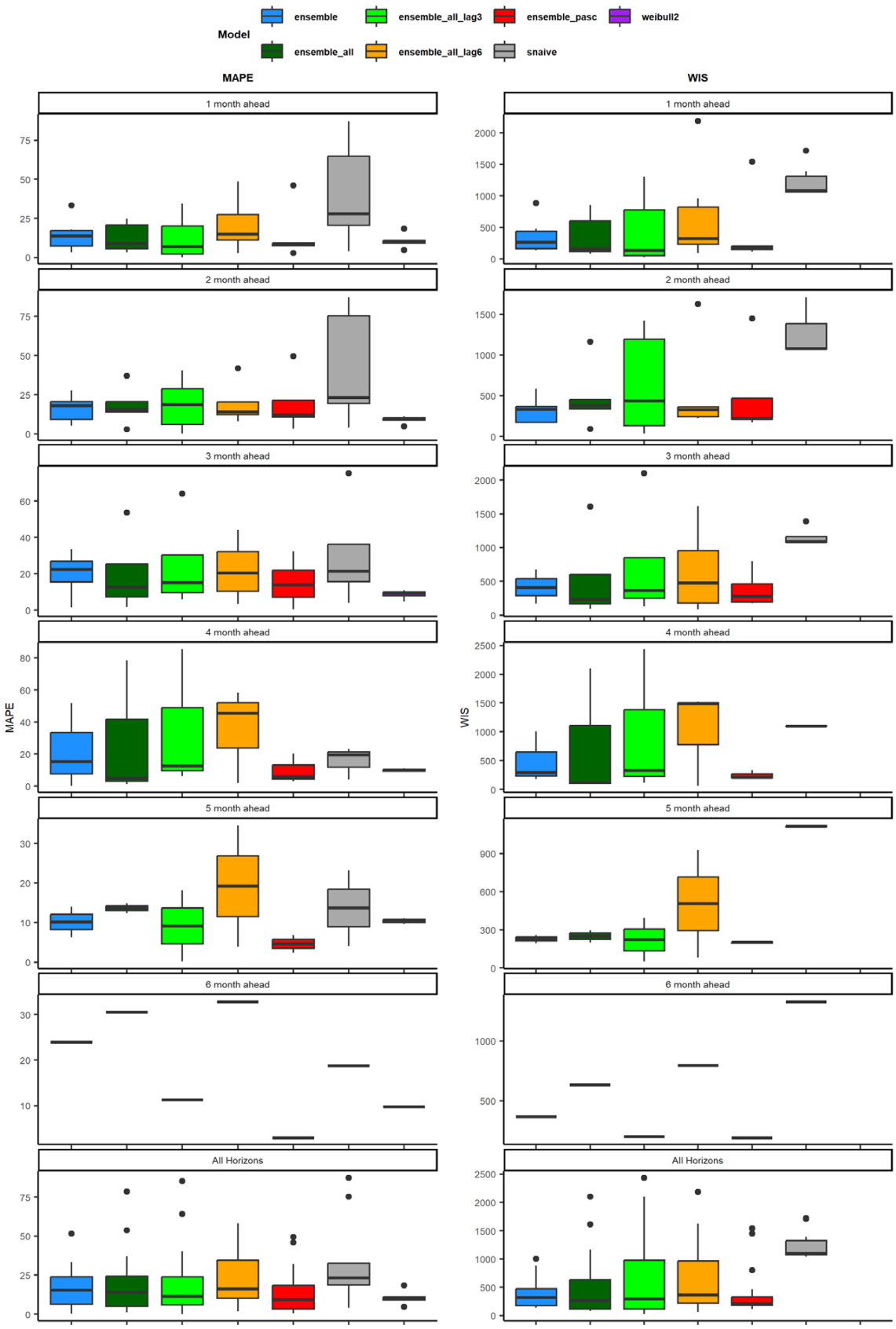
Abbreviations: ESSENCE, Electronic Surveillance System for the Early Notification of Community-based Epidemics; SARS, severe acute respiratory syndrome; 2019-nCov, 2019 novel coronavirus; COVID-19, coronavirus disease 2019.

SUPPLEMENTARY FIGURE 1. Observed Versus Median Fitted Prediction, by Training Covariates and Data Lag



Note: Observed cases shown in black; solid, colored lines represent the fitted value for each covariate and data lag.

SUPPLEMENTARY FIGURE 2. Observed Versus Median Fitted Prediction, by Training Covariates and Data Lag

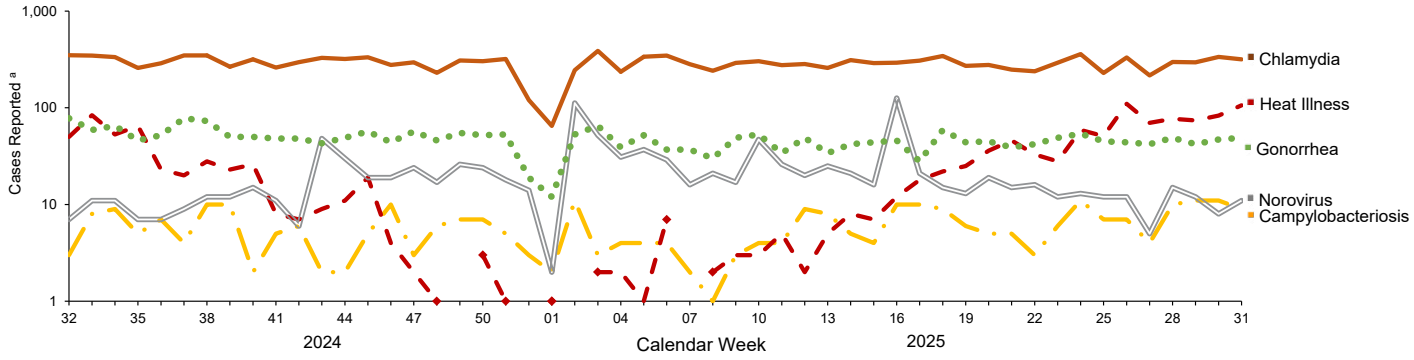


Note: MAPE, by model and forecasting horizon, in left column; WIS, by model and horizon, in right column. Smaller values indicate more accurate model performance; more narrow boxplots indicate more precise forecasts.

Reportable Medical Events at Military Health System Facilities Through Week 31, Ending August 2, 2025

Idalia Aguirre, MPH; Matthew W.R. Allman, MPH; Anthony R. Marquez, MPH; Katherine S. Kotas, MPH

TOP 5 REPORTABLE MEDICAL EVENTS BY CALENDAR WEEK, ACTIVE COMPONENT (AUGUST 10, 2024 - AUGUST 2, 2025)



Note: Cases shown on a logarithmic scale.

There were 0 reported heat illness cases during weeks 49, 52, 2, 7.

Reportable Medical Events (RMEs) are documented in the Disease Reporting System internet (DRSi) by health care providers and public health officials throughout the Military Health System (MHS) for monitoring, controlling, and preventing the occurrence and spread of diseases of public health interest or readiness importance. These reports are reviewed by each service's public health surveillance hub. The DRSi collects reports on over 70 different RMEs, including infectious and non-infectious conditions, outbreak reports, STI risk surveys, and tuberculosis contact investigation reports. A complete list of RMEs is available in the *2022 Armed Forces Reportable Medical Events Guidelines and Case Definitions*.[1] Data reported in these tables are considered provisional and do not represent conclusive evidence until case reports are fully validated.

Total active component cases reported per week are displayed for the top 5 RMEs for the previous year. Each month, the graph is updated with the top 5 RMEs, and is presented with the current month's (July 2025) top 5 RMEs, which may differ from previous months. COVID-19 is excluded from these graphs due to changes in reporting and case definition updates in 2023.

For questions about this report, please contact the Disease Epidemiology Branch at the Defense Centers for Public Health–Aberdeen. Email: dha.apg.pub-health-a.mbx.disease-epidemiologyprogram13@health.mil

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TABLE. Reportable Medical Events, Military Health System Facilities, July 2025[a]

Reportable Medical Event[b]	Active Component[c]					MHS Beneficiaries[d]
	July 2025	June 2025	YTD 2025	YTD 2024	Total 2024	July 2025
	No.	No.	No.	No.	No.	No.
Amebiasis	2	3	13	7	15	0
Arboviral diseases, neuroinvasive and non-neuroinvasive	0	1	1	1	4	0
Babesiosis	0	0	0	0	0	1
Brucellosis	0	0	0	0	1	0
COVID-19-associated hospitalization, death	3	2	23	25	41	13
Campylobacteriosis	41	33	190	200	326	38
Chikungunya virus disease	0	0	0	0	1	0
Chlamydia trachomatis infection	1,346	1,276	8,756	9,660	16,097	155
Cholera, O1 or O139	0	0	0	2	3	0
Coccidioidomycosis	1	0	12	40	53	5
Cold weather injury	0	8	279	134	174	N/A
Cryptosporidiosis	7	7	43	50	82	4
Cyclosporiasis	7	4	14	7	11	13
Dengue virus infection	0	1	6	9	12	1
E. coli, Shiga toxin-producing	7	8	41	50	93	5
Ehrlichiosis, anaplasmosis	0	1	1	1	1	2
Giardiasis	10	8	59	60	98	4
Gonorrhea	205	202	1,340	1,670	2,823	23
H. influenzae, invasive	0	0	2	3	3	0
Heat Illness[e]	360	264	864	787	1,276	N/A
Hepatitis A	0	1	1	5	7	1
Hepatitis B, acute, chronic[f]	2	11	45	68	108	5
Hepatitis C, acute, chronic	0	2	13	20	35	1
Influenza-associated hospitalization[g]	1	0	48	36	54	3
Lead poisoning, pediatric[h]	N/A	N/A	N/A	N/A	N/A	9
Legionellosis	0	1	1	3	5	1
Leprosy	0	0	0	0	1	0
Listeriosis	0	0	1	0	0	0
Lyme disease	21	21	65	61	101	10
Malaria	5	4	13	7	21	0
Meningococcal disease	0	0	1	0	2	0
Mpox	1	0	4	10	14	0
Mumps	1	0	2	0	0	0
Norovirus infection	50	49	796	295	654	48
Pertussis	5	3	33	15	39	9
Q fever	0	1	1	0	3	0
Rabies post-exposure prophylaxis (PEP)	60	54	343	372	637	57
Salmonellosis	19	27	88	76	160	25
Schistosomiasis	0	0	0	0	1	0
Shigellosis	1	8	21	32	53	0
Spotted fever rickettsiosis	4	4	21	12	22	8
Syphilis[i]	31	28	272	377	587	9
Toxic shock syndrome	0	0	0	2	2	0
Trypanosomiasis	0	0	1	2	5	0
Tuberculosis	2	0	6	2	6	2
Tularemia	2	0	2	1	1	0
Typhoid fever	0	0	0	0	1	0
Typhus fever	3	1	5	1	2	3
Varicella	3	1	10	10	18	6
Zika virus infection	0	0	0	1	1	0
Total Case Counts	2,200	2,034	13,437	14,114	23,654	461

Abbreviations: MHS, Military Health System; YTD, year-to-date; No., number; COVID-19, coronavirus disease 2019; N/A, not applicable; *E., Escherichia*; *H., Haemophilus*; PEP, post-exposure prophylaxis.

[a] RMEs submitted to DRSi as of Sep. 22, 2025. RMEs were classified by date of diagnosis or, where unavailable, date of onset. Monthly comparisons are displayed for the period of Jun. 1, 2025–Jun. 30, 2025 and Jul. 1, 2025–Jul. 31, 2025. YTD comparison is displayed for the period of Jan. 1, 2025–Jul. 31, 2025 for MHS facilities. Previous year counts are provided as the following: previous YTD, Jan. 1, 2024-Jul. 31, 2024; total 2024, Jan. 1, 2024–Dec. 31, 2024.

[b] RME categories with 0 reported cases among active component service members and MHS beneficiaries for the periods covered were not included in this report.

[c] Services included in this report include the Army, Navy, Air Force, Marine Corps, Coast Guard, and Space Force, including personnel classified as active duty, cadet, midshipman, or recruit in DRSi.

[d] Beneficiaries included individuals classified as retired and family members (e.g., spouse, child, 'other', 'unknown'). National Guard, reservists, civilians, contractors, and foreign nationals were excluded from these counts.

[e] Only reportable for service members.

[f] Observed 2024 to 2025 decrease in hepatitis B cases may be in part due to updated case validation process.

[g] Influenza-associated hospitalization is reportable only for individuals under age 65 years.

[h] Pediatric lead poisoning is reportable only for children ages 6 years or younger.

[i] Observed 2024 to 2025 drop in syphilis cases may be in part due to updated case validation process that began Jan. 2024.

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