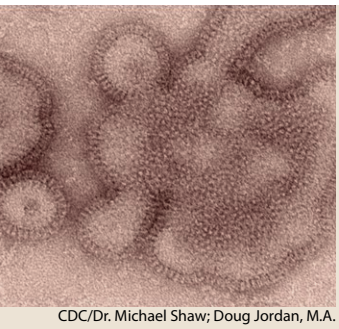
MARCH 2021

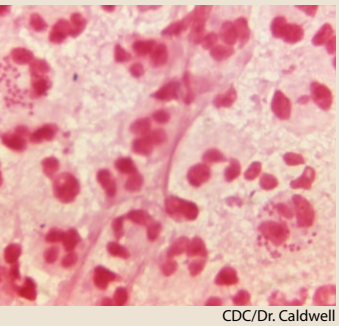
Volume 28
Number 03

MSMR

MEDICAL SURVEILLANCE MONTHLY REPORT



CDC/Dr. Michael Shaw; Doug Jordan, M.A.



CDC/Dr. Caldwell

Influenza Surveillance Trends and Influenza Vaccine Effectiveness Among Department of Defense Beneficiaries During the 2019–2020 Influenza Season

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Laboratory-based influenza surveillance was conducted in the 2019–2020 influenza season among Department of Defense (DoD) beneficiaries through the DoD Global Respiratory Pathogen Surveillance Program (DoDGRS). Sentinel and participating sites submitted 28,176 specimens for clinical diagnostic testing. A total of 5,529 influenza-positive cases were identified. Starting at surveillance week 45 (3–9 November 2019), influenza B was the predominant influenza type, followed by high activity of influenza A(H1N1)pdm09 three weeks thereafter. Both influenza B and influenza A(H1N1)pdm09 were then highly co-circulated through surveillance week 13 (22–28 March 2020). End-of-season influenza vaccine effectiveness (VE) was estimated using a test-negative case-control study design. The adjusted end-of-season VE for all beneficiaries, regardless of influenza type or subtype, was 46% (95% confidence interval: 40%–52%). The influenza vaccine was moderately effective against influenza viruses during the 2019–2020 influenza season.

WHAT ARE THE NEW FINDINGS?

Influenza B was the predominant influenza type starting from the beginning of November 2019. Influenza A(H1N1)pdm09 occurred actively 3 weeks thereafter, and then co-circulated highly with influenza B through the end of March 2020. The estimated VE (46%) indicated that the influenza vaccine during the 2019–2020 influenza season was moderately effective against these influenza viruses.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Influenza surveillance conducted by DoDGRS during the 2019–2020 influenza season identified circulating influenza virus (sub)types, provided timely data on the genetic characteristics of the circulating viruses, and estimated influenza VE. These surveillance data and findings help military authorities prioritize health resources and better plan appropriate health intervention measures for DoD service members and their beneficiaries.

Influenza viruses change from year to year as they undergo constant antigenic drifts and potential antigenic shifts. Because of the changing nature of these viruses, it is crucial to conduct annual surveillance to determine the circulating viruses and to detect changes in the viruses during the influenza season. Seasonal influenza vaccination is considered the main strategy to protect against influenza viruses, combat influenza infection, and reduce disease severity. To improve vaccine effectiveness (VE) against influenza viruses, the strains used in the influenza vaccine need to be updated regularly based on the surveillance findings. Every year, the Department of Defense (DoD) Global Respiratory Pathogen Surveillance Program (DoDGRS) performs routine respiratory pathogen surveillance among DoD service members and their beneficiaries, and evaluates influenza VE. The objective of this report is to describe influenza surveillance trends and the end-of-season VE estimates among DoD beneficiaries during the 2019–2020 influenza season.

METHODS

Surveillance population

The participant selection criteria in DoDGRS have been described elsewhere.[1,2] Briefly, all participants were selected at sentinel or participating sites throughout the U.S. and around the world, using criteria which meet the influenza-like illness (ILI) case definition. An ILI case is defined as a patient who exhibits a fever greater than or equal to 100.5 °F and a cough or sore throat that presents within 72 hours after illness onset, or has physician-determined ILI. Respiratory specimens were collected by nasopharyngeal wash or nasopharyngeal swab. Each sentinel or participating site was requested to submit 6–10 respiratory specimens per week for laboratory testing. Patients who had received at least 1 influenza vaccine dose 14 days or more before an ILI encounter were considered vaccinated. Vaccination status was verified through the records from the DoD Electronic Immunization Tracking System or self-reported questionnaire for each outpatient.

Laboratory testing

Influenza testing was conducted in 1 of 3 laboratories located within Landstuhl Regional Medical Center, Brooke Army Medical Center, or the U.S. Air Force School of Aerospace Medicine (USAFSAM). The specimens collected from the sentinel and participating sites were processed and subjected to testing via a multiplex respiratory pathogen panel, reverse transcriptase polymerase chain reaction (RT-PCR), and/or viral culture. In this way, the influenza-positive cases and other respiratory pathogens were identified and confirmed. The laboratory-confirmed influenza viruses were further genetically characterized via Illumina next-generation sequencing (NGS)

technology and analyzed using the Iterative Refinement Meta-Assembler (IRMA) package,[3] BioEdit software,[4] and components of the DNASTAR Lasergene Core Suite.[5]

Statistical analysis

A test-negative case-control study design was used to estimate influenza VE. The VE analysis was limited to surveillance weeks 46–12 (10 November 2019 to 21 March 2020), when approximately 10% or greater influenza positivity rate occurred, with an aim to minimize any potential bias due to high ratio of controls to cases that would typically occur earlier or later in the influenza season. Service members, due to their usually high influenza vaccination rate (>90%), and outpatients less than 6 months of age were excluded from the VE analysis. Age was categorized into 3 groups (i.e., children: 6 months to 17 years; adults: 18–64 years; and the elderly: 65 years or older). The odds of influenza vaccination among beneficiaries with laboratory-confirmed influenza-positive status (cases) were compared to the odds of influenza vaccination among beneficiaries who tested influenza-negative (controls), using backward stepwise multiple logistic regression models in SAS /STAT software, version 9.4 (2014, SAS Institute, Cary, NC). End-of-season VE was calculated as (1 – adjusted odds ratio) × 100% and estimates were presented with their associated 95% confidence intervals (CIs). VE estimates were adjusted for potential confounding factors, such as age group, sex, specimen collection date, and geographical region (i.e., eastern U.S., western U.S., and outside the continental U.S.). A point estimate of VE was considered statistically significant if the 95% CI did not contain zero or a negative value. In addition to VE estimated for all influenza in the entire beneficiary population, VE was estimated against any specific influenza, by influenza virus (sub)types in separate models [i.e., influenza A, A(H1N1)pdm09, A(H3N2), or influenza B], and in stratified models by beneficiary age group (i.e., children, adults, or the elderly).

RESULTS

Influenza virus and other pathogen surveillance

During the 2019–2020 influenza season, a total of 28,176 specimens were collected from 4 commands including 114 geographical locations **(Table 1, data not shown)**. These specimens included 23,466 (83.3%) from U.S. Northern Command, 2,989 (10.6%) from U.S. European Command, 1,699 (6.0%) from U.S. Indo-Pacific Command, and 22 (0.1%) from U.S. Central Command **(data not shown)**. Of those collected, 15,763 (55.9%) specimens were from male outpatients and 12,413 (44.1%) were from female outpatients **(data not shown)**. There were 13,353 (47.4%) specimens collected from service members, 7,091 (25.2%) from children, and 7,732 (27.4%) from other non-service member beneficiaries including retirees and spouses, etc. (18 years or older) **(data not shown)**.

The distribution of influenza (sub) types/lineages identified during the influenza season is shown in **Table 1**. Of the specimens tested, 5,529 (19.6%) were confirmed influenza positive. Among the 3,098 influenza A-positive specimens that were subtyped, 2,885 (93.1%) were influenza A(H1N1)pdm09, and 213 (6.9%) were influenza A(H3N2). A total of 2,336 specimens were characterized as influenza B positive. Of the influenza B with lineage information available, 856 (99.3%) belonged to the B/Victoria lineage, and 6 (0.7%) belonged to B/Yamagata lineage. Moreover, 31 specimens tested positive for dual influenza infections. Among the 7,681 (27.3%) noninfluenza pathogens, 6,865 (89.4%) specimens were found to be positive for single noninfluenza respiratory pathogens, and 816 (10.6%) for noninfluenza pathogen coinfections **(Table 1)**.

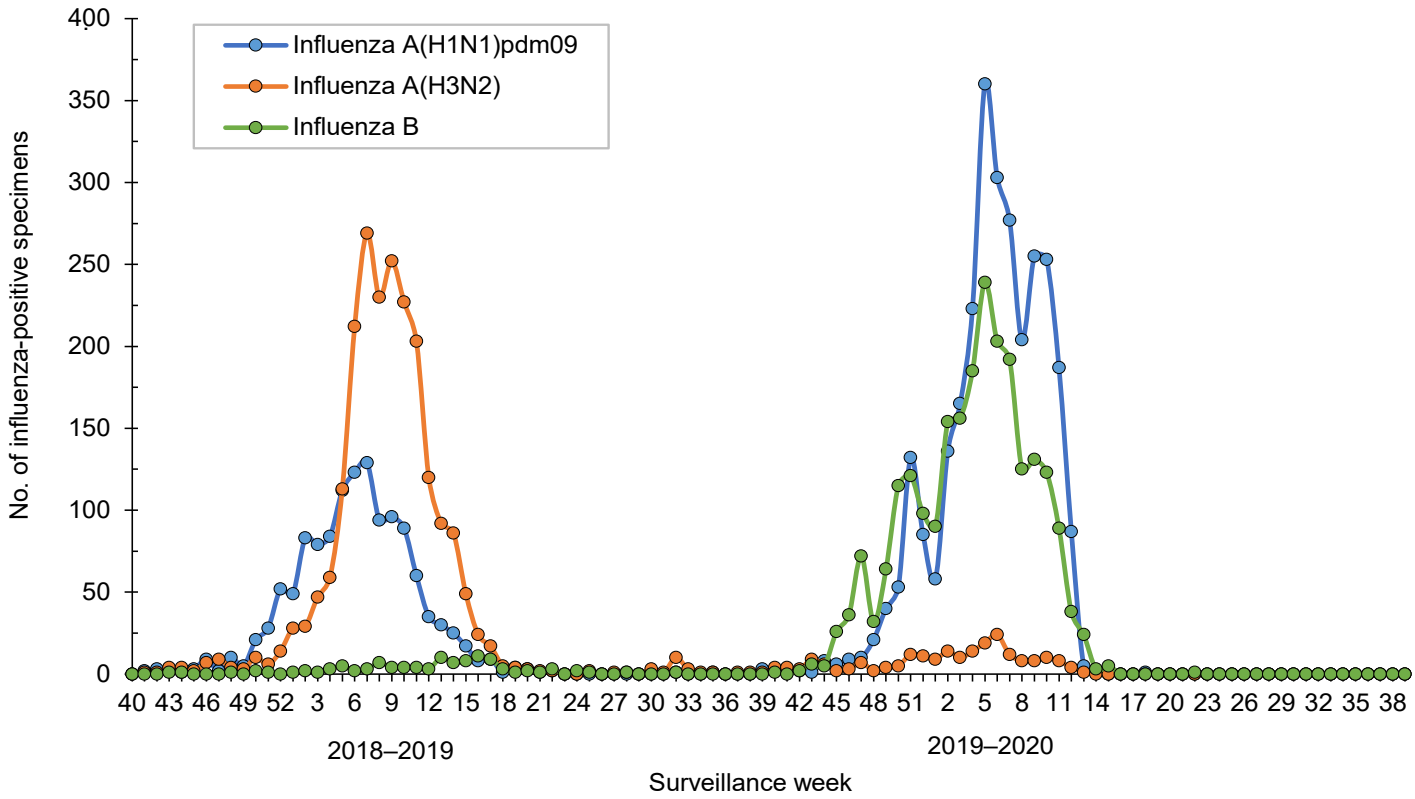
The numbers and percentages of influenza (sub)types that tested positive by week are presented in **Figures 1a** and **1b**. Also, data from the 2018–2019 influenza season are provided to indicate seasonal influenza change from year to year. The influenza seasonal pattern generally revealed the influenza activity in the area of Northern Command from which the vast majority of specimens were collected. During the beginning of the influenza season (surveillance weeks 40–44;

TABLE 1. Influenza and other respiratory pathogens, DoD beneficiaries, 2019–2020 influenza season

Pathogen	No. of specimens[a]	% total
Total	28,176	100
Influenza detected	5,529	19.6
A(H1N1)pdm09	2,885	10.2
Single infection	2,584	9.2
Coinfection[b]	301	1.1
A(H3N2)	213	0.8
Single infection	180	0.6
Coinfection[b]	33	0.1
A/Not subtyped	64	0.2
Single infection	53	0.2
Coinfection[b]	11	0.0
B/Not lineage classified	1,474	5.2
Single infection	1,293	4.6
Coinfection[b]	181	0.6
B/Victoria	856	3.0
Single infection	766	2.7
Coinfection[b]	90	0.3
B/Yamagata	6	0.0
Single infection	6	0.0
Dual influenza	31	0.1
Non-influenza pathogen detected	7,681	27.3
Adenovirus	278	1.0
Chlamydophila pneumoniae	60	0.2
Coronavirus	953	3.4
Human bocavirus	94	0.3
Human metapneumovirus	813	2.9
Mycoplasma pneumoniae	127	0.5
Parainfluenza	454	1.6
Respiratory syncytial virus	782	2.8
Rhinovirus/enterovirus	3,304	11.7
Non-influenza pathogen coinfection	816	2.9
Other	14,966	53.1
No pathogen detected	14,605	51.8
Test result inconclusive	2	0.0
Test not performed	359	1.3

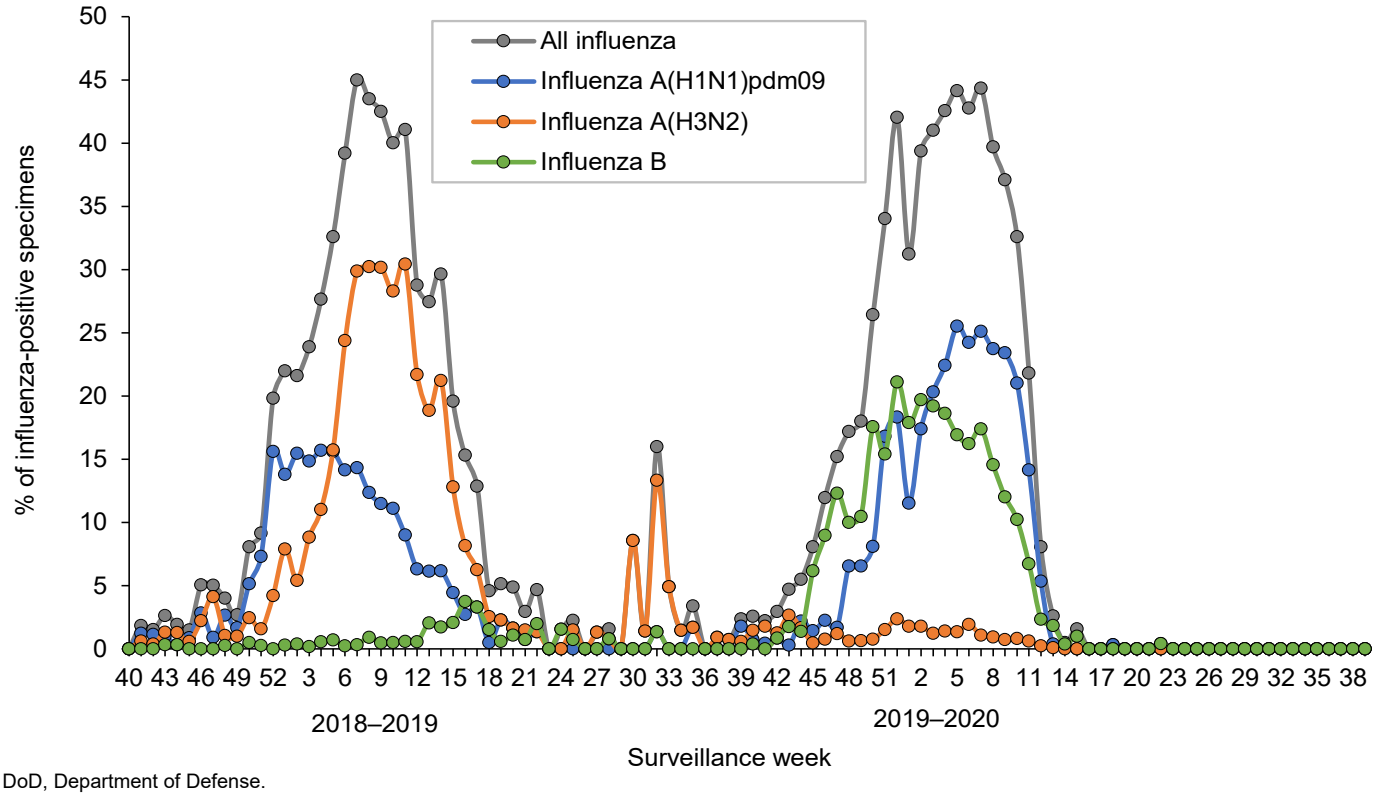
[a]Specimens contributed by partner laboratories for sequence analysis alone were not included.
[b]Coinfection with 1 or more non-influenza pathogens.
DoD, Department of Defense; No., number.

FIGURE 1a. Number of influenza-positive specimens, by influenza (sub)type and surveillance week, DoD beneficiaries, 2018–2019 and 2019–2020 influenza seasons



DoD, Department of Defense; No., number.

FIGURE 1b. Percentage of influenza-positive specimens, by influenza (sub)type and surveillance week, DoD beneficiaries, 2018–2019 and 2019–2020 influenza seasons



DoD, Department of Defense.

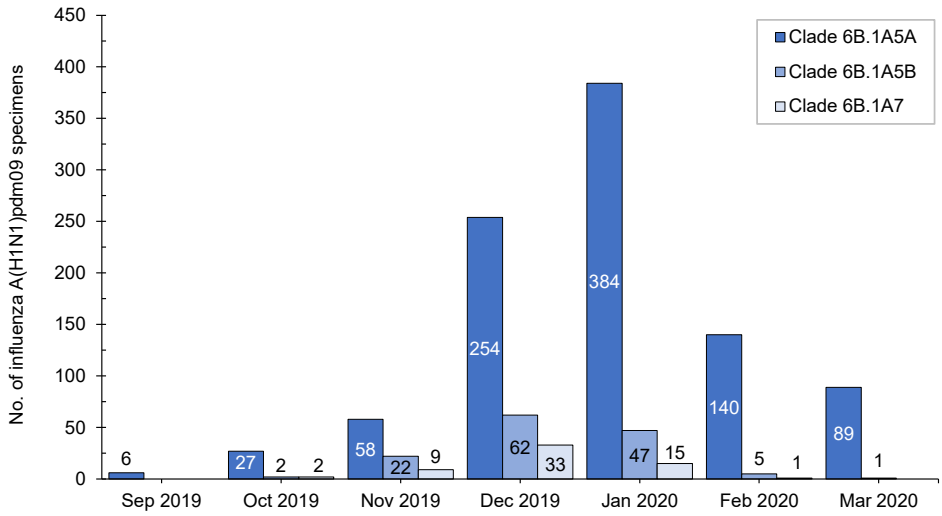
29 September to 2 November 2019), low levels of influenza activity occurred, with small positivity rates of influenza A(H1N1) pdm09, influenza A(H3N2), and influenza B viruses (<3.0%; **Figure 1b**). However, starting from surveillance week 45 (3–9 November 2019), influenza B was predominant. Three weeks thereafter, influenza A(H1N1)pdm09 activity increased quickly. From surveillance weeks 50 through 11 (8 December 2019 to 14 March 2020), the activities of both influenza B and influenza A(H1N1)pdm09 remained highly elevated. The highest numbers of specimens that tested positive for both influenza B and A(H1N1)pdm09 occurred in surveillance week 7 (9–15 February 2020; **Figure 1a**). The results indicated peak influenza activity for the influenza season occurred from the end of December 2019 through the end of February 2020.

Genetic characteristics of influenza virus

From 30 September 2019 through 14 August 2020, 2,652 influenza sequences were either generated at USAFSAM or contributed by partner laboratories at the Armed Forces Research Institute of Medical Sciences (AFRIMS), the Naval Medical Research Unit No. 2 (NAMRU-2), the Naval Health Research Center (NHRC), or the U.S. Army Medical Research Directorate-Kenya (USAMRD-K). In total, 1,157 (43.6%) influenza A(H1N1)pdm09, 255 (9.6%) influenza A(H3N2), 1,229 (46.3%) influenza B/Victoria lineage **(Figures 2a-2c)**, and 11 (0.4%) influenza B/Yamagata lineage hemagglutinin (HA) sequences were analyzed **(data not shown)**.

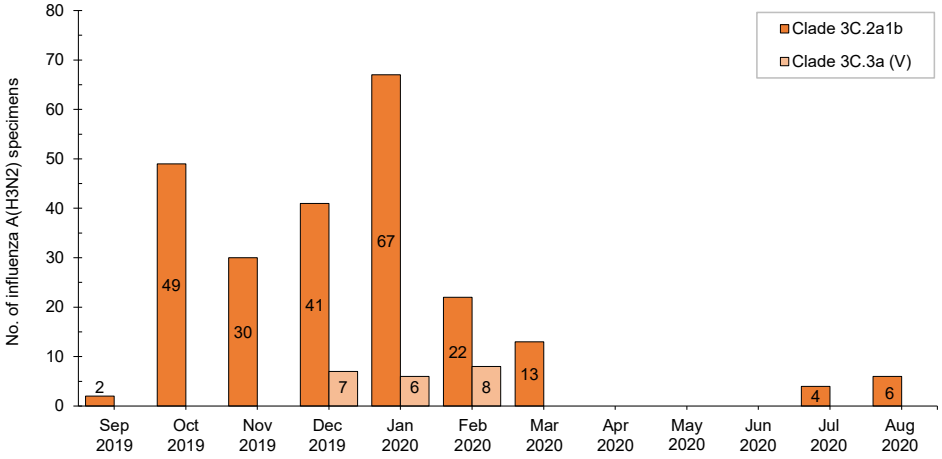
All 1,157 of the influenza A(H1N1) pdm09 HA sequences were in clade 6B.1A **(Figure 2a)** and contained the substitution S183P relative to the vaccine strain, with 82.8% in subgroup 183P-5A, 12.0% in 183P-5B, and 5.2% in 183P-7 **(data not shown)**. The average HA protein similarity of A(H1N1) pdm09 for the influenza season was 98.0% ± 0.38% (mean ± SD) compared with the 2019–2020 influenza vaccine A(H1N1) pdm09 component, A/Brisbane/02/2018-like virus (clade 6B.1A) **(data not shown)**. Among the 255 influenza A(H3N2) HA sequences, 91.8% were in clade 3C.2a1b and 8.2% were in clade 3C.3a **(Figure 2b)**. The average HA protein similarity of A(H3N2) for the

FIGURE 2a. Influenza A(H1N1)pdm09 clade dynamics, DoD beneficiaries, 2019–2020 influenza season (n=1,157)



DoD, Department of Defense; No., number.

FIGURE 2b. Influenza A(H3N2) clade dynamics, DoD beneficiaries, 2019–2020 influenza season (n=255)



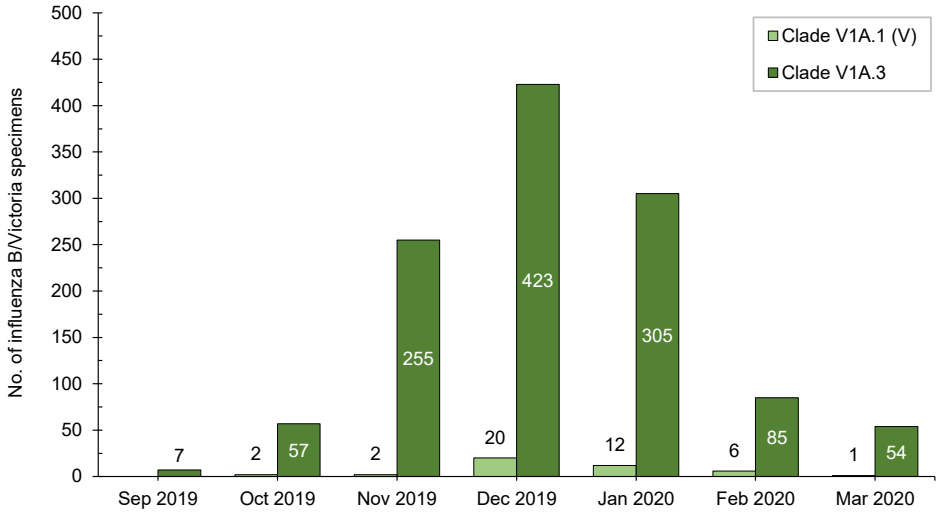
DoD, Department of Defense; No., number.

influenza season was 96.5% ± 0.91% compared with the 2019–2020 influenza vaccine A(H3N2) component, A/Kansas/14/2017-like virus (clade 3C.3a) **(data not shown)**. Among the 1,229 influenza B/Victoria HA sequences, 96.5% were in clade V1A.3 containing a three amino acid deletion at positions 162–164 and 3.5% were in clade V1A.1 containing a two amino acid deletion at positions 162–163 **(Figure 2c)**. The average HA protein similarity of B/Victoria for the influenza season was 98.3% ± 0.24% compared with the 2019–2020 influenza vaccine B/Victoria component, B/Colorado/06/2017-like virus (clade V1A.1) **(data not shown)**. All 11 of the influenza B/Yamagata HA sequences were in clade Y3 and had an average protein similarity for the influenza season of 99.1% ± 0.08% compared with the 2018–2019 influenza vaccine B/Yamagata component, B/Phuket/3073/2013-like virus (clade Y3), which was included in the quadrivalent vaccine only **(data not shown)**.

Vaccine effectiveness

For the VE analysis, data were limited to surveillance weeks 46–12 (10 November 2019 to 21 March 2020). There were 2,299 influenza-positive cases and 3,518 influenza-negative controls included in the VE

FIGURE 2c. Influenza B/Victoria clade dynamics, DoD beneficiaries, 2019–2020 influenza season (n=1,229)



DoD, Department of Defense; No., number.

TABLE 2. Characteristics of the surveillance population used for vaccine effectiveness analysis, DoD beneficiaries, 2019–2020 influenza season

	Cases		Controls		
	No.	%	No.	%	p-value
Total	2,299	100.0	3,518	100.0	
Sex					
Male	1,013	44.1	1,412	40.1	.003
Female	1,286	55.9	2,106	59.9	
Age group					
6 months–17 years	1,401	60.9	1,688	48.0	<.001
18–64 years	824	35.8	1,511	43.0	
65+ years	74	3.2	319	9.1	
Month of illness					
November 2019	112	4.9	352	10.0	<.001
December 2019	385	16.7	659	18.7	
January 2020	763	33.2	837	23.8	
February 2020	764	33.2	835	23.7	
March 2020	275	12.0	835	23.7	
Geographic region[a]					
Eastern U.S.	900	39.1	1,174	33.4	<.001
Western U.S.	1,043	45.4	1,545	43.9	
Outside continental U.S.	356	15.5	799	22.7	
Vaccination status					
Vaccinated	1,059	46.1	2,158	61.3	<.001
Unvaccinated	1,240	53.9	1,360	38.7	
Influenza status					
A(H1N1)pdm09	1,116	48.5	0	0.0	<.001
A(H3N2)	89	3.9	0	0.0	
A(not subtyped)	22	1.0	0	0.0	
B	1,072	46.6	0	0.0	
Not influenza	0	0.0	3,518	100.0	

[a]Eastern U.S. includes regions 1–5; western U.S. includes regions 6–10. Regions 1–10 are the U.S. Health and Human Services Regions (except for Guam, Alaska, and Hawaii).
DoD, Department of Defense; No., number.

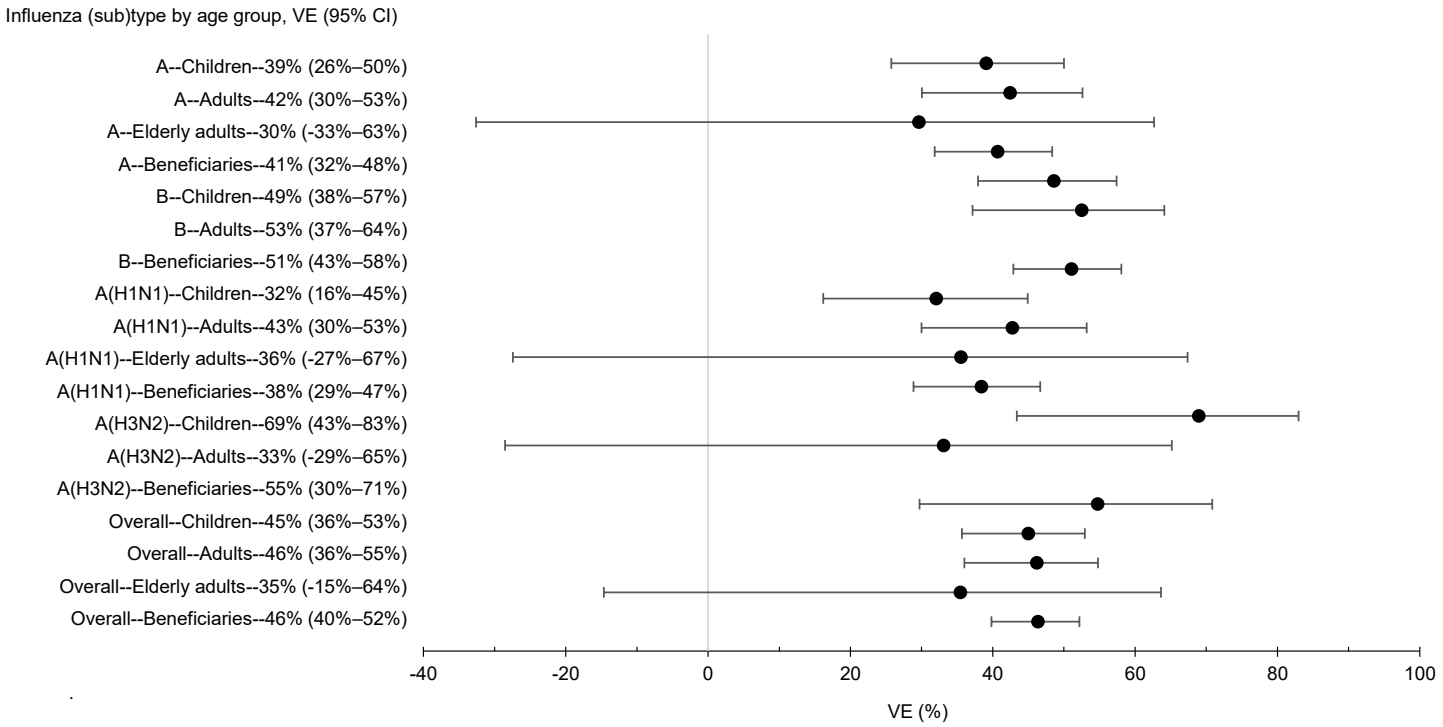
analysis **(Table 2)**. Of the influenza-positive cases, 46.1% had been vaccinated against influenza and 61.3% of the influenza-negative controls had been vaccinated. Influenza A and influenza B accounted for 53.4% and 46.6% of influenza-positive cases, respectively. Of the 1,227 outpatients infected with influenza A virus, only a small proportion (7.3%) were infected with influenza A(H3N2) virus **(Table 2)**.

Among medically attended beneficiaries, adjusted VE against laboratory-confirmed influenza types was 46% (95% CI: 40%–52%) overall, including 38% (95% CI: 29%–47%) against influenza A(H1N1) pdm09, 55% (95% CI: 30%–71%) against influenza A(H3N2), and 51% (95% CI: 43%–58%) against influenza B **(Figure 3)**. In addition, VE was estimated against any influenza viruses by age group. For children, the adjusted VE was 45% (95% CI: 36%–53%) against all influenza viruses, including 32% (95% CI: 16%–45%) against influenza A(H1N1)pdm09, 69% (95% CI: 43%–83%) against influenza A(H3N2), and 49% (95% CI: 38%–57%) against influenza B. In contrast, the adjusted VE for adults (18–64 years of age) was 46% (95% CI: 36%–55%) against any influenza viruses, including 43% (95% CI: 30%–53%) against influenza A(H1N1)pdm09, 33% (95% CI: -29%–65%) against influenza A(H3N2), and 53% (37%–64%) against influenza B. For elderly adults (≥65 years of age), none of the estimates of VE against any influenza viruses were statistically significant **(Figure 3)**.

EDITORIAL COMMENT

During the 2018–2019 influenza season, influenza B activity was low; however, for the 2019–2020 influenza season, influenza B made an early appearance and predominated at the start of the season, then maintained high activity until the end of March 2020. Influenza A(H1N1)pdm09 was active during the 2018–2019 influenza season, but its activity was higher during the 2019–2020 influenza season. In contrast to relatively high influenza A(H1N1) pdm09 activity during the 2019–2020 influenza seasons, influenza A(H3N2) was

FIGURE 3. Adjusted end-of-season vaccine effectiveness estimates, by influenza (sub)type, and age group, DoD beneficiaries, 2019–2020 influenza season



DoD, Department of Defense; VE, vaccine effectiveness; CI, confidence interval; A, influenza A; B, influenza B.

the dominant influenza A subtype circulating during the 2018–2019 season, but its activity was very low during the 2019–2020 influenza season. Overall, the magnitude of the influenza positivity rate during the 2019–2020 influenza season was similar to that during the 2018–2019 influenza season, with a peak influenza positivity among ILI-related specimens of 44%.

During the 2019–2020 influenza season, multiple genetic clades circulated for influenza A(H1N1)pdm09, A(H3N2), and B/Victoria. For these 3 (sub)types, the predominantly circulating genetic clades differed from the strain composition of the 2019–2020 influenza vaccine, with data suggesting that these clades are antigenically distinct with reduced inhibition by the vaccine.[6] Influenza viruses from these predominating clades were selected for the 2020–2021 influenza vaccine recommendations,[6] and there are no indications in the current data to suggest significant genetic changes in the circulating strains from the vaccine selections.

For the 2018–2019 influenza season, DoDGRS reported that adjusted VE against any influenza in the DoD beneficiary population was lower (30%; 95% CI: 22%–38%) than for the 2019–2020 influenza season.[1] Similarly, a lower VE (29%; 95% CI: 21%–35%) was found among participants during the 2018–2019 season using U.S. Influenza Vaccine Effectiveness Network data.[7] The decreased VE was associated with the spread of antigenically drifted influenza A(H3N2) viruses during the 2018–2019 season.[7] However, for the 2019–2020 influenza season, the estimated VE against all influenza based on DoD beneficiaries regardless of age group was higher (46%; 95% CI: 40%–52%) than the VE for the previous season. This finding is consistent with the interim VE estimate (45%; 95% CI: 36%–53%) against any influenza virus obtained using data from 4,112 children and adults enrolled in the U.S. Influenza Vaccine Effectiveness Network during 23 October 2019–25 January 2020.[8] The end-of-season VE estimates from the current analysis suggested that the 2019–2020 season's influenza vaccine was moderately effective against influenza viruses.

VE estimates were adjusted using potential confounders (e.g., age group, specimen collection date, geographical region) as covariates in multiple logistic regression models. However, due to the lack of randomization, inherent in any observational study, it is difficult to rule out unmeasured confounding factors (e.g., vaccination history) as a possible alternative explanation for the findings. In addition, the efforts to estimate the effect of vaccination rely on the DoD surveillance platform for data acquisition. The findings in the current study might be subject to limitations during the DoD surveillance data collection process. One important limitation is potential non-differential misclassification of vaccination status due to poor recall or record errors on the self-reported questionnaire.[9] Furthermore, it should be noted that VE was estimated from data across geographically disparate areas. Although effort was made to statistically adjust for the potential confounding effect of geographical region, there may still be residual heterogeneity across geographical regions that was not accounted for, which would potentially impact the estimation of VE.

The overall outpatient population was relatively large for estimating VE. However, when outpatients were stratified based on

age group and influenza virus sub(type) or lineage, VE in certain subgroups of interest could not be accurately estimated or even at all. For instance, in the current study, it was not possible to estimate VE against influenza A(H3N2) in the elderly. To improve the statistical power of tests, further study is warranted to accurately estimate VE, by combining DoDGRS surveillance data over multiple influenza seasons using generalized linear mixed modeling. Indeed, the measurement of influenza VE can be affected by many factors such as age and health of influenza vaccine recipients, (sub) type/lineage of circulating viruses, as well as the study methodology used.[10] Combining data from multiple influenza seasons may permit influenza VE analysis of relationships between VE and several viral and host factors.

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Acknowledgments: The authors would like to thank the Department of Defense Global Respiratory Pathogen Surveillance Program and its sentinel partners, and the U.S. Air Force School of Aerospace Medicine epidemiology laboratory for their valuable contributions to this work.

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Influenza Outbreak During Exercise Talisman Sabre, Queensland, Australia, July 2019

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Influenza appeared in Queensland, Australia during Exercise Talisman Sabre (TS-19) in July 2019 with an early focus within the New Zealand Defence Force members arriving in Australia aboard *HMNZS Canterbury*. A total of 76 cases of influenza-like illness (ILI) were reported, of which 43 were confirmed by rapid diagnostic tests to be influenza A (n=32) and B (n=11). Australia's influenza season (starting in March, peaked in July 2019) exposed large numbers of military members to a virus for which they had been suboptimally immunized either because of low uptake of the Southern Hemisphere vaccine by Australians/New Zealanders who were not mandated to be immunized, or because U.S. soldiers had received only the Northern Hemisphere vaccine for the 2018–2019 season. A low-intensity clinical unit separate from the main exercise was used as a means of isolating ILI cases both to facilitate their treatment and limit disease spread. Despite disease rates of <1%, influenza still had a major impact on TS-19 mostly in terms of the considerable medical resources required to manage ILI.

WHAT ARE THE NEW FINDINGS?

Influenza remains a threat during military exercises even in highly immunized populations mainly because of the virus's ability to cause illness in large numbers of soldiers which can overload an austere medical system designed mainly to care for traumatic injuries. Use of low-intensity clinical isolation areas is one means of limiting influenza's impact on major exercises scheduled during expected influenza transmission seasons.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Immunization remains the primary force health protection measure for military exercises, but exercises that extend into the Southern Hemisphere may result in the inability to use the most appropriate hemispheric vaccine because of restricted access to products not manufactured for the domestic U.S. market.

Joint and combined military exercises concentrate large numbers of military members under circumstances that favor introduction of new viruses into stressed populations. Currently, the risk influenza poses to military exercises is not mass mortality but mass casualties that could overwhelm the usually limited medical support capabilities designed mainly to treat traumatic injuries during field exercises. This report summarizes an influenza epidemic that occurred within a combined military exercise, Talisman Sabre (TS-19), which took place in Queensland, Australia during July–August 2019.

Talisman Sabre is a long-running series of military exercises in which more than 32,000 soldiers, sailors, and marines mainly from Australia, New Zealand, and the U.S. gather in Queensland in northeastern Australia at mid-year for a 3-week field exercise. Although each national contingent operates under its own command chain, there is considerable intermixing of forces. Southern Hemisphere influenza transmission season occurs at midyear with a usual peak in August/September.

In 2009, when the influenza A(H1N1) virus's potential was not yet known, advanced diagnostic capability was deployed into the field during Talisman Sabre and enabled the detection of 12 persons with the pandemic influenza strain.[1] Fortunately the pathogenic potential of the 2009 influenza A(H1N1) strain was inferior to its distant predecessor of 1918, and there was no serious disruption of the exercise although some naval units were removed from participation when influenza appeared shipboard.

Immunization remains the primary force health protection measure against influenza, although protection may be suboptimal depending on the degree to which the vaccine strains chosen for production match the viruses that eventually circulate. Although U.S. forces have high immunization participation rates because influenza vaccination is mandatory, they are immunized with vaccine tailored for the Northern Hemisphere and have usually been immunized more than 6 months prior to TS-19. While influenza immunization of Australian and New Zealand soldiers is strongly encouraged, it is not mandatory for exercise participation, and immunization rates are usually less than ideal.

Additional concerns regarding influenza during TS-19 were generated by the early start to the influenza season in March 2019 in Australia. The start of this season was dominated by influenza A(H3N2) viruses reminiscent of the relatively severe 2017 season (the so-called "Aussie flu").[2] The U.S. Indo-Pacific Command (INDOPACOM) Surgeon's office had investigated the possibility of using the Southern Hemisphere influenza vaccine for U.S. forces during port visits of *USS Carl Vinson* to Sydney in June 2019, but timing and supply issues made such use of the vaccine impractical.

METHODS

As the largest scheduled series of military exercises in Australia, the biennial TS-19 involved a great deal of preliminary healthcare planning which began during planning conferences in Hawaii in October 2018 and March 2019. Influenza was an identified medical threat subject to usual precautions and immunization. Deployed forces were supported by a Role 1 clinic (basic ambulatory care) at Rockhampton, a holding/isolation ward at Williamson Airfield, and a Role 2+ (enhanced care) facility from the 2nd General Health Battalion at Shoalwater Bay, as well as on-board medical capability from *USS Wasp, HMAS Canberra,* and *HMAS Adelaide*. Disease surveillance systems were instituted upon buildup to the official start of the exercise on 17 June 2019.

Influenza-like illness (ILI) was defined as an illness marked by fever greater than 100 °F with either cough or sore throat in the absence of a known cause other than influenza. Influenza testing was performed on nasal swabs using a rapid detection test, the Quidel QuickVue Influenza A+B test. All influenza-positive samples were then confirmed via polymerase chain reaction testing on the Biofire FilmArray using the Respiratory Panel 2 plus by the pathology department at the Role 2+ facility.

RESULTS

ILI cases initially appeared among the New Zealand Defence Force (NZDF) contingent, which had arrived largely aboard the *HMNZS Canterbury* on or about 7 July 2019 after a 3-day transit from Auckland. Investigation of the ship's berthing arrangements indicated person-to-person spread of ILI in up to 12 cases while shipboard. The major concern was that the occurrence of several cases of influenza early in the exercise foreshadowed a much larger problem that would arise later when many more soldiers were involved under austere field conditions. A communicable disease plan was revised and instituted in early July 2019. The emphasis was on rapid identification of ILI cases and patient management in Rockhampton away from the main body of troops, which represented more an isolation effort than a quarantine effort. A 20-bed low-intensity clinical facility was set up (with contingency plans for another 20 beds if required) and largely staffed by Australian Defence Force (ADF) reserve component members. Patients did not require inpatient care but could not be left in an austere field environment with ILI symptoms. Oseltamivir was provided for treatment and to reduce infectiousness among those found to be rapid diagnostic test-positive for the influenza virus.

From 17 June 2019 through 27 July 2019, 254 sick call visits were recorded at the various medical treatment units and 76 patients were diagnosed with ILI on clinical grounds. Of the 76 ILI cases that were identified, 32 (42.1%) tested positive for influenza A and 11 (14.5%) for influenza B. These illnesses represented a substantial proportion of all sick call visits during TS-19 as shown in **Figure 1**. The remaining 33 tests (43.4%) were negative for influenza virus. National contingent composition is shown in **Figure 2** and illustrates the early predominance of cases of influenza among NZDF members aboard *Her Majesty's New Zealand Ship (HMNZS) Canterbury*. No other shipboard outbreaks were noted. Confirmed influenza cases peaked at 10 per day on 12 July 2019 before the formal start of the exercise **(data not shown)**.

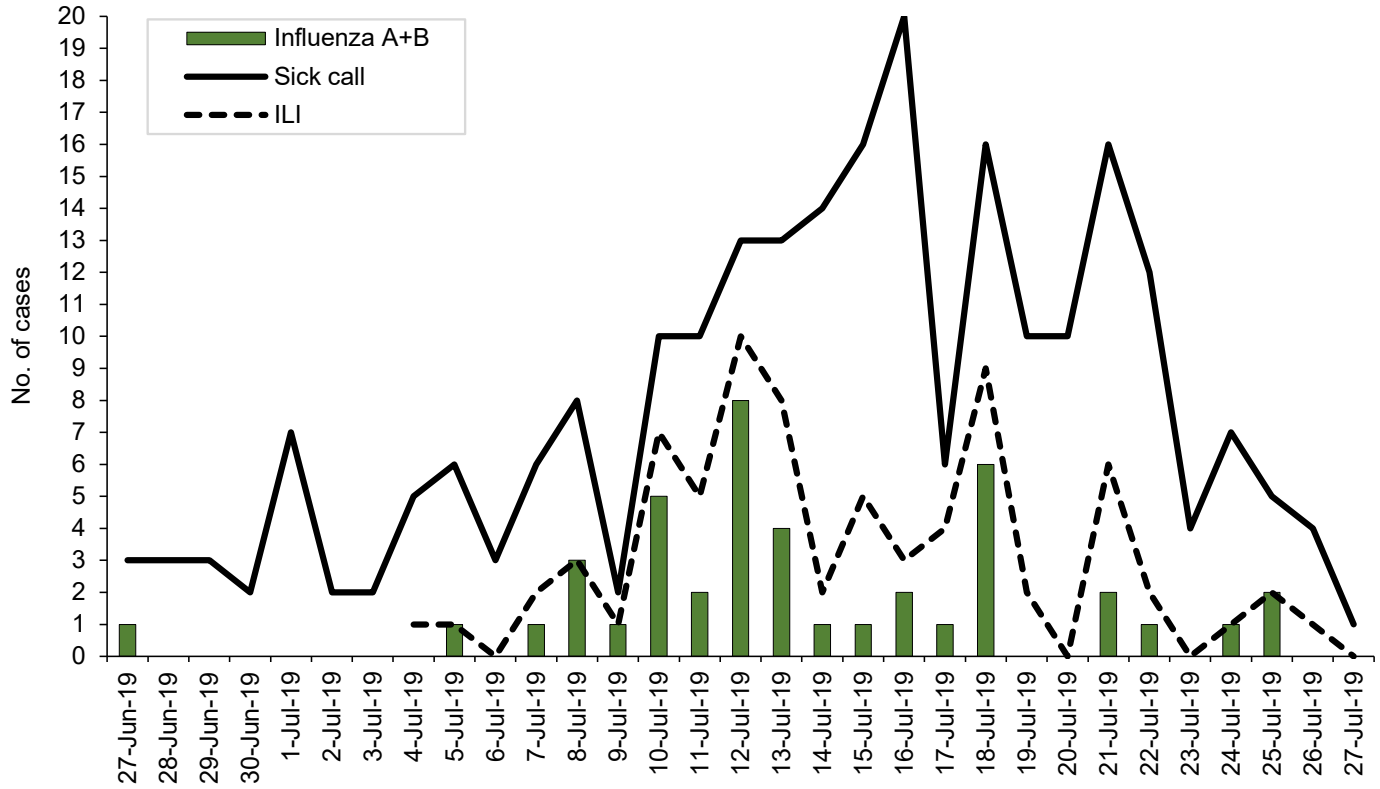
EDITORIAL COMMENT

Respiratory infections have long been known as threats to military operations and many modern exercises have been disrupted by viruses including influenza.[3-4] TS-19 was not unique in this regard, but its location in Australia presented additional challenges. The exercise occurred during the peak of influenza season in the Southern Hemisphere, and the early phase of the outbreak placed particular focus on a naval ship. In addition, there was the possibility that influenza cases would affect a range of national groups (U.S., Australia, New Zealand, Canada, UK, Japan) each employing different approaches to addressing influenza. Rapid diagnostics have evolved to become important tools in the management of ILI; now it is possible to quickly determine whether the causative pathogen is influenza and then manage the public health consequences of a virus with such epidemic potential. For TS-19, a special isolation facility was set up, not because otherwise healthy soldiers were thought to be at risk of life-threatening disease, but rather because of the likelihood that the limited medical capability of usual field medical facilities would otherwise be overwhelmed by sick soldiers. During military exercises in a soldier population which has already been immunized, the remaining option in managing an influenza outbreak consists of isolating ILI cases from uninfected troops who are receiving prophylactic antiviral treatment. Isolation of cases within a health facility away from troops under antiviral treatment is the best way to minimize generalized spread in the population which should have already been immunized. The civilian healthcare system of Queensland was extremely supportive of military medical efforts during TS-19, but it could not be expected to house multiple influenza cases that did not otherwise require hospitalization. The low-intensity clinical facility in Rockhampton was a pragmatic response that worked well to optimize treatment and likely minimized the total number of ILI cases.

Influenza during joint and combined military exercises often is seen as particularly important to Air Forces because responding to the virus may require suspension of flight operations, but naval operations are also vulnerable to influenza. As demonstrated during a 1996 outbreak on the *USS Arkansas*, even highly vaccinated crews may be subject to high attack rates (42%) which may result in aborted exercises if single individuals with influenza A(H3N2) viruses poorly matched to seasonal influenza vaccine infect the ship's crew.[5] The situation was never so dire on *HMNZS Canterbury*, but it did serve as a focus of initial influenza cases that could have infected a much larger number of soldiers in the absence of an effective communicable disease plan.

Influenza immunization is far from perfect, but there is hope that universal

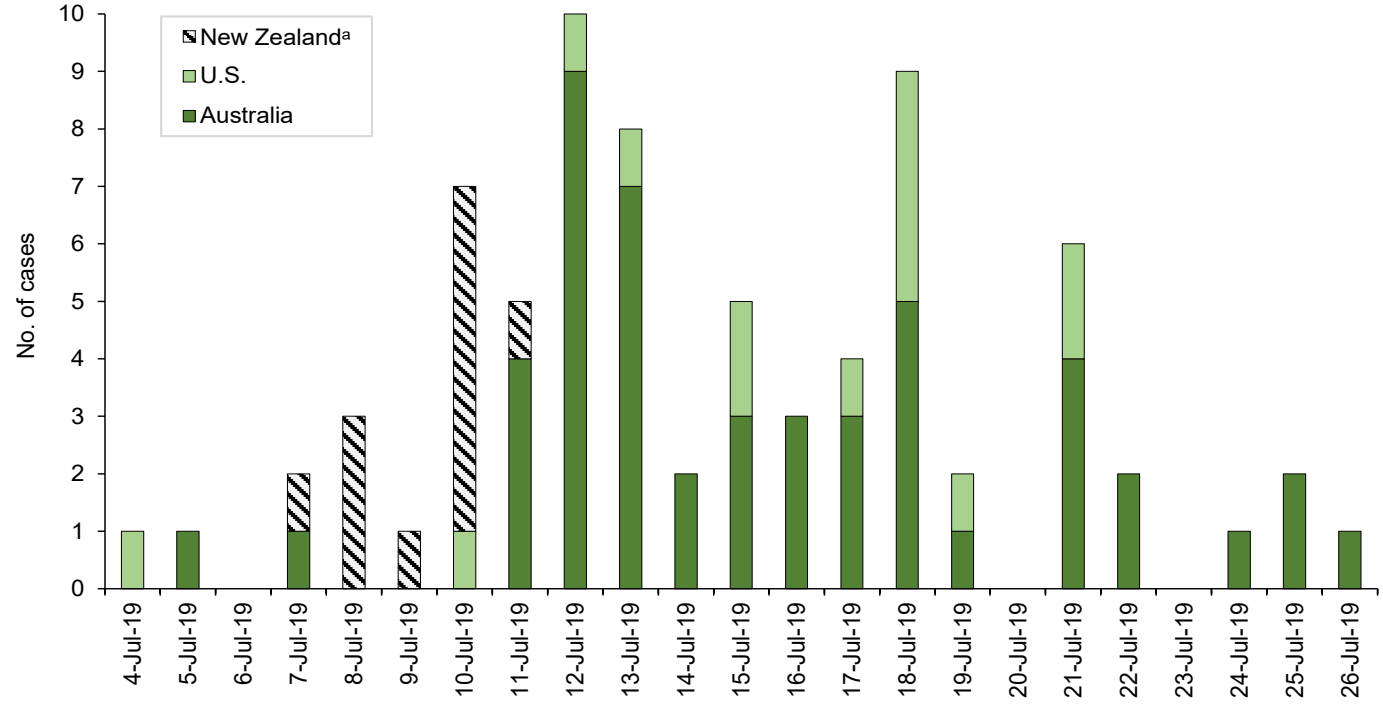
FIGURE 1. Epidemic curve of ILI[a] during Exercise Talisman Sabre, Queensland, Australia, 27 June–27 July 2019



[a]Cases having positive results for influenza A (n=32) or B (n=11) are shown as a subset of ILI cases.

ILI, influenza-like illness; No., number.

FIGURE 2. ILI[a] during Exercise Talisman Sabre, by national group, Queensland, Australia, 4 July–26 July 2019



[a]Early contribution of New Zealand Defence Force members who had transited to Queensland on *Her Majesty's New Zealand Ship (HMNZS) Canterbury* in late June 2019.

ILI, influenza-like illness; No., number.

influenza vaccines may eventually be developed that will end the evolutionary arms race conducted each year using seasonal vaccines that are at best modestly effective.[6] The particular problem experienced during TS-19 was that the Southern Hemisphere influenza A(H3N2) 2019 vaccine component (A/Switzerland/8060/2017) was an updated version of what the U.S. forces had been immunized against (A/Singapore/INFIMH-16-0019/2016) which used the Northern Hemisphere 2018–2019 vaccine.[7] Whether this would have made a difference was unknown, but valid concerns had been raised because during the relatively severe 2017 Australian season the influenza A(H3N2) component's vaccine efficacy was estimated to be 10% (95% confidence interval: -16%–31%).[6] Although adequate Southern Hemisphere 2019 vaccine was available, it was not approved by the U.S. Food and Drug Administration as there was no motivation for a manufacturer to register a vaccine not intended for U.S. use. Stringent regulatory authority approval by the Australian Therapeutic Goods Administration existed but was bureaucratically insufficient for use in U.S. forces. Further inquiry regarding exceptions to policy might be useful in improving management of influenza immunization for soldiers outside their usual jurisdiction. Such exceptions may prove important as future influenza pandemics are unlikely to provide sufficient time for preparation of stocks of new vaccines, as was demonstrated during 2009 when vaccine became available only after the peak of the pandemic.

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Acknowledgements: The authors thank the many military medical personnel from Australia, New Zealand, and the U.S. who helped manage the ill service members during Exercise Talisman Sabre 2019.

Disclaimer: The opinions expressed are those of the authors and do not necessarily reflect those of the Australian Defence Force or the U.S. Department of Defense.

Conflicts of interest: The authors do not claim any conflict of interest.

Funding: Authors are employees of the Australian Defence Organization. No specific funding was given for this epidemiological study.

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Update: Sexually Transmitted Infections, Active Component, U.S. Armed Forces, 2012–2020

This report summarizes incidence rates of the 5 most common sexually transmitted infections (STIs) among active component service members of the U.S. Armed Forces during 2012–2020. Infections with chlamydia were the most common, followed in decreasing order of frequency by infections with genital human papillomavirus (HPV), gonorrhea, genital herpes simplex virus (HSV), and syphilis. Compared to males, females had higher rates of all STIs except for syphilis. In general, compared to their respective counterparts, younger service members, non-Hispanic Blacks, soldiers, and enlisted members had higher incidence rates of STIs. Although rates of chlamydia and gonorrhea increased among both male and female service members during the latter half of the surveillance period, there was a notable decrease in the rates of chlamydia in both sexes from 2019 through 2020, and the rates of gonorrhea decreased slightly for both males and females during 2018–2020. Rates of syphilis increased among male service members through 2018 but decreased during 2019–2020; the rate among female service members increased between 2012 and 2014, generally leveled off through 2018, increased in 2019, and then decreased in 2020. Rates of genital HSV declined during the period from 2016 through 2020 for both male and female service members. The rates of genital HPV decreased steadily between 2012 and 2020 in males and declined between 2015 and 2020 among females. Similarities to and differences from the findings of the last *MSMR* update on STIs are discussed.

WHAT ARE THE NEW FINDINGS?

The incidence of chlamydia and gonorrhea generally increased among male and female service members in the latter half of the surveillance period; however, the rates decreased in 2020. The incidence of genital HPV and HSV continued to decrease. The incidence of syphilis decreased among male and female service members in 2020.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

STIs can adversely impact service members' availability and ability to perform their duties and can result in serious medical sequelae if untreated. Establishing standards for screening, testing, treatment, and reporting would likely improve efforts to detect STI-related health threats. Continued behavioral risk-reduction interventions are needed to counter STIs among military service members.

Sexually transmitted infections (STIs) are relevant to the U.S. military because of their relatively high incidence, adverse impact on service members' availability and ability to perform their duties, and potential for serious medical sequelae if untreated.[1] Two of the most common bacterial STIs are caused by *Chlamydia trachomatis* (chlamydia) and *Neisseria gonorrhoeae* (gonorrhea). Rates of chlamydia and gonorrhea have been steadily increasing in the general U.S. population among both males and females since 2000.[2] A March 2020 *MSMR* report documented more than 221,000 incident infections of chlamydia and more than 34,000 incident infections of gonorrhea among active component U.S. military members between 2011 and 2019, with increasing incidence rates of these conditions among both males and females in the latter half of the surveillance period, mirroring trends in the general U.S. population.[3]

Another important bacterial STI is syphilis, which is caused by the bacterium *Treponema pallidum*. Rates of primary and secondary syphilis in the U.S. have risen steadily from a historic low in 2001 and increased 71.4% from 6.3 cases per 100,000 persons in 2014 to 10.8 cases per 100,000 persons in 2018.[2] This upward trend is mirrored in the active component of the U.S. Armed Forces, in which the incidence of syphilis (of any type) increased steadily between 2011 and 2018, with most of the increase after 2014 occurring among males.[3] Although these 3 relatively common bacterial STIs are curable with antibiotics, there is continued concern regarding the threat of multidrug resistance.[4–6]

Common viral STIs in the U.S. include infections caused by human papillomavirus (HPV) and genital herpes simplex virus (HSV). HPVs are DNA viruses that infect basal epithelial (skin or mucosal) cells. HPV genotypes 6 and 11 are responsible for 90% of all genital wart infections,[7] while genotypes 16 and 18 cause most HPV-related cancers.[8] HSV can cause genital or oral herpes infections that are characterized by the appearance of 1 or more vesicles that can break and leave painful ulcers. Most genital herpes infections are caused by type 2 (HSV-2); however, type 1 (HSV-1), which is most often associated with oral herpes infection, is estimated to be responsible for 50% of new genital herpes infections.[9] Neither HPV nor HSV viral infections are curable with antibiotics; however, suppression of recurrent herpes manifestations is attainable using antiviral medication, and there is a vaccine to prevent infection with 4 of the most common HPV serotypes as well as 5 additional cancer-causing types.[7] From 2011 through 2019, the overall incidence rates of genital HPV and HSV in the active component were 56.4 and 23.3 cases per 10,000 person-years (p-yrs), respectively.[3]

The current analysis updates the findings of previous *MSMR* articles on STIs among active component service members.[1,3] Specifically, this report summarizes incident cases and incidence rates of 5 of the most common STIs during 2012–2020 and describes their distributions by demographic and military characteristics.

METHODS

The surveillance period was 1 January 2012 through 31 December 2020. The surveillance population consisted of all active component service members of the U.S. Army, Navy, Air Force, or Marine Corps who served at any time during the period. Diagnoses of STIs were ascertained from medical administrative data and reports of notifiable medical events routinely provided to the Armed Forces Health Surveillance Division (AFHSD) and maintained in the Defense Medical Surveillance System (DMSS) for surveillance purposes. STI cases were also derived from positive laboratory test results recorded in the Health Level 7 (HL7) chemistry and microbiology databases maintained by the Navy and Marine Corps Public Health Center at the EpiData Center.

For each service member, the number of months in active military service was ascertained and then aggregated into a total for all service members during each calendar year. The resultant annual totals were expressed as person-years of service and used as the denominators for the calculation of annual incidence rates. Person-time that was not considered to be time at risk for each STI was excluded (i.e., the 30 days following each incident chlamydia or gonorrhea infection and all person-time following the first diagnosis, medical event report, or positive laboratory test of HSV, HPV, or syphilis).

An incident case of chlamydia was defined by any of the following: 1) a case-defining diagnosis **(Table 1)** in the first or second diagnostic position of a record of an outpatient or in-theater medical encounter, 2) a confirmed notifiable disease report for chlamydia, or 3) a positive laboratory test for chlamydia (any specimen source or test type). An incident case of gonorrhea was similarly defined by 1) a case-defining diagnosis in the first or second diagnostic position of a record of an inpatient or outpatient or in-theater encounter, 2) a confirmed notifiable disease report for gonorrhea, or 3) a positive laboratory test for gonorrhea (any specimen source or test type). For both chlamydia and gonorrhea, an individual could be counted as having a subsequent case only if there were more than 30 days between the dates on which the case-defining diagnoses were recorded.

Incident cases of HSV were identified by 1) the presence of the requisite International Classification of Diseases, 9th or 10th Revision (ICD-9 or ICD-10, respectively) codes in either the first or second diagnostic positions of a record of an outpatient or in-theater encounter or 2) a positive laboratory test from a genital specimen source. Antibody tests were excluded because they do not allow for distinction between genital and oral infections. Incident cases of HPV were similarly identified by 1) the presence of the requisite ICD-9 or ICD-10 codes in either the first or second diagnostic positions of a record of an outpatient or in-theater encounter or 2) a positive laboratory test from any specimen source or test type. Outpatient encounters for HPV with evidence of an immunization for HPV within 7 days before or after the encounter date were excluded, as were outpatient encounters with a Current Procedural Terminology (CPT) code indicating HPV vaccination, as such encounters were potentially related to the vaccination administration. An individual could be counted as an incident case of HSV or HPV only once during the surveillance period. Individuals who had diagnoses of HSV or HPV infection before the surveillance period were excluded from the analysis.

An incident case of syphilis was defined by 1) a qualifying ICD-9 or ICD-10 code in the first, second, or third diagnostic position of a hospitalization, 2) at least 2 outpatient or in-theater encounters within 30 days of each other with a qualifying ICD-9 or ICD-10 code in the first or second position, 3) a confirmed notifiable disease report for any type of syphilis, or 4) a record of a positive polymerase chain reaction or treponemal laboratory test. Stages of syphilis (primary, secondary, late, latent) could not be distinguished because the HL7 laboratory data do not allow for differentiation of stages and because there is a high degree of misclassification associated with the use of ICD diagnosis codes for stage determination.[10,11] An individual could be considered an incident case of syphilis only once during the surveillance period; those with evidence of prior syphilis infection were excluded from the analysis.

TABLE 1. ICD-9 and ICD-10 diagnostic codes used to identify cases of STIs in electronic healthcare records

Name of STI	ICD-9[a]	ICD-10[a]
HPV	078.11, 079.4, 795.05, 795.09, 795.15, 795.19, 796.75, 796.79	A63.0, R85.81, R85.82, R87.81, R87.810, R87.811, R87.82, R87.820, R87.821, B97.7
Chlamydia	099.41, 099.5*	A56.*
Genital HSV	054.1*	A60.*
Gonorrhea	098.*	A54.*
Syphilis	091.*, 092.*, 093.*–096.*, 097.0, 097.1, 097.9	A51.* (excluding A51.31), A52.*, A53.0, A53.9

[a]An asterisk (*) indicates that any subsequent digit/character is included.
ICD, International Classification of Diseases; STIs, sexually transmitted infections; HPV, Human papillomavirus; HSV, herpes simplex virus.

RESULTS

Between 2012 and 2020, the number of incident chlamydia infections among active component service members was greater than the sum of the other 4 STIs

TABLE 2. Incident counts and incidence rates of STIs, active component, U.S. Armed Forces, 2012–2020

	Chlamydia		Gonorrhea		Syphilis		Genital HSV		Genital HPV	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	228,857	192.4	35,971	30.2	5,621	4.7	28,180	24.0	59,468	51.9
Sex										
Male	144,878	144.6	28,407	28.3	4,933	4.9	15,434	15.5	24,508	24.9
Female	83,979	448.2	7,564	40.2	688	3.7	12,746	70.6	34,960	216.0
Age group (years)										
<20	31,174	377.0	3,622	43.7	522	6.3	1,983	23.9	1,126	13.6
20–24	133,070	353.5	19,315	51.2	2,153	5.7	11,729	31.3	23,635	63.5
25–29	44,552	158.4	8,003	28.4	1,483	5.3	7,404	26.7	16,032	59.5
30–34	13,346	69.9	3,172	16.6	768	4.0	3,775	20.2	10,856	61.1
35–39	4,695	34.4	1,204	8.8	347	2.5	1,919	14.5	4,811	37.9
40+	2,020	16.6	655	5.4	348	2.9	1,370	11.5	3,008	25.9
Race/ethnicity group										
Non-Hispanic White	90,668	131.7	9,633	14.0	1,957	2.8	12,926	19.0	30,060	45.2
Non-Hispanic Black	75,051	392.5	18,701	97.6	1,944	10.2	8,353	44.8	12,491	68.7
Hispanic	40,034	228.7	4,650	26.5	1,098	6.3	4,300	24.9	9,661	57.4
Asian/Pacific Islander	7,251	154.7	915	19.5	212	4.5	670	14.4	2,150	47.3
Other/unknown	15,853	180.2	2,072	23.5	410	4.7	1,931	22.2	5,106	60.6
Education level										
High school or less	198,890	259.8	30,518	39.8	4,103	5.4	20,014	26.4	38,149	51.2
Some college	14,539	99.2	2,648	18.1	641	4.4	3,535	24.8	7,896	58.2
Bachelor's or advanced degree	12,955	51.5	2,434	9.7	800	3.2	4,194	17.0	12,010	50.4
Other/unknown	2,473	95.2	371	14.3	77	3.0	437	17.0	1,413	56.2
Marital status										
Single, never married	156,970	316.4	23,728	47.7	3,501	7.1	14,592	29.6	29,376	60.5
Married	58,076	91.0	10,149	15.9	1,772	2.8	10,749	17.1	24,073	39.4
Other/unknown	13,811	251.3	2,094	38.0	348	6.3	2,839	54.0	6,019	123.0
Service										
Army	96,493	218.3	18,404	41.6	2,117	4.8	12,214	28.1	21,608	50.6
Navy	53,737	184.9	8,351	28.7	1,986	6.8	6,644	23.2	15,944	57.1
Air Force	45,600	158.1	5,162	17.9	1,000	3.5	6,253	22.0	16,123	58.9
Marine Corps	33,027	196.1	4,054	24.0	518	3.1	3,069	18.4	5,793	35.0
Rank/grade										
Junior enlisted (E1–E4)	172,179	334.4	25,481	49.4	3,394	6.6	15,286	29.8	29,714	58.4
Senior enlisted (E5–E9)	47,762	102.7	8,949	19.2	1,764	3.8	9,726	21.4	20,587	47.2
Junior officer (O1–O3)	7,616	65.3	1,184	10.1	296	2.5	2,199	19.1	6,781	60.5
Senior officer (O4–O10)	757	10.0	239	3.1	134	1.8	696	9.3	1,923	26.6
Warrant officer (W01–W05)	543	32.1	118	7.0	33	2.0	273	16.7	463	29.2
Military occupation										
Combat-specific[b]	26,407	156.9	4,454	26.4	510	3.0	2,883	17.3	5,042	30.5
Motor transport	10,342	299.3	1,941	56.1	298	8.6	975	28.5	2,189	65.2
Pilot/air crew	2,322	52.6	282	6.4	83	1.9	568	13.0	1,363	32.1
Repair/engineering	65,343	186.8	9,857	28.1	1,355	3.9	7,456	21.6	14,945	44.0
Communications/intelligence	56,758	220.2	9,976	38.6	1,341	5.2	7,858	31.1	16,275	66.9
Healthcare	17,118	162.7	2,552	24.2	544	5.2	3,082	29.9	8,378	85.1
Other	50,567	220.3	6,909	30.1	1,490	6.5	5,358	23.6	11,276	50.7

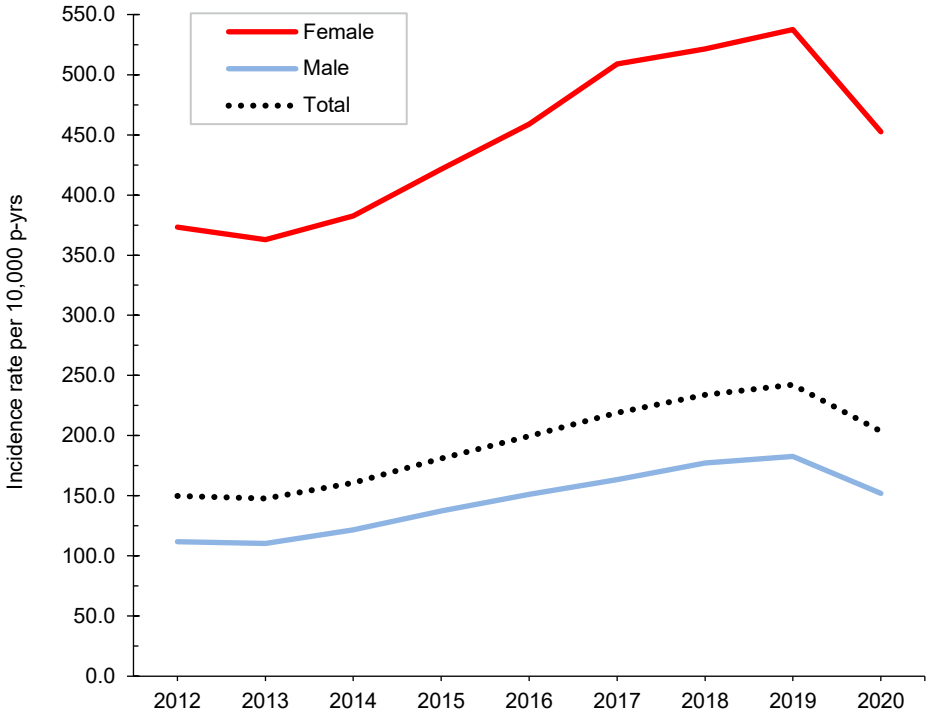
[a]Incidence rate per 10,000 person-years.
[b]Infantry/artillery/combat engineering/armor.
STIs, sexually transmitted infections; HSV, herpes simplex virus; HPV, human papillomavirus; No., number.

combined and 3.8 times the total number of genital HPV infections—the next most frequently identified STI during this period **(Table 2)**. With the exception of syphilis, the crude overall incidence rates of all STIs were markedly higher among female service members than male service members. For chlamydia, gonorrhea, and syphilis, overall incidence rates were highest among those aged 24 years or younger and decreased with advancing age. However, overall rates of genital HSV and HPV infections were highest among those aged 20–24 years. Overall rates of all STIs were highest among non-Hispanic Black service members compared to those in other race/ethnicity groups. For chlamydia, gonorrhea, and genital HSV infections, overall rates were highest among members of the Army. The overall incidence rate of syphilis was highest among Navy members, and the overall rate of genital HPV infections was highest among Air Force members. Compared to their respective counterparts, enlisted service members and those with lower levels of educational achievement tended to have higher overall rates of all STIs. Married service members had the lowest overall incidence rates of all 5 STIs compared to service members who were single and never married or those of other/unknown marital status. Overall rates of chlamydia, gonorrhea, and syphilis were highest among those working in motor transport occupations. In contrast, overall genital HPV infection rates were highest among those in healthcare occupations, and the highest rates of genital HSV infections were among those working in communications/intelligence, health care, or motor transport **(Table 2)**. Patterns of incidence rates over time for each specific STI are described in the subsections below.

Chlamydia

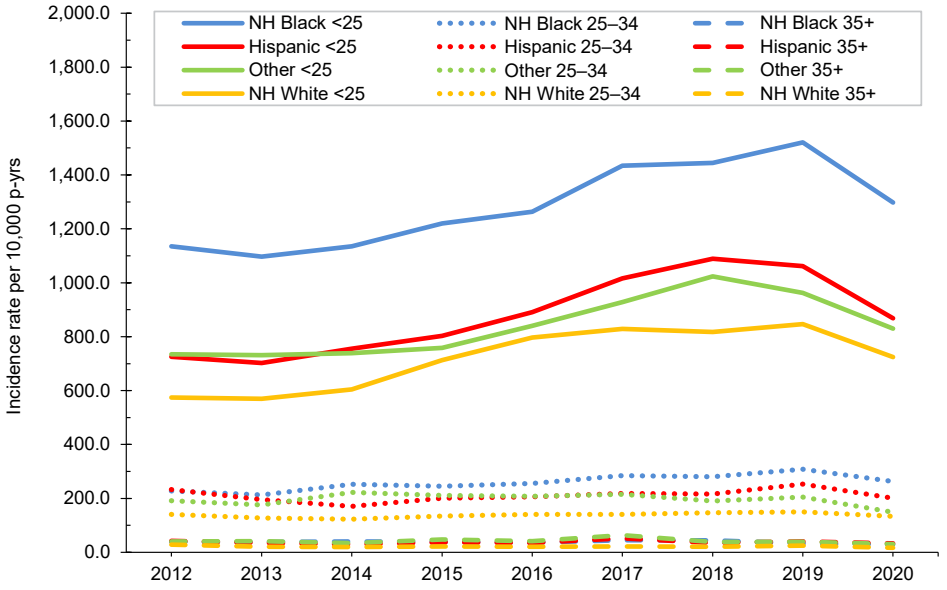
During the surveillance period, annual incidence rates of chlamydia among female service members were generally 3 times the rates among male service members. Annual rates among all active component members increased 64.0% between 2013 and 2019, with rates among both females and males peaking in 2019 (537.5 per 10,000 p-yrs and 182.7 per 10,000 p-yrs, respectively)

FIGURE 1. Incidence rates of *Chlamydia trachomatis* infections, by sex, active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years.

FIGURE 2. Incidence rates of *Chlamydia trachomatis* infections among females, by age group (years) and race/ethnicity group, active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years; NH, non-Hispanic.

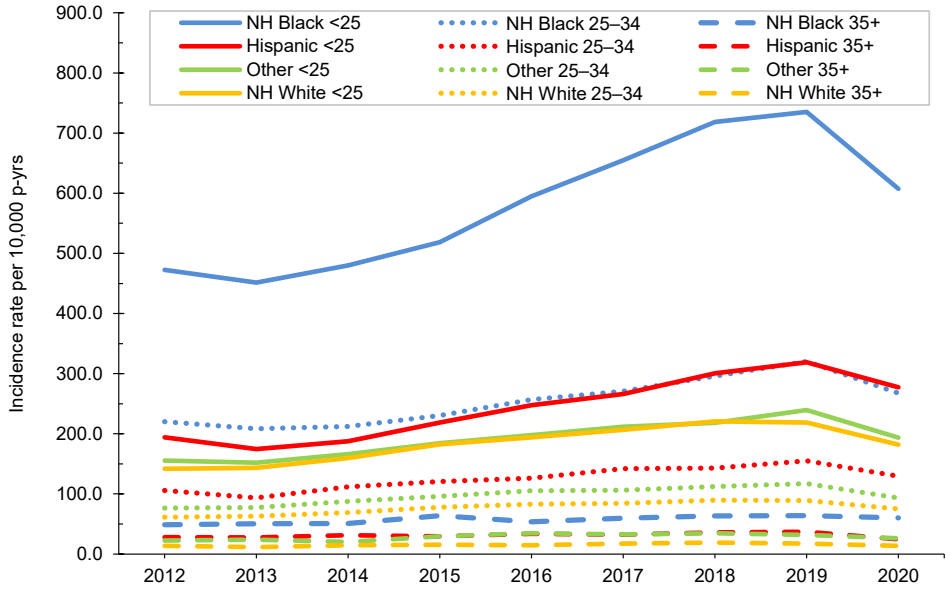
(Figure 1). In both sexes, this increase was primarily attributed to service members in the youngest age groups (less than 25 years among females; less than 30 years among males) **(data not shown)**.

Among female service members in each race/ethnicity group, annual rates of chlamydia generally increased among those under 25 years old during 2013–2018 **(Figure 2)**. Among non-Hispanic Black and non-Hispanic White female service members in this age group, annual rates of chlamydia increased between 2018 and 2019; in contrast, annual rates among Hispanic female service members and female service members of other/unknown race/ethnicity decreased from 2018 through 2019. Then, between 2019 and 2020, annual rates decreased among female service members under 25 years old in all race/ethnicity groups. Rates remained relatively stable among female service members aged 25–34 years and among those aged 35 years or older **(Figure 2)**. Among male service members, annual rates of chlamydia increased consistently between 2013 and 2019 in all age and race/ethnicity groups under 35 years old, with the exception of non-Hispanic Whites. Among non-Hispanic White male service members under 35 years old, annual rates of chlamydia leveled off between 2018 and 2019. During 2013–2019, annual rates remained relatively stable among male service members aged 35 or older **(Figure 3)**. Between 2019 and 2020, rates decreased among male service members in all age and race/ethnicity groups, with the most pronounced decline among non-Hispanic Black male service members under 25 years old **(Figure 3)**.

Genital HPV

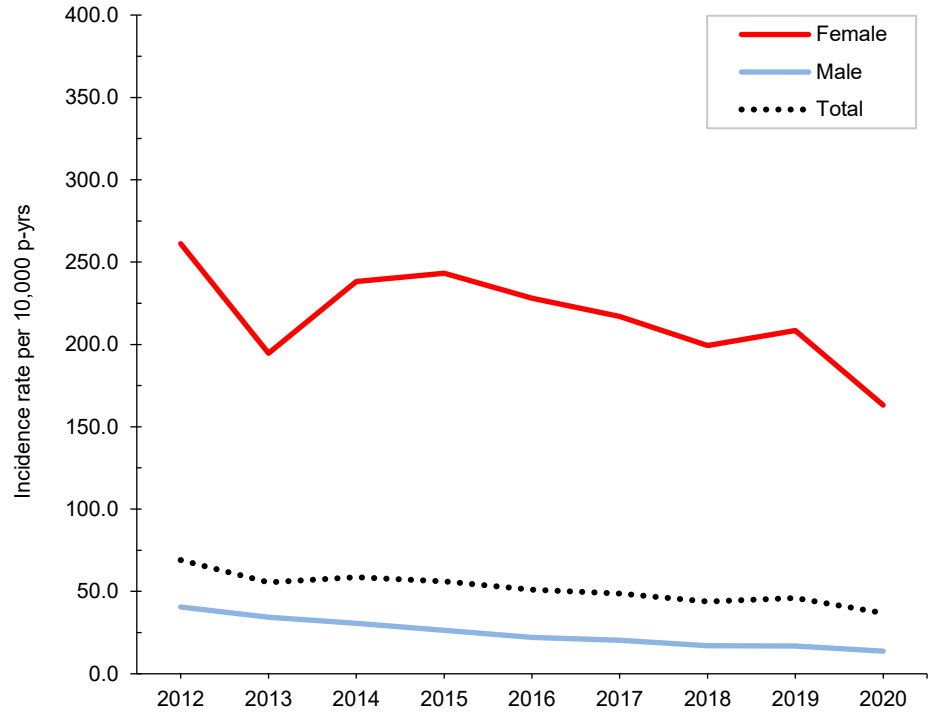
The crude annual incidence rates of genital HPV infections decreased 46.6% among all active component service members from the beginning to the end of the surveillance period, with the most marked decrease occurring among females **(Figure 4)**. There was a slight dip in the overall incidence of genital HPV infections among all active component service members in 2013 at 55.6 cases per 10,000 p-yrs, but the lowest point was reached in 2020 at 36.9 cases per 10,000 p-yrs. Incidence rates

FIGURE 3. Incidence rates of *Chlamydia trachomatis* infections among males, by age group (years) and race/ethnicity group, active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years; NH, non-Hispanic.

FIGURE 4. Incidence rates of genital HPV infections, by sex, active component, U.S. Armed Forces, 2012–2020



HPV, human papillomavirus; p-yrs, person-years.

of genital HPV infections among female service members declined by 37.5% during the surveillance period, from a high of 261.2 cases per 10,000 p-yrs in 2012 to a low of 163.1 cases per 10,000 p-yrs in 2020 **(Figure 4)**. Rates among male service members decreased, from 40.6 per 10,000 p-yrs in 2012 to 16.9 per 10,000 p-yrs in 2019 (66.1%). Between 2015 and 2020, annual rates of genital HPV infections decreased among female service members in all age groups **(Figure 5)**. The decrease in the genital HPV infection rates among male service members overall during 2012–2020 was driven mainly by decreases in the rates in those aged 20–29 years **(Figure 6).**

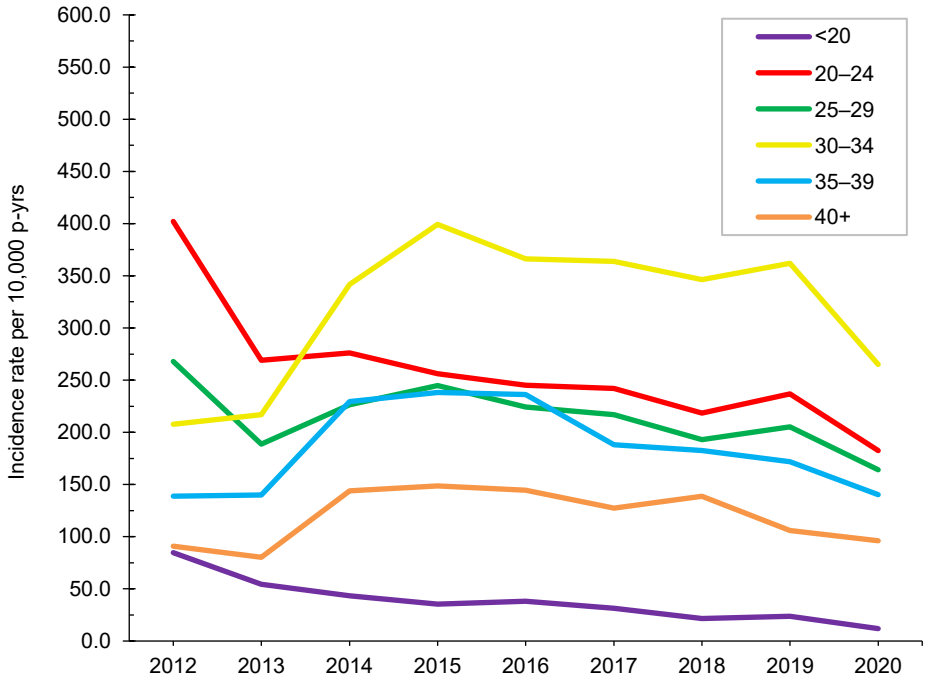
Gonorrhea

Between 2012 and 2020, the crude annual incidence rate of gonorrhea increased by 48.7%; however, after increasing steadily from 2012 through 2018, the rate decreased slightly in 2019 and 2020 **(Figure 7)**. The annual rates among female service members declined between 2012 and 2015 then increased through 2018 before decreasing slightly in 2019 and 2020. After increasing steadily between 2012 and 2018, the rate among male service members also decreased slightly through 2020 **(Figure 7)**. These trends in gonorrhea incidence were primarily driven by similar trends among females under age 25 years old and among males under age 30 years old **(Figures 8, 9)**. The annual rates of gonorrhea increased during the surveillance period among all race/ethnicity groups through 2018, but then fell slightly in 2019 and 2020 for all groups except non-Hispanic Black service members and Asian-Pacific Islander service members. Among non-Hispanic Black service members, rates continued to increase in 2019 and 2020. For Asian-Pacific Islander service members, the rate dropped in 2018 but then leveled off in 2020 **(data not shown)**.

Genital HSV

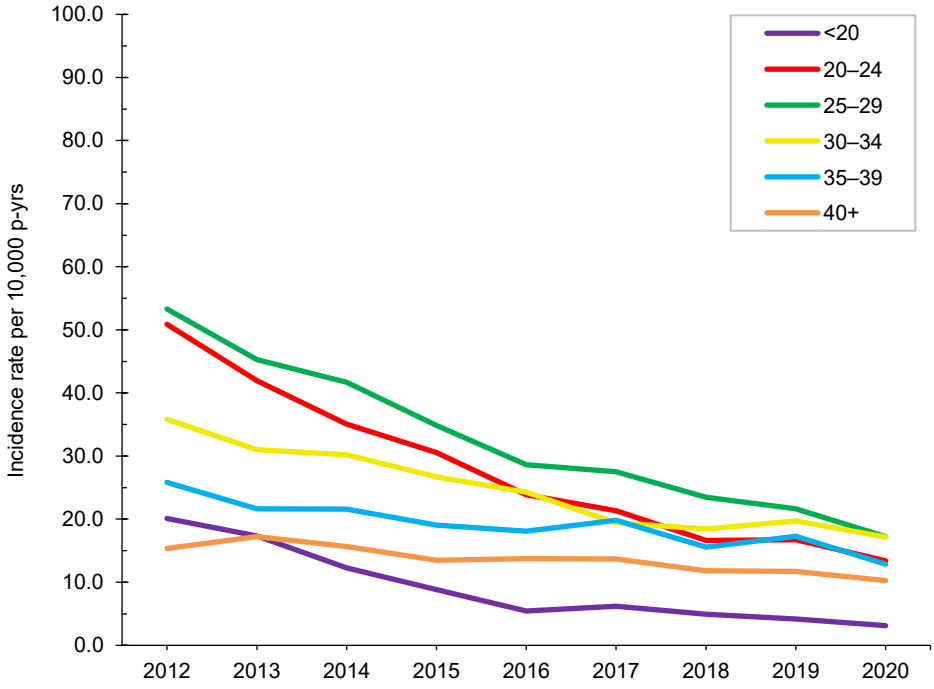
Crude annual incidence rates of genital HSV infections decreased from 24.6 to 18.2 per 10,000 p-yrs over the course of the surveillance period. Rates among female service members ranged from a high of

FIGURE 5. Incidence rates of genital HPV infections among females, by age group (years), active component, U.S. Armed Forces, 2012–2020



HPV, human papillomavirus; p-yrs, person-years.

FIGURE 6. Incidence rates of genital HPV infections among males, by age group (years), active component, U.S. Armed Forces, 2012–2020



HPV, human papillomavirus; p-yrs, person-years.

77.6 per 10,000 p-yrs in 2016 to a low of 55.0 per 10,000 p-yrs in 2020. The rates for male service members were also highest in 2016 (18.1 per 10,000 p-yrs) and reached the lowest point in 2020 (10.9 per 10,000 p-yrs) **(Figure 10)**. Over the course of the surveillance period, the incidence rates of genital HSV infections decreased among service members in all age groups **(data not shown).** The rates decreased between 2018 and 2020 among females in all age groups except for those aged 35–39 years, among whom rates leveled off during 2019–2020. Annual rates decreased among males in all age groups during 2019–2020 **(data not shown)**. In addition, the incidence rates decreased among all race/ethnicity groups from 2017 through 2020 **(data not shown)**.

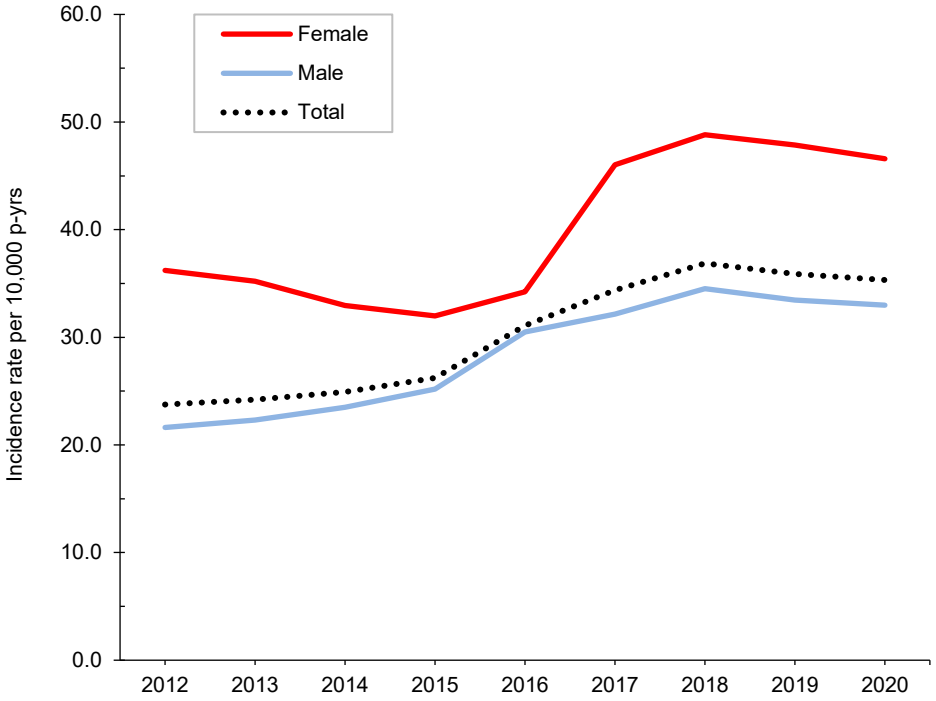
Syphilis

The crude incidence rate for syphilis in the last year of the surveillance period (5.2 per 10,000 p-yrs) was 2.2 times that observed in 2012 (2.4 per 10,000 p-yrs), with the increase primarily driven by cases identified among male service members **(Figure 11)**. Rates of syphilis steadily increased among males until 2018, after which rates decreased through 2020. Among females, rates increased between 2012 and 2014, generally leveled off through 2018, increased in 2019, and then decreased in 2020. The overall incidence rates of syphilis generally decreased with advancing age among both sexes **(data not shown)**. Among males, this pattern of decreasing overall incidence with increasing age was consistent among all race/ethnicity groups; there were not enough cases to evaluate associations between age and race/ethnicity group among females **(data not shown)**.

EDITORIAL COMMENT

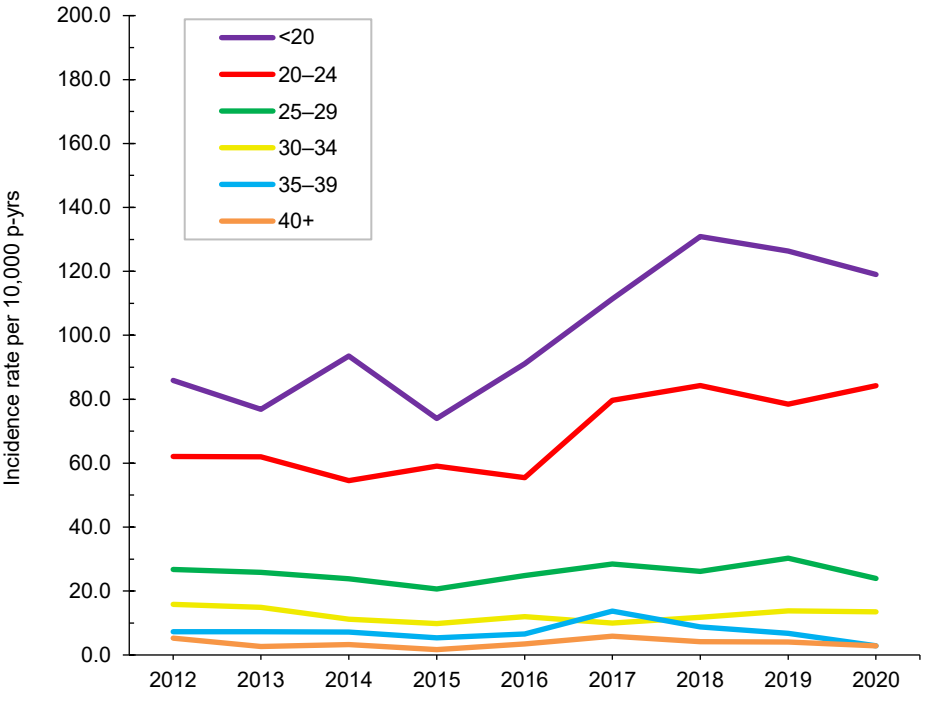
As in previous reports, the crude annual incidence rates of chlamydia, gonorrhea, and syphilis generally increased during the surveillance period. However, from 2019 through 2020, the rates of chlamydia and syphilis infections decreased in service members of both sexes. Between 2018 and 2020, the rates of gonorrhea decreased

FIGURE 7. Incidence rates of gonorrhea infections, by sex, active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years.

FIGURE 8. Incidence rates of gonorrhea infections among females, by age group (years), active component, U.S. Armed Forces, 2012–2020

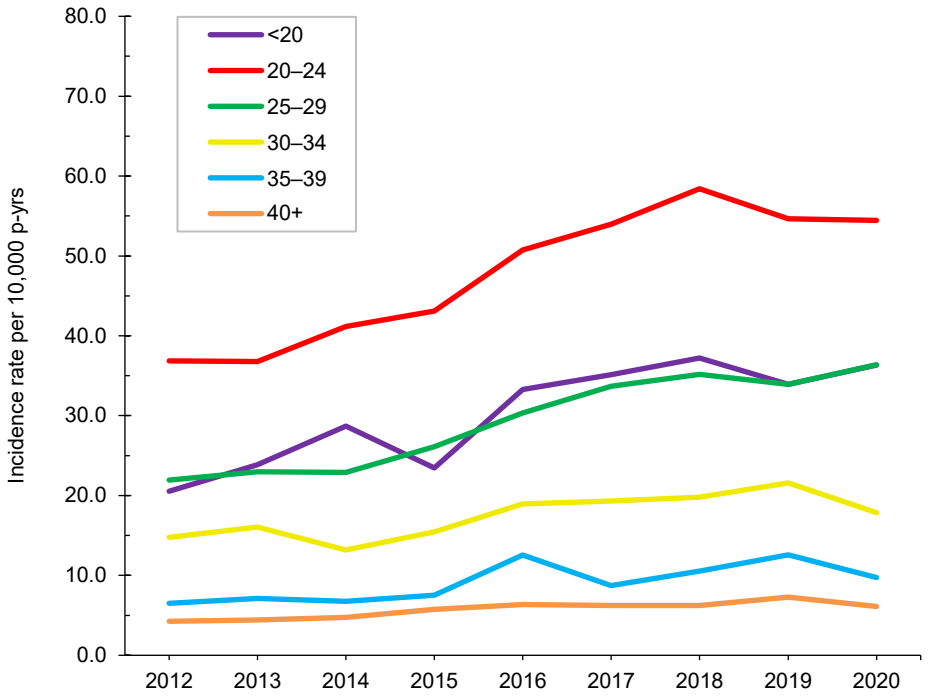


P-yrs, person-years.

slightly in both males and females. In contrast, the decline in incidence rates of genital HSV spanned the period from 2016 through 2020 for both male and female service members. The rates of genital HPV decreased steadily between 2012 and 2020 in males and declined between 2015 and 2020 among females. Overall incidence rates of STIs were higher among females compared to males for HPV, HSV, gonorrhea, and chlamydia. Syphilis was the only STI in this analysis for which the incidence was, on average, higher among male compared to female service members.

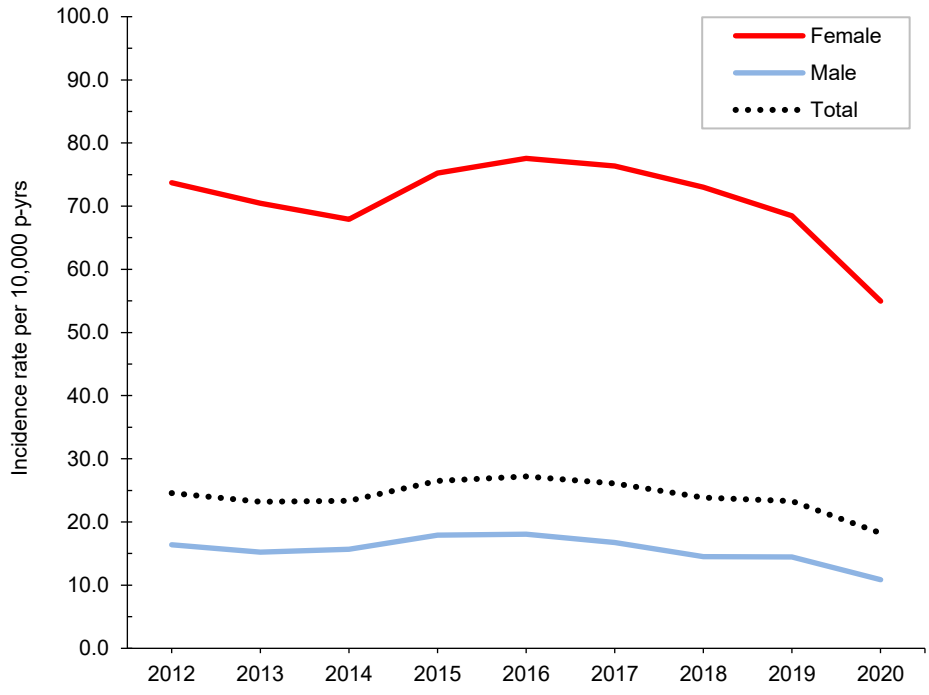
Higher incidence rates of most STIs among females compared to males can likely be attributed to implementation of the services' screening programs for STIs among female service members as they enter active service and during the subsequent annual screenings for females younger than 26 years old. Because asymptomatic infection with chlamydia, gonorrhea, or HPV is common among sexually active females, widespread screening may result in sustained high numbers of infections diagnosed among young females. Although rates of chlamydia and gonorrhea increased among both male and female service members during the latter half of the surveillance period, mirroring the increasing rates in the civilian population,[2] there was a notable decrease in service members' rates of chlamydia in both sexes from 2019 through 2020, and the rates of gonorrhea decreased slightly for both males and females during 2019 and 2020. In the U.S., rates of chlamydia have been increasing among both males and females since 2000, and rates of gonorrhea have been increasing among both sexes since 2013.[2] The increases seen through 2018 in both the civilian and military populations could reflect true increases in the incidence of infections as well as improved screening coverage in males, particularly extragenital screening in males who have sex with males.[12] Analyses of provisional data from the Centers for Disease Control and Prevention's (CDC's) National Notifiable Disease Surveillance System (NNDDS) for the first 40 weeks of 2019 and 2020 revealed that, at week 40 of 2020, the cumulative year-to-date count of chlamydia cases was

FIGURE 9. Incidence rates of gonorrhea infections among males, by age group (years), active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years.

FIGURE 10. Incidence rates of HSV infections, by sex, active component, U.S. Armed Forces, 2012–2020



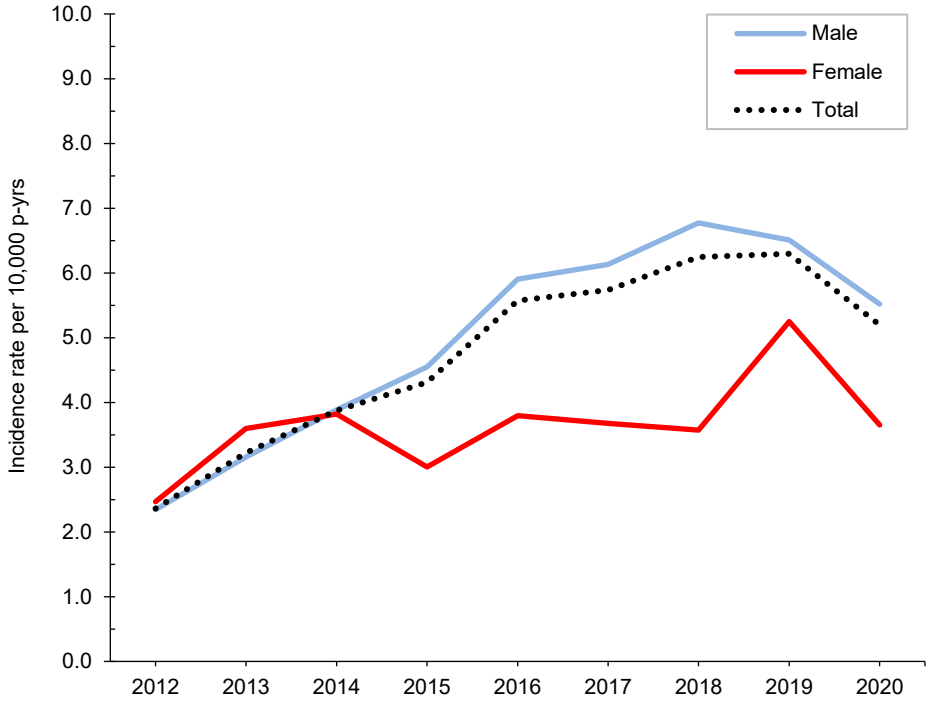
P-yrs, person-years.

down 18% relative to the cumulative count at that time in 2019.[13] A smaller decrease (7%) was observed in the cumulative count of syphilis (primary and secondary) cases at week 40 in 2020 compared with week 40 in 2019.[13] No significant reduction was seen for gonorrhea.[13] A similar pattern was observed among active component service members in the current study. The incidence of chlamydia decreased by 16% between 2019 and 2020, and the incidence of gonorrhea remained relatively stable between 2019 and 2020. The decreases in civilian case counts have so far been attributed mostly to COVID-19 pandemic-related declines in the testing and/or reporting of cases,[14] and it is possible that the COVID-19 pandemic had a similar effect on the military health system. It is important to note, however, that national civilian data for both 2019 and 2020 were preliminary at the time of this report.

No data on sexual risk behaviors were available for this study, but prior surveys of military personnel have indicated high levels of sexual risk behaviors. The 2015 Department of Defense Health Related Behaviors Survey (HRBS) documented that 19.4% of respondents reported having more than 1 sex partner in the past year and that 36.7% reported sex with a new partner in the past year without using a condom; these percentages were almost double those reported from the previous survey in 2011.[15] Data from the 2018 HRBS were not available at the time of this report, precluding any comparisons.

The general downward trend in incidence rates of genital HPV infections observed during the surveillance period may be related to the introduction of the HPV vaccine for adult and young females in 2006 and for males in 2010. Among civilian females aged 14–24 years, cervical/vaginal prevalence of HPV types 6, 11, 16, and 18 decreased by approximately 6% from the period 2003–2006 to 2009–2012.[16] The HPV vaccine is currently not a mandatory vaccine for military service, but it is encouraged and offered to service members. Because the HPV vaccine (Gardasil) is approved for use among males and females beginning at age 9, it is possible that an increasing number of members who entered military service during the surveillance period may have been vaccinated for HPV before entering service. This prior vaccination may account for the decrease in the annual rates of genital HPV infections during the surveillance period.

FIGURE 11. Incidence rates of syphilis infections, by sex, active component, U.S. Armed Forces, 2012–2020



P-yrs, person-years.

The trends in the incidence of HSV and syphilis in the U.S. military are also similar to what is observed in the civilian population. Data from the CDC's National Health and Nutrition Examination Survey indicate that the seroprevalence of both HSV-1 and HSV-2 has decreased in the U.S. population since 1999.[2] In contrast, the incidence of primary and secondary syphilis reported to the CDC has increased markedly since 2001, with males accounting for the majority of cases.[2,17]

This report has several limitations that should be considered when interpreting the results. First, diagnoses of STIs may be incorrectly coded. For example, STI-specific "rule out" diagnoses or vaccinations (e.g., HPV vaccination) may be reported with STI-specific diagnostic codes, which would result in an overestimate of STI incidence. Cases of syphilis, genital HSV, and genital HPV infections based solely on laboratory test results are considered "suspect" because the laboratory test results cannot distinguish between acute and chronic infections. However, because incident cases of these STIs were identified based on the first qualifying encounter or laboratory result, the likelihood is high that most such cases are acute and not chronic.

STI cases may not be captured if coded in the medical record using symptom codes (e.g., urethritis) rather than STI-specific codes. In addition, the counts of STI diagnoses reported here may underestimate the actual numbers of diagnoses because some affected service members may be diagnosed and treated through non-reimbursed, non-military care providers (e.g., county health departments or family planning centers) or in deployed settings (e.g., overseas training exercises, combat operations, or aboard ships). Laboratory tests that are performed in a purchased care setting, a shipboard facility, a battalion aid station, or an in-theater facility were not captured in the

current analysis. Finally, medical data from sites that were using the new electronic health record for the Military Health System, MHS GENESIS, between July 2017 and October 2019 are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounter data for individuals seeking care at any of these facilities from July 2017 through October 2019 were not included in the current analysis.

For some STIs, the detection of prevalent infections may occur long after the time of initial infections. As a result, changes in incidence rates may reflect, at least in part, temporal changes in case ascertainment, such as a shift to more aggressive screening. The lack of standard practices across the services and their installations regarding screening, testing, treatment, and reporting complicate interpretations of differences between services, military and demographic subgroups, and locations. Establishing screening, testing, treatment, and reporting standards across the services and ensuring adherence to such standards would likely improve efforts to detect and characterize STI-related health threats. In addition, continued behavioral risk-reduction interventions are needed to counter STIs among military service members.

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A Retrospective Cohort Study of Blood Lead Levels Among Special Operations Forces Soldiers Exposed to Lead at a Firing Range in Germany

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This report describes the results of testing for blood lead levels (BLLs) among special operations forces at a single installation in Germany where occupational exposures to lead were associated with use of a firing range. After recognition of elevated BLLs in some service members who used the firing range, a detailed industrial hygiene confirmation of lead exposures prompted mitigation measures undertaken by command authorities, facilities management, public health, and clinical occupational medicine. To assess the impact of the mitigation efforts, this study retrieved the results of all BLLs performed between 1 January 2016 and 30 September 2018 among SOF soldiers enrolled in an Occupational Safety and Health Administration (OSHA)-required medical surveillance program for lead exposure. Mitigation steps were taken during July–September 2017. BLLs from the periods before and after the mitigation efforts were compared. Among the 57 individuals who had levels measured both before and after the mitigation period, the range of BLL values fell from a range of 1–35 µg/dL to a range of 1–15 µg/dL. The number of individuals who had BLLs of greater than 20 µg/dL fell from 9 before, to 0 after the mitigation period. The various types of mitigation steps useful in reducing firing range-related lead exposure are described.

WHAT ARE THE NEW FINDINGS?

Among a group of service members whose duties involved frequent weapons training and exposure to lead, a focused effort to reduce exposures to lead was associated with a reduction in BLLs among the exposed service members.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

This article emphasizes the special occupational hazards associated with lead related to firing ranges, the general nature of mitigation measures, and the health effects that are associated with lead toxicity. Awareness of these issues and surveillance of service members at risk of lead toxicity will enable leaders and public health officials to act to prevent adverse health effects among those who are commonly exposed.

Use of indoor and outdoor firing ranges is a well-known source of airborne lead exposure for Special Operations Forces (SOF) populations and can result in subsequent elevated blood lead levels (BLL). This source of lead exposure can be especially problematic during high-volume training and/or use of inadequately ventilated firing areas.[1–3] Lead toxicity can have a significant negative impact on military readiness[4] and can degrade physical and psychological performance, especially in this population of specialized soldiers. Symptoms associated with elevated BLLs include abdominal distress, depression, distractibility, forgetfulness, irritability, weakness, fatigue, memory loss, pain, and/or paresthesias in hands and/or feet, and headaches.[5] Prolonged lead exposure can cause hematologic disorders, hypertension, degradation of the central and peripheral nervous systems, renal disease, miscarriages, and male fertility complications.[6]

Important sources of lead exposure include fine particulates from primers and projectile fragments from ammunition as well as primers used in pyrotechnics and explosives. Such lead exposures are especially concerning in high-volume training and/or enclosed or inadequately ventilated firing areas. The major routes of lead internalization are inhalation and ingestion. The primary cause of inhalation exposure occurs during the process of firing a weapon when fine, aerosolized lead particulates escape from the chamber, port, and barrel of a weapon. Many of these particulates can be inhaled during weapons' firing. Lead particulates that are not inhaled will eventually fall to the ground or adhere to bodies, clothing, and equipment. Additional lead particulates are generated when lead projectiles strike hardened targets or the firing range backstop. The accumulation of these lead particulates on the ground, backstop, bodies, clothing, and equipment are sources of secondary inhalation exposure. Disruption and re-aerosolization of accumulated lead particulates occur as a result of movements of shooters, projectiles striking the backstop, the use of explosives and pyrotechnics, cleaning of firing ranges and equipment, and the changing of contaminated clothing. The primary sources of lead ingestion exposure are particulates that are adherent to hands and that contaminate hydration sources. Ingestion occurs if lead has not been washed from the hands before eating, smoking, or using smokeless tobacco, or if it is not removed from a hydration source before drinking.

In response to the risks associated with occupational lead exposure, the Occupational Safety and Health Administration (OSHA) and the Department of Defense (DoD) have set guidelines regarding acceptable levels for blood lead and for medical surveillance of workers exposed to lead. Medical surveillance is critical for documenting effects of lead exposure and providing employers and employees with appropriate

medical guidance. For workers above certain lead exposure levels, OSHA requires enrollment in a medical surveillance program with initial and periodic exams to track and review BLLs.[7] DoD lead exposure surveillance standards comply with those of OSHA, yet are more stringent, particularly with regard to standards of when an employee is to be removed from and returned to lead work.[8]

This current report describes a SOF population at a single installation in Germany with exposure to airborne lead, resultant elevated BLLs, and the successful cooperative efforts that resulted in a significant overall decrease in that population's BLLs. As early as 2000, Mancuso et al. recognized that this unique population had elevated BLLS believed to be primarily due to high-volume firing in enclosed or partially covered ranges.[1] Several groups undertook efforts between 2016 and 2017 to decrease this exposure, including industrial hygiene (IH), facilities (range) management, unit command, public health, and clinical occupational medicine.

An IH assessment of unit firing ranges in 2016 revealed that the soldiers' exposure to airborne lead was the equivalent of breathing lead concentrations of 190 to 250 μg/m^3 for 8 hours. This exposure is up to 5 times the OSHA permissible exposure limit of an 8-hour time-weighted average (TWA) of 50 μg/m^3 and more than 8 times the OSHA action level of an 8-hour TWA of 30 μg/m^3.[7] Informed by these findings, IH made key recommendations to remediate these exposures. Based on these recommendations, facilities management replaced contaminated sand and synthetic backstops, exchanged some sand backstops with synthetic backstops, and limited 1 firing range with a sand backstop to low-volume firing exercises only. Unit leadership implemented additional risk mitigation measures that included enforcing more stringent removal of any soldier with a single BLL of ≥20 μg/dL from live weapons training, as well as requiring the use of unit laundering facilities and lead abatement hand wipes after firing. Public health and occupational medicine personnel advocated for the implementation of IH recommendations and provided lead exposure education to SOF personnel and leadership during site visits and clinical encounters.

METHODS

Venous BLLs measured in 130 SOF soldiers enrolled in OSHA-required medical surveillance at 1 installation in Germany between 1 January 2016 and 30 September 2018 were reviewed. To allow for a paired comparison, only the BLLs of SOF soldiers with results from the pre-mitigation and post-mitigation time frames were included in this analysis **(Table 1)**. Laboratory results of venous BLLs were collected from electronic medical records in Armed Forces Health Longitudinal Technology Application (AHLTA). For purposes of this study, to address inconsistent frequency of lab draws, only 1 BLL value was included per calendar month for any individual. If multiple BLL samples were drawn from an individual during a single month, the highest recorded value was included and all others were excluded **(Table 1)**. Each BLL value was recorded in units of micrograms of lead per deciliter of blood (μg/dL). All BLL values were reported in whole numbers; any BLL value 1 μg/dL or less was recorded as 1 μg/dL.

Descriptive statistical data analysis was performed using QI Macros Statistical Process Control software add-in version 2018.07 (KnowWare International, Inc.) for Microsoft Excel. The resulting BLL data were categorized as pre-mitigation or post-mitigation based on the timing of the blood draw. Three months of data immediately after mitigation (July–September 2017; 60 BLL samples) were excluded to avoid a potential positive bias; this period is consistent with the half-life of lead in blood, 36 ± 5 days.[6] Statistical analysis was performed with R version 3.6.1 (2019, R Core Team, R Foundation for Statistical Computing). Since an individual's BLLs are temporally interdependent and there was inconsistent follow-up, specialized statistical techniques were required. To overcome the interdependence problem, 1 million resampling simulations were performed. In each simulation, a single BLL measurement was randomly sampled from each of the pre- and post-mitigation periods for each individual, thereby ensuring the independence of observations within each simulation. For each simulation, the ratio of post-mitigation over pre-mitigation BLLs was calculated. The proportion exceeding 1 is the p-value for this nonparametric, simulation-based approach, which was similarly used to estimate the effect size.

RESULTS

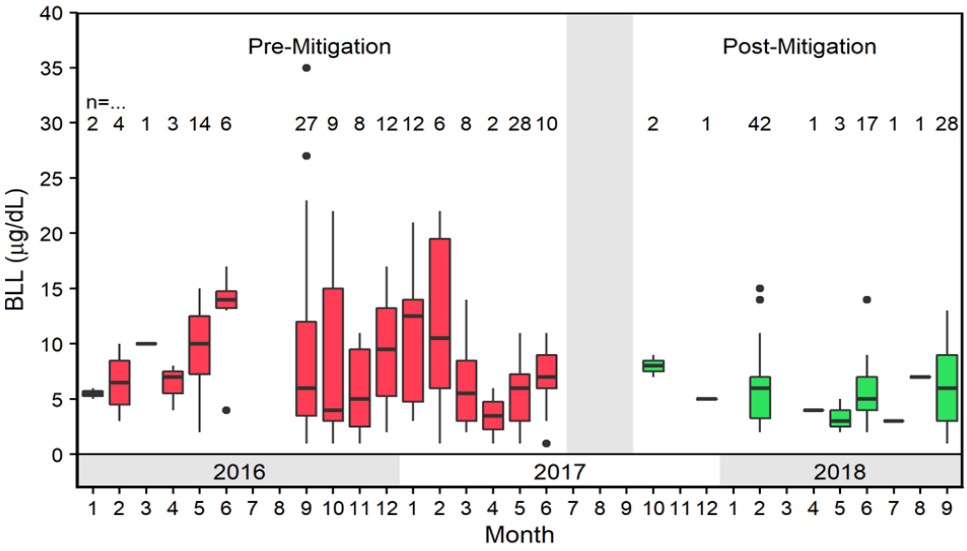
Between 1 January 2016 and 30 September 2018, a total of 473 BLL samples were drawn from 130 individuals of a SOF company stationed in Germany **(Figure)**. The number of samples drawn per individual during the 33-month surveillance period ranged from 1–11, while the number of samples drawn from the company per month varied from 0–58. For the 57 individuals with both pre- and post-mitigation samples, the BLL values fell from a range of 1–35 μg/dL during the pre-mitigation interval to a range of 1–15 μg/dL post-mitigation **(Table 2)**. The number of individuals with a BLL of ≥20 μg/dL (the company action level for removal from lead exposure) before mitigation efforts was 9; after mitigation, there were no individuals with a BLL at or above the action level.

A 1 million trial, non-parametric simulation (on the ranks of BLLs within each individual, not on the actual BLL values) determined that post-mitigation BLLs were lower than pre-mitigation BLLs (p=.02). The corresponding simulation on the actual BLL values was consistent with this result, although not statistically significant (p=.05). Post-mitigation BLLs were on average 87% of the pre-mitigation value (95% confidence interval: 75%–102%).

EDITORIAL COMMENT

This study demonstrates the effectiveness of a multidisciplinary approach to providing a training environment that is both realistic and safe for soldiers who participate in frequent live-fire small arms training. The reduction of the mean BLLs within this population demonstrates an association with the mitigation strategies recommended by IH and implemented by facilities management and the unit

FIGURE. Box plot of pre-mitigation versus post-mitigation BLL values from SOF soldiers at 1 installation in Germany between 1 January 2016 and 30 September 2018



BLL, blood lead level; SOF, Special Operations Forces.

Note: The shaded column represents a 3-month washout period July–September 2017.

TABLE 1. Inclusion and exclusion criteria for the retrospective cohort, paired comparison study of SOF soldiers' BLLs

Inclusion criteria	Exclusion criteria
BLL values from SOF soldiers stationed in Germany and enrolled in OSHA medical surveillance between 1 January 2016 and 30 September 2018	BLL values drawn from 1 July through 30 September 2017
BLL values from soldiers who had BLL values from both pre- and post-mitigation time frames	
Highest BLL value for each soldier within a calendar month if multiple BLLs were drawn within the same month	

SOF, Special Operations Forces; BLL, blood lead level; OSHA, Occupational Safety and Health Administration.

TABLE 2. Pre-mitigation and post-mitigation data analysis of BLL values from the surveillance period, excluding the washout period of July–September 2017

	Pre-mitigation	Post-mitigation
	January 2016–June 2017	October 2017–September 2018
No. of BLL values analyzed	152	96
No. of soldiers	57	57
Mean BLL, µg/dL	8.19	5.92
Range, µg/dL	<1–35	<1–15
No. of BLL values ≥20 µg/dL	9	0

BLL, blood lead level; No., number.

command. The following measures were carried out: replacing sand backstops with synthetic backstops; limiting types of firearms on firing ranges with sand backstops; reducing the BLL threshold to a single result of 20 µg/dL for removing a soldier from lead exposure; and enforcing the use of unit laundering facilities and lead abatement hand wipes after firing.

Additional actions that may be helpful in lead exposure mitigation include but are not limited to the following: replacement of lead ammunition with lead-free ammunition such as SINTOX; improvement of range ventilation systems; provision of hand-washing facilities and running water at every firing range; provision of lead abatement hand wipes and lead-specific soap and laundry detergents; enforcement of respiratory protection measures during range cleanup; and provision of "wet sweep" materials and enforcement of their use. Ongoing IH monitoring at these firing ranges (annually or more frequently) and continued medical surveillance are crucial tools for unit leadership, medical providers, and the individual in order to assure range safety, optimal soldier readiness, and treatment recommendations.

Several limitations to the current analysis merit mention. Although the exposures focused on in this report are at the same ranges as discussed by Mancuso et al.,[1] it is unknown to the authors if there were any soldiers who were included in both studies (i.e., 2000–2005 and 2016–2018). It is also unknown to the authors of any engineering controls that were implemented from 2005 through July 2017. The data presented here were derived from a very active, fluid population. Accordingly, not all individuals were available at each recommended testing interval (baseline and quarterly). Some individuals did not receive each test, for reasons such as deployments, training, or permanent moves. The personnel dates of assignment to this unit, previous unit assignments and thus previous lead exposures are unknown to the authors. A true washout period of 5 half-lives without further lead exposure was precluded by the necessity of continued training on other available firing ranges. Because of the medical requirements of certain schools and the request of unit-assigned medical personnel,

testing occurred more frequently than quarterly for some soldiers; this led to a wide range of sample sizes per individual (1–11) and a wide variance in the number of tests drawn from this population per month (0–58). Because these data were analyzed and considered at the population level and not the individual level, they present a strong association; however, this association cannot be considered causal. Ranked BLLs were found to decrease, and this change was statistically significant; however, results of a similar analysis on the actual BLLs were consistent but not statistically significant. Small sample size and the limited number of paired samples may have contributed to limited findings, as well. Furthermore, follow-up IH sampling is required to evaluate the effects of the newly implemented engineering controls on lead exposure at these firing ranges.

Overexposure to lead in the U.S. military is an ongoing risk, especially in populations that participate in frequent live-fire small arms training within enclosed spaces. Service members whose mission requires frequent live-fire small arms training may be at highest risk of decreased readiness if exposed to lead. While mild overexposure to lead and subsequent low-level toxicity may not affect a service member's deployability, some of the subtle symptoms (e.g., decreased attention, slower cognition, or decreased reaction time) could have an adverse impact on an affected individual's physical and psychological performance.[9] Family members, particularly children, are additionally at risk of exposure and subsequent medical concerns if the lead particulates are not removed from the bodies, equipment, and clothing of soldiers before entering their personal vehicles or their homes.

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Acknowledgements: MAJ Philip Castaneda for consultation and assistance with the Special Forces Soldier and Unit; COL (Ret) Mark D. Swofford, PhD, MHA for leadership and consultation; CSM Kevin P. Dorsh for unit coordination and advocacy; Paul G. Sweeney, CIH for Industrial Hygiene support and consultation; and Ashby Payne, BSN, MPA, for Public Health Nursing support and consultation.

Financial support: All work described herein was performed as part of paid regular duties as part of employment by the U.S. Government.

Conflict of interest: None.

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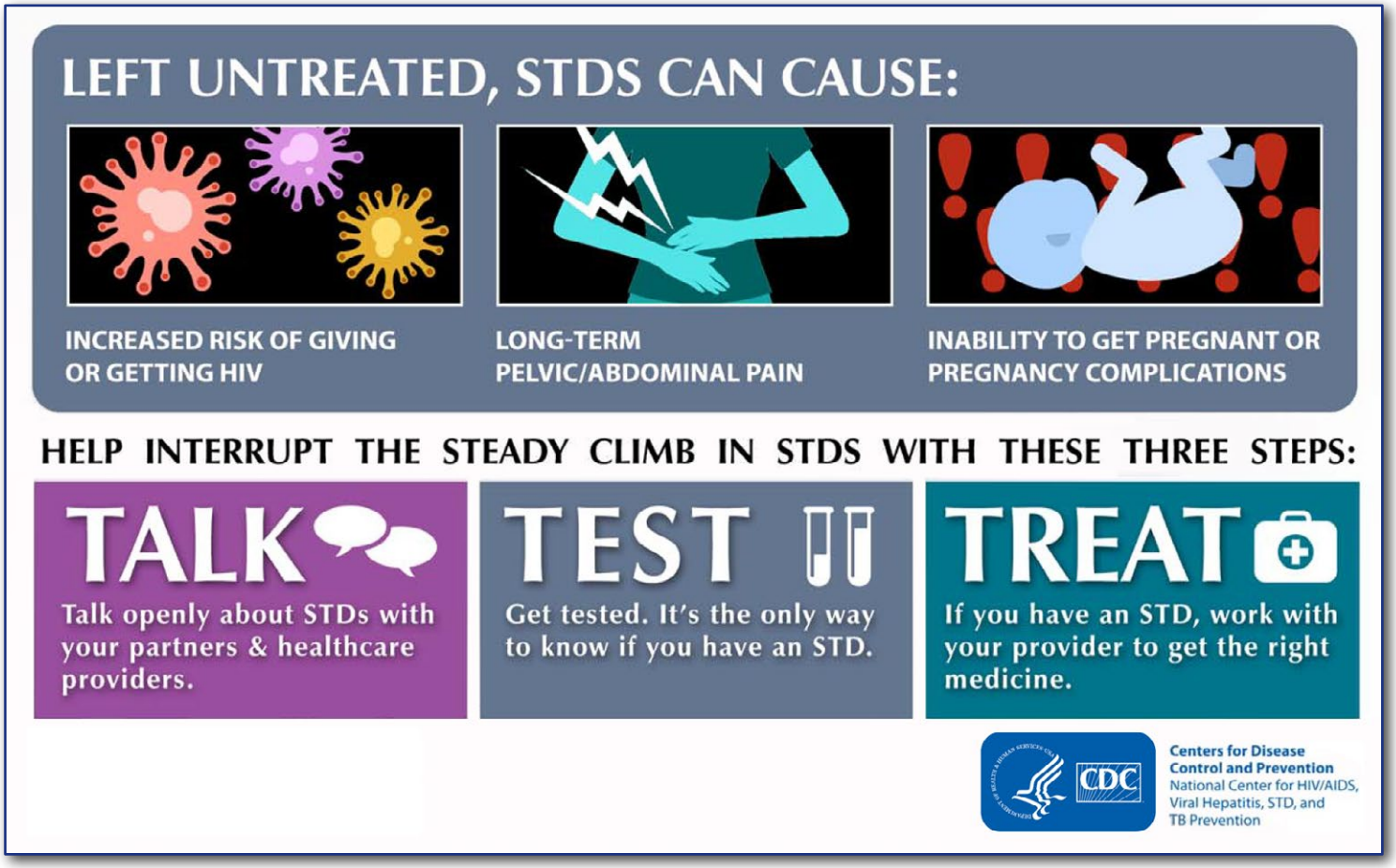

Medical Surveillance Monthly Report (MSMR)
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ISSN 2158-0111 (print)
ISSN 2152-8217 (online)