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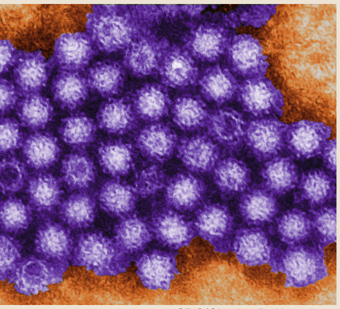

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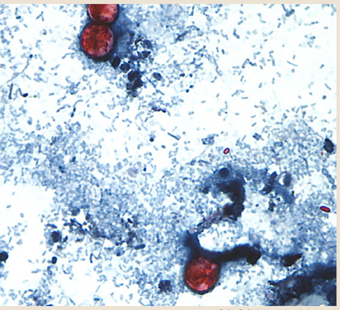

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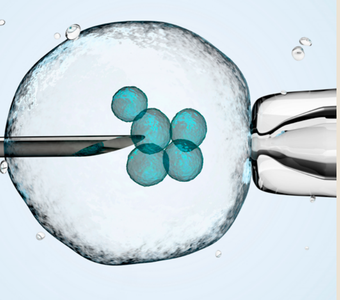

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Offspring Sex Ratio of Male Active Duty U.S. Navy Submariners, 2001–2015

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The natural human sex ratio at birth (male:female) slightly favors males, and altered sex ratios might be indicative of exposure to reproductive hazards. In the U.S. Navy submarine community, there is a widespread belief that submariners are more likely to father females, but corroborating scientific evidence is limited. To assess this, Department of Defense Birth and Infant Health Research program data were used to identify 7,087 singleton infants whose fathers were considered submariners. Chi-square tests and unconditional logistic regression models were used to compare the offspring sex ratio of male submariners with 2 other active duty populations and the U.S. population. The offspring sex ratio of male submariners was 1.048, which did not substantially differ from the sex ratio of each comparison population. Furthermore, this study found no meaningful variation in offspring sex ratio by length of submarine or military service or by rating.

WHAT ARE THE NEW FINDINGS?

Contrary to previous studies, this large, record-based analysis found no evidence to suggest the offspring sex ratio of male active duty U.S. Navy submariners is different from that of other active duty populations or the U.S. population as a whole.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

This study's null findings suggest that submariners are not likely exposed to reproductive hazards in the workplace that alter offspring sex ratio. Current safety measures sufficiently protect the submariner force from such harmful exposures.

Sex ratio is conventionally defined as the proportion of male to female live births in a given population. The natural human sex ratio at birth slightly favors males, with about 104 to 106 males born for every 100 females.[1,2] Though considered a stable measure, sex ratio has steadily declined in most North American and European countries over the past several decades, albeit modestly.[2–4] In the U.S., the sex ratio at birth decreased from 1.055 in 1940 to 1.048 in 2002;[1] in 2016, the sex ratio of all live born U.S. infants was 1.047.[5]

Offspring sex ratio is often used in demographic, environmental, and occupational studies to assess the impact of certain exposures on reproductive and endocrine health.[6–8] Because low sex ratios have been linked to reduced sperm quality and quantity,[9–11] some postulate that a low offspring sex ratio is an early indicator for exposure to reproductive hazards or damage to the male reproductive system.

In the U.S. Navy submarine community, there is a widespread and longstanding belief that male submariners are more likely to father females than males; however, scientific evidence in support of this belief and biologic plausibility are limited. A 1970 record-based study from the Naval Submarine Medical Research Laboratory found a higher proportion of female offspring among male Navy personnel serving aboard nuclear-powered submarines than among the general U.S. population.[12] A 2004 survey-based study did not corroborate this finding, but it did report a decrease in offspring sex ratio with additional time in the submarine community and detected lower sex ratios among submariners with certain naval ratings (i.e., occupational specialties), such as sonar technicians.[13] A 2019 electronic survey-based study designed to assess whether male submariners have an altered offspring sex ratio found a low offspring sex ratio among respondents (sex ratio=0.95), particularly among those who reported being on sea duty (i.e., having a submarine-based job) at the time of conception (sex ratio=0.88), but no trends over time in the community were detected nor were there apparent differences by occupational speciality.[14] However, as noted by the authors of the 2019 study, the fact that potential respondents were informed of the purpose of the survey likely introduced selection bias in favor of those who endorsed or held a belief that higher ratios of female offspring are associated with sea duty.[14] While no other studies have investigated the offspring sex ratio of U.S. submariners, a cross-sectional survey of military men in the Royal Norwegian Navy found lower sex ratios among men with high degrees of exposure to radiofrequency electromagnetic fields, an occupational exposure also common among U.S. submariners.[15]

The present report used a record-based approach to assess whether male U.S. Navy submariners have an atypical offspring sex ratio, a possible indicator for exposure to reproductive hazards. In order to better elucidate the relationship between paternal submariner occupation and offspring sex ratio, this study examined whether sex ratio differed by length of submarine assignment or military service or by paternal occupational specialty.

METHODS

This study utilized records from the Department of Defense (DoD) Birth and Infant Health Research (BIHR) program, an ongoing population-based surveillance effort established in 1998 to identify live births and associated outcomes among DoD beneficiaries.[16] In brief, this effort gathers demographic, personnel, and occupational data from the Defense Manpower Data Center (DMDC) and electronic administrative medical data from the Military Health System Data Repository. The primary BIHR program population consists of all infants born to DoD beneficiaries from 1998–2015. Medical encounters through the infant's first year of life are coded with International Classification of Diseases, 9th/10th Revision, Clinical Modification (ICD-9-CM/ICD-10-CM) diagnostic codes, which are used to define the live birth population and health outcomes of interest. In this report, ICD-10 codes are used for encounters only in October 2015 and later. Same-sex multiple infants are excluded from BIHR program data because of difficulty distinguishing their medical records. Estimated gestational age (EGA) is derived from ICD codes; date of last menstrual period (LMP) is calculated by subtracting EGA from delivery date; and date of conception is calculated by adding 2 weeks to date of LMP.

Infants were included in this study if their father was an active duty member of the U.S. Navy assigned a submarine-specific unit identification code (UIC) within 3 months before their conception; this timeframe was used to capture the period of spermatogenesis, which is estimated to last 74–120 days. Using DMDC personnel records, complete service histories—including information on assigned UICs—were obtained for all active duty sailors who began their service in 2000 or later. If an individual's assigned UIC was associated with a nuclear-powered, general-purpose attack submarine (SSN), ballistic missile submarine (SSBN), or cruise missile submarine (SSGN), they were considered a submariner and are referred to as such throughout this report. Infants resulting from multiple births were excluded from the analysis.

Of note, SSBNs and SSGNs are 2-crew submarines; in other words, sailors assigned to these submarines may be in an "on-crew" phase (when they would report to the submarine) or an "off-crew" phase (when they would report elsewhere); however, this study was unable to distinguish between on-crew and off-crew phases. Because the current analysis sought to assess the offspring sex ratio of fathers whose primary duties were aboard an underway submarine, sensitivity analyses excluding submariners assigned SSBN/SSGN-associated UICs were conducted; this subpopulation consisted of singleton infants born from 2001–2015 to male active duty submariners assigned SSN-specific UICs during preconception.

Three comparison populations were identified to assess whether the offspring sex ratio of active duty male submariners was atypical. Two comparison populations were derived from BIHR program data and included all singleton live births between 2001 and 2015 among 1) all male active duty U.S. Navy sailors and 2) all active duty military service men. The third comparison group was drawn from the U.S. population; information on the sex of all live births from 1995 through 2016 was obtained from the Centers for Disease Control and Prevention's Wide-ranging ONline Data for Epidemiologic Research (WONDER) database.[5] Contingency tables and chi-square tests were used to compare the offspring sex ratio of male active duty submariners with the offspring sex ratio of each comparison population.

In order to assess the potential cumulative effect of submariner occupation, the current study also examined whether offspring sex ratio differed by length of submarine assignment or length of military service. These exposures were categorized based on the distribution in the population; sex ratios with 95% confidence intervals (CIs) were calculated according to quadratic formulas for binomial proportions.[17] Length of submarine assignment was defined by the consecutive number of months (categorized in years) an infant's father was assigned a submarine-specific UIC before their month of conception (<1 year, $\geq$1 to <2 years, $\geq$2 to <3 years, or 3+ years); end of consecutive submarine assignment was defined as the first month a sailor was not assigned a submarine-specific UIC according to DMDC personnel records. Total length of military service was calculated by counting the number of months (categorized as years) from the father's first date of enrollment in the U.S. military to their offspring's month of conception (<5 years, $\geq$5 to <10 years, or 10+ years).

In order to examine whether offspring sex ratio varied by paternal occupation, naval ratings were used to categorize enlisted submariners by their occupational specialty; ratings were used as proxies for occupational exposures relevant to submariners. Offspring sex ratios and 95% CIs for binomial proportions were calculated for each rating and compared with the offspring sex ratio and 95% CIs of the overall submariner population. In 2012, the ratings system was altered to offer more specificity for certain ratings (e.g., the rating "machinist's mate" was expanded to consist of machinist's mate, nuclear power; machinist's mate, non-nuclear, submarine weapons; and machinist's mate, non-nuclear, submarine auxiliary). Because of small sample sizes, these expanded ratings were not included in the current analysis.

To account for potentially confounding factors, additional analyses were conducted on a population of exposed and unexposed infants identified from BIHR program data. Infants were considered exposed if their father was assigned a submarine-specific UIC during preconception, while infants were considered unexposed if their father was an active duty military service man in any other community during preconception or a service man previously assigned a submarine-specific UIC but not during preconception. In addition to a binary exposure variable (i.e., submariner=yes/no), a cumulative exposure measure was created based on the number of consecutive months an infant's father was assigned a submarine-specific UIC before their month of conception. Unconditional multivariable logistic regression models were used to estimate the odds of siring a female for fathers assigned submarine-specific UICs during preconception (both binary and cumulative exposure), with adjustment for paternal age (continuous), maternal age (continuous), and paternal race/ethnicity (American Indian/Alaska Native, Asian/Pacific Islander, non-Hispanic white, non-Hispanic black, Hispanic, other, and unknown), as variation in sex ratio by these demographic characteristics exists.[1] Covariate information was obtained from BIHR program data. For analyses of cumulative exposure, the independent variable was rescaled by a factor of 6, so the effect estimate is interpreted as the odds of siring a female for every 6 additional consecutive months of assignment to a submarine-specific UIC. To assess potential exposure misclassification, a sensitivity analysis excluding unexposed service men previously assigned a submarine-specific UIC but not during preconception (n=3,972) was conducted. All statistical analyses were performed using SAS/STAT© software, version 9.4 (2014, SAS Institute, Cary, NC).

RESULTS

Demographic characteristics of offspring and parents, including information on paternal rank and rating, are outlined for both submariner study populations **(Table 1)**. The current study identified a total of 7,087 singleton infants born to 5,931 male active duty submariners during 2001–2015. Excluded from this analysis were 135 infants resulting from multiple births. All submariner fathers were predominantly of non-Hispanic white or Hispanic race/ethnicity. Among enlisted submariners, the most common naval ratings were machinist's mate, electronics technician, electrician's mate, and sonar technician. Parental demographic and occupational characteristics were similar for both submariner populations; however, no fathers assigned SSN-specific UICs during preconception had a rating of missile technician, as only SSGN and SSBN submarines have ballistic missile systems.

TABLE 1. Offspring[a] and parental characteristics of the active duty submariner study populations, 2001–2015

	Active duty submariners			
	SSN, SSBN, SSGN		SSN only	
Characteristics	No.	%	No.	%
Offspring sex	(n=7,087)		(n=3,756)	
Female	3,460	48.8	1,845	49.1
Male	3,627	51.2	1,911	50.9
Paternal race/ethnicity				
Non-Hispanic black	428	6.0	226	6.2
Non-Hispanic white	4,714	66.5	2,494	66.4
Hispanic	895	12.6	475	12.7
American Indian/Alaska Native	495	7.0	271	7.2
Asian/Pacific Islander	201	2.8	105	2.8
Other	341	4.8	177	4.7
Unknown	13	0.2	8	0.2
Paternal rank				
Enlisted	6,288	88.7	3,291	87.6
Officer	799	11.3	465	12.4
Paternal rating (enlisted only)				
Culinary specialist	265	4.2	133	4.0
Electrician's mate	676	10.8	373	11.3
Electronics technician	1,430	22.7	805	24.5
Fire control technician	374	5.9	198	6.0
Machinist's mate	2,114	33.6	1,170	35.6
Missile technician[b]	358	5.7	0	0.0
Sonar technician	653	10.4	372	11.3
Other[c]	1,217	19.4	705	21.4
	Mean	SD	Mean	SD
Maternal age at preconception	25.2	3.9	25.4	4.0
Paternal age at preconception	25.8	3.4	25.9	3.4

[a]135 infants resulting from multiple births were excluded from the analysis.
[b]No fathers were assigned SSN-specific unit identification codes during preconception.
[c]Includes all ratings with fewer than 200 submariners in the overall submariner population.
SSN, nuclear-powered, general-purpose attack submarine; SSBN, ballistic missile submarine; SSGN, cruise missile submarine; No., number; SD, standard deviation.

In this population, offspring sex ratio differed by paternal race/ethnicity; the highest offspring sex ratios were observed among fathers who reported race/ethnicity as American Indian/Alaska Native (sex ratio=1.250), other (sex ratio=1.229), or Asian/Pacific Islander (sex ratio=1.185) **(data not shown)**. Relatively lower offspring sex ratios were detected among Hispanic (sex ratio=1.096) and non-Hispanic white (sex ratio=1.019) fathers, while non-Hispanic black fathers were the only subgroup with an offspring sex ratio that favored females (sex ratio=0.911). Offspring sex ratios by race/ethnicity were similar when restricted to fathers assigned SSN-specific UICs during preconception **(data not shown)**.

Among all singleton live births between 2001 and 2015, a total of 236,551 infants were identified among the comparison group of male active duty U.S. Navy sailors, and 1,128,232 infants were identified among the comparison group of active duty service men **(Table 2)**. The third comparison

TABLE 2. Offspring sex ratio of male active duty submariners (singleton live births 2001–2015) compared with the offspring sex ratio of other male active duty populations (singleton live births 2001–2015) and the general U.S. population as a whole (all live births 1995–2016)

Population	Total infants No.	Males No.	Males %	Females No.	Females %	Sex ratio	p-value[a]	p-value[b]
Active duty submariners								
SSN, SSBN, SSGN	7,087	3,627	51.2	3,460	48.8	1.048	--	N/A
SSN only	3,756	1,911	50.9	1,845	49.1	1.036	N/A	--
All male active duty U.S. Navy sailors	236,551	121,803	51.5	114,748	48.5	1.061	0.60	0.46
All active duty U.S. military service men	1,128,232	580,080	51.4	548,152	48.6	1.058	0.69	0.51
Total U.S. population	88,730,364	45,405,511	51.2	43,324,853	48.8	1.048	1.00	0.72

[a]p-values correspond to associations for infants of all active duty submariners (n=7,087).
[b]p-values correspond to associations for infants of active duty submariners assigned a SSN-specific unit identification code during preconception (n=3,756).
No., number; SSN, nuclear-powered, general-purpose attack submarine; SSBN, ballistic missile submarine; SSGN, cruise missile submarine; N/A, not applicable.

group was derived from all live births in the general U.S. population from 1996 through 2016 and included 88,730,364 infants. The offspring sex ratio of male submariners did not differ substantially from the offspring sex ratio of male active duty U.S. Navy sailors, active duty U.S. military service men, or the U.S. population **(Table 2)**.

Considering cumulative exposure, submariners with less than 2 years of consecutive submarine assignment had lower offspring sex ratios than submariners with 2 or more years of consecutive submarine assignment **(Table 3)**. There was little variation in offspring sex ratio by total length of military service. Offspring sex ratios were similar for the 3,756 singleton infants born to 3,220 fathers assigned SSN-specific UICs during preconception from 2001–2015 **(data not shown)**.

In analyses of occupational specialty, lower sex ratios were detected for enlisted fathers with a rating of culinary specialist (sex ratio=1.038), electrician's mate (sex ratio=0.994), and electronics technician (sex ratio=0.981), while higher sex ratios were observed for fathers with a rating of fire control technician (sex ratio=1.125), machinist's mate (sex ratio=1.081), missile technician (sex ratio=1.118), and sonar technician (sex ratio=1.100) **(Figure)**. Overall, these estimates were imprecise and any observed differences by rating do not appear to be large or meaningful.

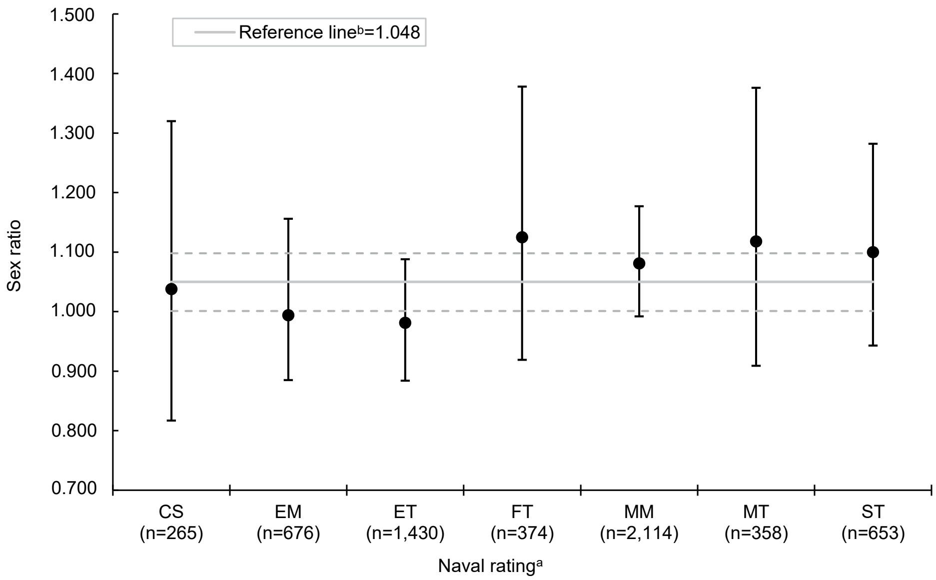
In supplementary analyses, the offspring sex ratio of male active duty submariners was compared with that of all active duty U.S. military service men, adjusting for parental age and paternal race/ethnicity. For infants whose fathers were active duty U.S. military service men, their parents were, on average, older at the time of preconception (mean ± standard deviation; maternal age=26.2±5.1; paternal age=27.4±5.4) **(data not shown)** than the parents of infants whose fathers were submariners **(Table 1)**. Active duty U.S. military fathers were more likely to identify as non-Hispanic white (68.0%) or non-Hispanic black (12.2%) and less likely to identify as American Indian/Alaska Native (1.7%) **(data not shown)** than submariner fathers **(Table 1)**. Multivariable logistic regression models estimated null associations between paternal submariner occupation and siring female offspring for both binary exposure (adjusted odds ratio [AOR]=1.01; 95% CI: 0.96–1.06) and cumulative exposure (AOR=1.00; 95% CI: 0.98–1.01). Results were similarly null for the population of infants whose fathers were assigned SSN-specific UICs during preconception, when all U.S. Navy sailors were used as the comparison group and when unexposed sailors previously assigned a submarine-specific UIC were excluded from analyses **(data not shown)**.

TABLE 3. Sex ratios and 95% CIs for offspring of male active duty submariners (n=7,087), by father's length of submarine assignment and total military service, 2001–2015

Characteristic	Males No.	Males %	Females No.	Females %	Sex ratio	95% CI
Submariner time (years)[a]						
<1	1,145	50.5	1,124	49.5	1.019	0.938–1.106
1 to <2	1,085	50.2	1,075	49.8	1.009	0.928–1.098
2 to <3	794	51.7	742	48.3	1.070	0.968–1.183
3+	603	53.7	519	46.3	1.161	1.033–1.306
Military service time (years)[b]						
<5	1,543	50.9	1,491	49.1	1.035	0.964–1.111
5 to <10	1,621	51.4	1,531	48.6	1.057	0.987–1.135
10+	463	51.4	438	48.6	1.057	0.928–1.204

[a]Defined by consecutive time assigned a submarine-specific unit identification code before the index infant's month of conception.
[b]Defined by total amount of time since first enrollment in the military.
CI, confidence interval; No., number.

FIGURE. Sex ratios for offspring of enlisted submariners (n=6,288) belonging to select naval ratings[a]



[a]CS, culinary specialist; EM, electrician's mate; ET, electronics technician; FT, fire control technician; MM, machinist's mate; MT, missile technician; ST, sonar technician.
[b]Reference line indicates offspring sex ratio (1.048), and the dashed lines represent the 95% confidence interval (1.001–1.098) for the overall study population.

EDITORIAL COMMENT

The results of this large, record-based study suggest that the offspring sex ratio of male active duty U.S. submariners is normal. These findings conflict with results from previous studies of submariner offspring sex ratios, which detected lower sex ratios among all male submariners or by length of service and occupational specialty.[12–14]

While offspring sex ratio is known to differ by certain demographic characteristics (e.g., parental age and race/ethnicity),[1] there are many suspected causes of variation in sex ratio. Perhaps the most well established is maternal stress, which is theorized to alter sex ratio through male-biased fetal losses. Studies have shown that mothers who experience catastrophic events in pregnancy, adverse periconceptional life events, or psychological stress during early gestation are more likely to experience fetal loss.[18–20] Furthermore, evidence suggests these losses selectively cull frail males, thus resulting in a higher proportion of live born females among affected women.[21,22] Other suspected causes of variation in sex ratio include parental hormone concentrations at the time of conception,[23–25] ambient temperature during gestation,[26] parental smoking status,[27] and paternal occupation.[28,29] Studies of the Chernobyl disaster suggest that exposure to high levels of environmental ionizing radiation increases the offspring sex ratio.[30,31]

The submarine environment is prone to a variety of potentially hazardous exposures, including radiation, disrupted circadian cycles, high stress, prolonged isolation, and altered oxygen and carbon monoxide levels. Of these, only radiation has been investigated in studies of paternal occupational exposure and offspring sex ratio, but evidence is conflicting.[15,32–35] For submariners, the extent of exposure to radiation differs by occupational specialty. For example, all enlisted submariners with a rating of electrician's mate are nuclear-trained, but submariners with other ratings, such as machinist's mate and electronics technician, include those with and without nuclear training. However, it is important to note that sailors serving aboard submarines currently receive less total annual radiation exposure than they would if stationed ashore.[36] Although the 2012 change to the ratings system better clarified which sailors worked with nuclear power, this study lacked the statistical power to conduct a sensitivity analysis for the years following this change. In this study, relatively low offspring sex ratios were detected for enlisted submariners with a rating of electrician's mate (sex ratio=0.994; 95% CI: 0.885–1.156) and electronics technician (sex ratio=0.981; 95% CI: 0.884–1.088), but a relatively high offspring sex ratio was detected for those with a rating of machinist's mate (sex ratio=1.081; 95% CI: 0.992–1.177). These findings are similar to those reported in a previous study of U.S. submariners.[13] Although limited by imprecision, the current study did not find evidence to suggest that submariners' occupational specialty influenced offspring sex.

Because this was a record-based study, there was nondifferential misclassification of submariners and their exposure status, which would bias associations towards the null. Although historical personnel information was used to identify submariners based on their assigned UIC, it is possible that a sailor was assigned a UIC captured by DMDC records but did not actually serve aboard the corresponding vessel. To the authors' knowledge, there are no existing validation efforts that assess the accuracy of assigned UICs in military or Navy populations. Thus, it is unclear whether or how often UIC misclassification occurs. Furthermore, the assignment of a submarine-specific UIC does not necessarily indicate that sailors are serving aboard an underway submarine. While this study attempts to address this issue by conducting a sensitivity analysis of fathers assigned SSN-specific UICs during preconception, it cannot entirely account for all possible misclassification of submariner exposure status.

Additionally, because ICD codes were used to define EGA, date of conception (and therefore the preconception window used for exposure assessment) was also prone to nondifferential misclassification. However, a previous BIHR program validation study found ICD-9 codes provide an accurate assessment of EGA in this military population,[37] thus limiting misclassification attributable to ICD coding errors. Additionally, the current study's record-based nature eliminates any recall or selection bias, which, given the widespread belief in the community that submariners are more likely to father females, has the potential to strongly affect a survey-based study of this population. The large sample of infants in the current study, prospectively collected over several years, sets it apart from most previous analyses of offspring sex ratio and submariners. Nonetheless, this study lacked the statistical power to detect small differences in offspring sex ratio.

The results of this study contradict the longstanding belief that male submariners are more likely to father females. These findings further indicate that submariners are not likely exposed to reproductive hazards in the workplace that alter offspring sex ratio and that current safety measures sufficiently protect the submariner force from such harmful exposures.

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REFERENCES

1. Mathews TJ, Hamilton BE. Trend analysis of the sex ratio at birth in the United States. *Natl Vital Stat Rep*. 2005;53(20):1–17.
2. Davis DL, Gottlieb MB, Stampnitzky JR. Reduced ratio of male to female births in several industrial countries: a sentinel health indicator? *JAMA*. 1998;279(13):1018–1023.
3. Grech V, Vassallo-Agius P, Savona-Ventura C. Secular trends in sex ratios at birth in North America and Europe over the second half of the 20th century. *J Epidemiol Community Health*. 2003;57(8):612–615.
4. Grech V. Sex ratios at birth in the British Isles over the past sixty years. *Eur J Pediatr*. 2013;172(4):525–528.
5. CDC WONDER online database. Atlanta, GA: Centers for Disease Control and Prevention. https://wonder.cdc.gov/. Updated 18 December 2018. Accessed 4 April 2019.
6. Mocarelli P, Gerthoux PM, Ferrari E, et al. Paternal concentrations of dioxin and sex ratio of offspring. *Lancet*. 2000;355(9218):1858–1863.
7. Mackenzie CA, Lockridge A, Keith M. Declining sex ratio in a first nation community. *Environ Health Perspect*. 2005;113(10):1295–1298.
8. Hertz-Picciotto I, Jusko TA, Willman EJ, et al. A cohort study of in utero polychlorinated biphenyl (PCB) exposures in relation to secondary sex ratio. *Environ Health*. 2008;7:37.
9. Arikawa M, Jwa SC, Kuwahara A, Irahara M, Saito H. Effect of semen quality on human sex ratio in in vitro fertilization and intracytoplasmic sperm injection: an analysis of 27,158 singleton infants born after fresh single-embryo transfer. *Fertil Steril*. 2016;105(4):897–904.
10. Eisenberg ML, Murthy L, Hwang K, Lamb DJ, Lipshultz LI. Sperm counts and sperm sex ratio in male infertility patients. *Asian J Androl*. 2012;14(5):683–686.
11. James WH. Male reproductive hazards and occupation. *Lancet*. 1996;347(9003):773.
12. Bachmann WT. *Births to Submarine Based Personnel—A Statistical Study*. Groton, CT: Naval Submarine Medical Research Laboratory; 1970.
13. Volk B. Evaluating the sex ratio in the offspring of U.S. Navy submariners. *Mil Med*. 2004;169(11):890–893.
14. Kramer K, Raiciulescu S, Olsen C, Hickey K, Ottolini M. Altered sex ratios in offspring of U.S. submariners urban legend or fact—Do submariners have more daughters? *Mil Med*. 2019; Jan 24 [Epub ahead of print].
15. Baste V, Riise T, Moen BE. Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. *Eur J Epidemiol*. 2008;23(5):369–377.
16. Ryan MA, Pershyn-Kisor MA, Honner WK, Smith TC, Reed RJ, Gray GC. The Department of Defense Birth Defects Registry: overview of a new surveillance system. *Teratology*. 2001;64(suppl 1):S26–S29.
17. Spiegel MR. *Theory and Problems of Statistics*. New York, NY: McGraw-Hill; 1961.
18. Bruckner TA, Catalano R, Ahern J. Male fetal loss in the U.S. following the terrorist attacks of September 11, 2001. *BMC Public Health*. 2010;10:273.
19. Hansen D, Moller H, Olsen J. Severe periconceptional life events and the sex ratio in offspring: follow up study based on five national registers. *BMJ*. 1999;319(7209):548–549.
20. Obel C, Henriksen TB, Secher NJ, Eskenazi B, Hedegaard M. Psychological distress during early gestation and offspring sex ratio. *Hum Reprod*. 2007;22(11):3009–3012.
21. Bruckner T, Catalano R. The sex ratio and age-specific male mortality: evidence for culling in utero. *Am J Hum Biol*. 2007;19(6):763–773.
22. Catalano R, Bruckner T. Secondary sex ratios and male lifespan: damaged or culled cohorts. *Proc Natl Acad Sci U S A*. 2006;103(5):1639–1643.
23. James WH, Grech V. Offspring sex ratio: coital rates and other potential causal mechanisms. *Early Hum Dev*. 2018;116:24–27.
24. James WH, Grech V. A review of the established and suspected causes of variations in human sex ratio at birth. *Early Hum Dev*. 2017;109:50–56.
25. James WH. Proximate causes of the variation of the human sex ratio at birth. *Early Hum Dev*. 2015;91(12):795–799.
26. Catalano R, Bruckner T, Smith KR. Ambient temperature predicts sex ratios and male longevity. *Proc Natl Acad Sci U S A*. 2008;105(6):2244–2247.
27. Fukuda M, Fukuda K, Shimizu T, Andersen CY, Byskov AG. Parental periconceptional smoking and male: female ratio of newborn infants. *Lancet*. 2002;359(9315):1407–1408.
28. Magnuson A, Bodin L, Montgomery SM. Father's occupation and sex ratio of offspring. *Scand J Public Health*. 2007;35(5):454–459.
29. Dickinson HO, Parker L. Sex ratio in relation to fathers' occupations. *Occup Environ Med*. 1997;54(12):868–872.
30. Grech V. The Chernobyl accident, the male to female ratio at birth and birth rates. *Acta Medica (Hradec Kralove)*. 2014;57(2):62–67.
31. Scherb H, Kusmierz R, Voigt K. Increased sex ratio in Russia and Cuba after Chernobyl: a radiological hypothesis. *Environ Health*. 2013;12:63.
32. Hama Y, Uematsu M, Sakurai Y, Kusano S. Sex ratio in the offspring of male radiologists. *Acad Radiol*. 2001;8(5):421–424.
33. Dickinson HO, Parker L, Binks K, Wakeford R, Smith J. The sex ratio of children in relation to paternal preconceptional radiation dose: a study in Cumbria, northern England. *J Epidemiol Community Health*. 1996;50(6):645–652.
34. Maconochie N, Roman E, Doyle P, Davies G, Smith PG, Beral V. Sex ratio of nuclear industry employees' children. *Lancet*. 2001;357(9268):1589–1591.
35. Terrell ML, Hartnett KP, Marcus M. Can environmental or occupational hazards alter the sex ratio at birth? A systematic review. *Emerg Health Threats J*. 2011;4:7109.
36. Mueller TJ, Weishar TM, Hallwoth JM, Bonamer DG; Naval Nuclear Propulsion Program, Department of the Navy. Report NT-18-2: Occupational radiation exposure from U.S. Naval nuclear plants and their support facilities. https://www.energy.gov/sites/prod/files/2018/07/f53/NT-18-2.pdf. Published May 2018. Accessed 4 April 2019.
37. Barrett JP, Sevick CJ, Conlin AM, et al. Validating the use of ICD-9-CM codes to evaluate gestational age and birth weight. *J Registry Manag*. 2012;39(2):69–75.

Norovirus Outbreak in Army Service Members, Camp Arifjan, Kuwait, May 2018

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In May 2018, an outbreak of gastrointestinal illnesses due to norovirus occurred at Camp Arifjan, Kuwait. The outbreak lasted 14 days, and a total of 91 cases, of which 8 were laboratory confirmed and 83 were suspected, were identified. Because the cases occurred among a population of several thousand service members transiting through a crowded, congregate setting of open bays of up to 250 beds, shared bathrooms and showers, and large dining facilities, the risk of hundreds or thousands of cases was significant. The responsible preventive medicine authorities promptly recognized the potential threat and organized and monitored the comprehensive response that limited the spread of the illness and the duration of the outbreak. This report summarizes findings of the field investigation and the preventive medicine response conducted from 18 May–3 June 2018 at Camp Arifjan.

WHAT ARE THE NEW FINDINGS?

Introduction of norovirus disease into a crowded, congregate setting of transient service members precipitated an outbreak of at least 91 recognized cases in a vulnerable population of thousands. Prompt actions to halt air traffic in and out of the base, to isolate and quarantine infected persons, and to restrict movement to separate the well from the sick aborted the outbreak.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Norovirus is the leading cause of gastrointestinal illnesses in military settings. The contagiousness of the virus and the short incubation period can result in high case counts in concentrated military populations whose mission readiness may be impaired by widespread illness and necessary control measures. Recognition of this illness should prompt rapid and vigorous countermeasures.

Norovirus is the leading cause of acute gastrointestinal (GI) illness outbreaks in military settings.[1–7] Norovirus can be transmitted through person-to-person direct contact and exposure to contaminated food, water, aerosols, and fomites.[7–9] Additionally, the virus is resistant to extreme temperatures and many standard disinfection methods.[9] Following a short incubation period of 24–72 hours, symptoms, lasting 1 to 3 days, may include diarrhea, vomiting, nausea, and stomach pain. Patients recovering from a norovirus infection may shed the virus in their stool for up to 14 days, increasing the risk of secondary infection.[7–9]

Setting

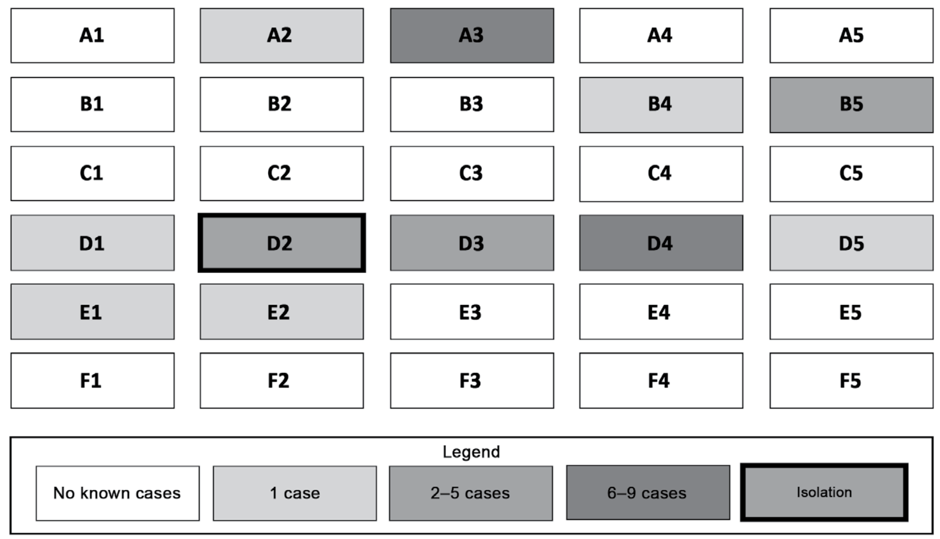
Camp Arifjan, Kuwait, is the largest U.S. military base in the U.S. Central Command (USCENTCOM) and, at the time of the reported outbreak, accommodated over 10,000 service members from all branches of the U.S. military and the North Atlantic Treaty Organization as well as Department of Defense (DoD) civilians and contractors. Camp Arifjan's gateway serves as the hub for U.S. military and DoD personnel traveling throughout the Southwest Asian Theater. On a daily basis, a minimum of 1,000 personnel are transiting through Camp Arifjan's gateway to return to the U.S. or to travel to other points within the USCENTCOM, making the area highly susceptible to the spread of infectious disease. At the time of the outbreak described in this report, there were approximately 14,000 service members at Camp Arifjan, of which about 3,000–4,000 were in transit and 10,000 were permanently assigned there.

For transient personnel awaiting transportation, separate housing and bathrooms are located within the gateway area; however, transients' movements throughout the rest of Camp Arifjan are not restricted. Dining, laundry, recreation, and transportation facilities are shared between the transient and permanent populations. Housing comprises concrete buildings with beds located in open bays that can accommodate up to 250 people. Latrine and shower facilities are in separate trailers but are also used by those who work within the gateway area. Of the 35 buildings within the gateway, 5 are reserved for latrine/showers, 7 function as administrative offices for the gateway transportation and postal services, 7 serve as offices for the theater engineer brigade, and 16 operate as transient barracks.

Outbreak timeline

On 18 May at approximately 0800 hours, the 75th Combat Support Hospital emergency department (ED) evaluated a male active duty patient who presented with symptoms of nausea, vomiting, and diarrhea. This patient had traveled from a classified country to Ali Al Salem Air Base and then to Camp Arifjan en route to redeploy to the U.S. The patient and his unit had slept outside while at Ali Al Salem and were there for less than 8 hours before traveling via bus to Camp Arifjan. During the 2-hour bus drive from Ali Al Salem to Camp Arifjan, with an estimated 30 other personnel on the bus, the patient vomited and soiled himself multiple times. Upon arriving in Camp Arifjan, the patient was transported by his unit directly from the bus to the ED. In the ED, after the patient was assessed and treated, a stool specimen was collected for clinical testing, and he was released to his unit into the transient barracks in building D2 at the gateway **(Figure 1)**.

FIGURE 1. Layout of gateway area, where the majority of initial cases resided.[a]



[a]Not all cases' building numbers were tracked. Buildings have been renamed for classification purposes.

The 223rd Medical Detachment (Preventive Medicine [PM]) and the theater PM physician at the medical brigade were immediately notified of the patient, and an aliquot of the stool specimen was transferred to the PM laboratory for surveillance testing via the BioFire® FilmArray® GI panel. Norovirus, enteropathogenic *Escherichia coli*, and enteroaggregative *E. coli* were all detected in the stool specimen. The 223rd Medical Detachment microbiologist immediately notified the public health nurse stationed with the 75th Combat Support Hospital. Twenty minutes after receiving the results of the GI test, the detachment commander and the PM physician decided that the index patient was to be immediately readmitted to the hospital. Two hours after being initially discharged, the patient was readmitted to the hospital and put into isolation.

On 20 May, 2 additional cases presented with nausea, vomiting, and diarrhea. One case tested positive for norovirus on the FilmArray® GI panel. This case was housed at the gateway in building B4. When interviewed, he reported that 1 of the soldiers who lived in building D2 was also sick. The other case could not produce a stool specimen for testing. Social media postings seen by the PM staff reported anecdotally that other soldiers were sick during this time, but no other soldiers presented to the hospital with GI symptoms, resulting in several days without patients.

On 23 May, an Army unit departed Kuwait and arrived at North Fort Hood, TX, the next day. The soldiers in the unit were not symptomatic upon their departure; however, during the course of the flight, a total of 21 soldiers exhibited symptoms consistent with norovirus, and 1 case was later laboratory confirmed. These 21 cases were not counted in the total case count from Camp Arifjan. All symptomatic soldiers were seen, treated, and released to quarters per the chief of PM at Carl R. Darnall Army Medical Center in Fort Hood.

On 24 May, 3 patients presented with norovirus symptoms at the ED at Camp Arifjan; all patients were confirmed positive for norovirus with the BioFire® FilmArray®. On 25 May, a medic arrived at 0500 to the ED to request Imodium® for soldiers in his unit who were sick and were scheduled to redeploy home that day. Throughout the day, 12 patients presented to the ED and clinic with symptoms consistent with norovirus illness, and an outbreak was officially declared by the medical brigade commander, who notified the installation commander of Camp Arifjan. Based upon the recommendation of the theater PM physician, the command authorities and the Air Force agreed to halt flights coming in and out of Camp Arifjan. The flight leaving for Fort Hood mentioned above had departed Camp Arifjan before flights were halted; however, no other flights departed Camp Arifjan until the outbreak had resolved, and Fort Hood reported this incident and response to the Disease Reporting System internet on 30 May. All new cases presenting with symptoms consistent with norovirus were assumed to be part of this outbreak unless proven otherwise. Over the course of 14 days, a total of 91 cases experienced symptoms of nausea, vomiting, diarrhea, and/or abdominal pain while at Camp Arifjan.

METHODS

All cases were symptomatically identified. The BioFire® system was used for presumptive testing during the outbreaks in theater. Testing via the BioFire® system was suspended once norovirus was identified in the first 8 cases and thus determined to be the cause of the outbreak. BioFire® testing began again at the end of the outbreak to separate those patients without norovirus to preclude them from the quarantine area in an effort to prevent them from acquiring a nosocomial illness.

For the epidemiologic investigation described here, a confirmed case of norovirus was defined as a patient at Camp Arifjan from 18–31 May who experienced nausea, vomiting, diarrhea, or abdominal cramps and whose stool specimen tested positive for norovirus via polymerase chain reaction using the FilmArray® GI Panel for norovirus. A suspected case was defined as a patient having any of the same symptoms as a confirmed case but whose stool sample was not tested. After the index case, individuals who had experienced symptoms outside of Camp Arifjan, including the aforementioned soldiers who traveled to Fort Hood, were not included in the overall case count.

RESULTS

From 18–31 May 2018, a total of 91 cases (8 confirmed and 83 suspected) of norovirus were found in Camp Arifjan, Kuwait **(Figure 2)**. Two symptomatic cases (1 confirmed and 1 suspected) did not have a recorded onset date.

The most common symptoms reported by patients were diarrhea, vomiting, and nausea **(Table)**. Most cases were among men (84%) and among junior enlisted (48%) and senior enlisted (35%) personnel **(Table)**. Six cases (6%) had been previously deployed in neighboring countries and had been in Kuwait for fewer than 4 days before their illness onset date. Twelve cases (13%) belonged to 1 unit, which had the highest concentration of cases in any single unit. Attack rates by unit were not available.

Confirmed and suspect cases were symptomatic for 1 day on average (range: 1–4 days). The index case and the last known case were both hospitalized, primarily for isolation purposes. The last hospitalized case was moved from the barracks to the hospital to allow the barracks to be cleaned and opened to house other service members again.

Countermeasures

On 18 May, PM made initial recommendations to the gateway staff to limit the number of new service members placed in building D2. The staff refused because of overcrowding and the need to place service members in beds. However, in the effort to reduce the spread of infection, signs were placed that evening by the 223rd Detachment team on building D2 and the closest men's bathroom. It was later ascertained through patient interviews that the precautions on these signs were generally ignored.

On the evening of 18 May, PM specialists were sent to observe cleaning contractors while latrines were being disinfected and to oversee the cleaning dilution used. The cleaning contractors were directly observed using toilet water to mop and clean the bathroom sinks. On 19 May, PM notified the base contracting officers about the unsanitary cleaning practices and the potential of an upcoming norovirus outbreak, emphasizing how improper cleaning practices exacerbate the spread of disease. No changes were made to the cleaning schedule to disinfect those sinks until after the outbreak had started.

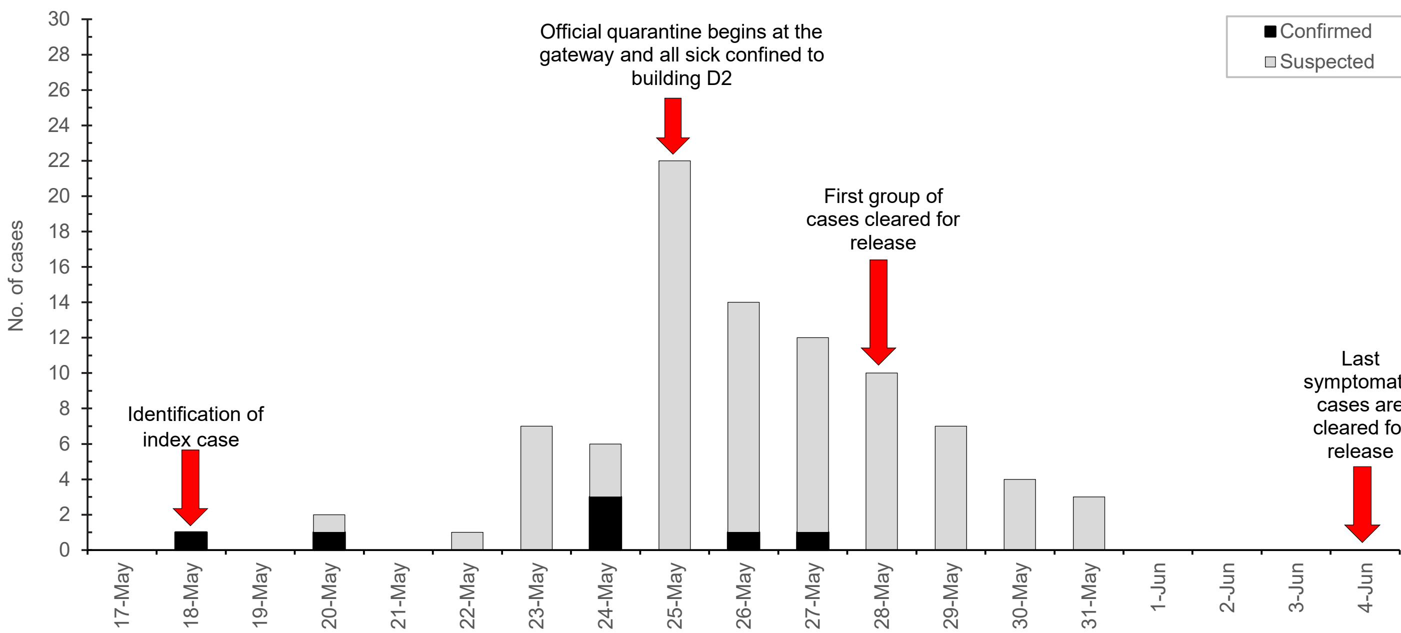
Daily briefings were held to keep all healthcare providers, medics, and cleaning teams informed. These briefings provided information to help facilitate the plan for the next 12–24 hours, including a reminder of the cleaning protocols and updates on the status of housing, food, the cleaning of latrines, and the numbers of service members who were quarantined, cleared, or with active symptoms.

On 25 May, at the recommendation of the theater PM physician, all flights departing Kuwait were halted and a 72-hour quarantine at the gateway was initiated. An incident commander worked closely with base stakeholders to ensure infection control measures were implemented while medical care, security, food, and other accommodations were provided for the more than 1,200 personnel housed in the quarantine area, which included the 30 buildings shown in

TABLE. Demographics of, and symptoms reported by, cases at Camp Arifjan, Kuwait

	n	% of total
Demographics		
Female	15	16.5
Male	76	83.5
Rank		
Junior enlisted	44	48.4
Non-commissioned officers	32	35.2
Commissioned officers	11	12.1
Warrant officers and civilians	4	4.4
Reported symptoms		
Diarrhea	71	78.0
Nausea	52	57.1
Vomiting	45	49.5
Abdominal pain	4	4.4
Total	91	100.0

FIGURE 2. Daily case count for confirmed and suspected norovirus cases, Camp Arifjan, May 2018



No., number.

Figure 1. Building D2 was designated the isolation building for all newly identified sick cases. That building was chosen to isolate symptomatic patients because the index case originally slept there and all service members residing in that building had potentially been exposed. The building was also chosen because it was closest to the latrine that had already been used by several confirmed cases.

The same day, the theater PM physician recommended a tiered approach to isolation and quarantine in an effort to control the spread of disease by placing all service members into 4 groups. Group 1 consisted of symptomatic cases who were isolated in building D2. Group 2 comprised those recovering from GI illness who were isolated in another building for an additional 24 hours after symptoms resolved. Group 3 included exposed service members who had not exhibited any symptoms but were being contained in the D and E blocks during the length of the incubation period (72 hours). Group 4 was composed of others in the general population who never exhibited symptoms and were not knowingly exposed to the ill population. Groups 1–3 remained inside the quarantine area, and most were released by 29 May. Service members in group 4 were free to move throughout Camp Arifjan but were restricted from entering the quarantine area. Barricade tape sectioned off the approximately 300 yard perimeter, and military police secured the

FIGURE 3. Gastrointestinal infections surveillance form used during norovirus outbreak

Date of Visit	DD/MMM/YYYY	Name		RANK	
Date of Birth	DD/MMM/YYYY	Unit		Gender	
SSN		Email			
Clinics Visited		Work Phone:		Cell Phone:	

Symptoms (please circle all that apply):	First Symptom Onset - date: DD/MMM/YYYY____	
1 = Abdominal Cramps **2 = Diarrhea** **3 = Fever** **4 = Nausea** **5 = Vomiting** **6 = Other:**	Max # of diarrheic stools w/in any 24hr period: ______	Total # of diarrheic stools since start of episode: _____
	Max # of vomit w/in any 24hr period: ______	Total # of vomiting episodes since start of episode: ____
Stool Grade (please circle the one that applies):	Body Temperature (Fever): ______˚F	
1 = Fully formed (normal) **2 = Soft (normal)** **3 = Thick liquid (diarrheal)** **4 = Opaque watery (diarrheal)**	Visible Bloody Stool: ____ Yes; ____ NO	
5 = Rice-water (diarrheal)	Any Medication taken since the onset of current episode:	
Any travel within last 14 days: ___ Yes ___ NO	Destination: _______________	Duration of the travel: ___ Days

Food History	**Meals consumed prior to the onset of symptoms**	**Beverage**	**Dining Locations:**
Last meal:		Ice: ___ Yes; ___ No	
Second last meal:		Ice: ___ Yes; ___ No	
Third last meal:		Ice: ___ Yes; ___ No	
Provider Info:	**Name:**	**Contact Phone:**	

For Infectious Diseases Surveillance Laboratory Use Only: (Note: Tests are real time PCR or RT-PCR assays)			
■ *Clostridium difficile*	___ Detected; ___ Not Detected	■ Norovirus Group I	___ Detected; ___ Not Detected
■ *Salmonella spp.*	___ Detected; ___ Not Detected	■ Norovirus Group II	___ Detected; ___ Not Detected
■ *Vibrio cholera*	___ Detected; ___ Not Detected	■ Rotavirus	___ Detected; ___ Not Detected
■ *Vibrio parahaemolyticus*	___ Detected; ___ Not Detected	■ Astrovirus	___ Detected; ___ Not Detected
■ *Yersinia enterocolitica*	___ Detected; ___ Not Detected	■ *Giardia lamblia*	___ Detected; ___ Not Detected
■ *Campylobacter jejuni*	___ Detected; ___ Not Detected	■ Others Pathogens:	
■ Shigella spp. + EIEC	___ Detected; ___ Not Detected		
■ EHEC	___ Detected; ___ Not Detected		___ Detected; ___ Not Detected

perimeter to prevent service members from entering or leaving the quarantine zone.

On 28 May, survey forms **(Figure 3)** were developed to expedite the screening process for medically clearing service members. Providers and medics were recruited from the quarantined units to assist with administering the survey in the quarantined area. The form was designed to be cut in half so that service members could keep a copy and use it as their ticket to leave the quarantined area and move freely within Camp Arifjan if they had been medically cleared to do so. Two healthcare providers, 20 medics, and 1 public health nurse administered the surveys to the service members who were billeted in the quarantine buildings. Two PM technicians were assigned to each row of quarantined buildings. PM technicians and the public health nurse instructed cleaning teams in each building on the mixing of bleach solution and proper cleaning procedures, according to guidelines from the Centers for Disease Control and Prevention. All personnel were medically evaluated and all buildings were sanitized by 2300 on May 28. At 2400 that evening, the quarantine area was reduced to building D2, where sick personnel remained, and to specified bathrooms.

EDITORIAL COMMENT

The operational impact of the outbreak at Camp Arifjan was dramatic. Not only was there a surge in illness among service members in transit, the definitive steps taken to preclude the spread of the contagious virus elsewhere resulted in the shutdown of a key USCENTCOM transit station for about 10 days. The unique setting and circumstances of this outbreak highlight several public health gaps faced by deployed service members and those providing health care in this environment. Because no outbreak investigation standard operating procedure (SOP) was in place before this outbreak, the investigation and response were implemented de novo. The absence of an SOP for handling outbreaks is an acknowledged gap across many military treatment facilities, both within the U.S. and in deployed operations.[10] The lack of an SOP delayed the initiation of an outbreak investigation by PM and nursing teams. The outbreak highlighted that cleaning staff were not initially using proper techniques to disinfect the latrines, which may have contributed to additional cases. The size of the outbreak and the concomitant tasks of identifying, finding, treating, and responding to the high number of cases overwhelmed the PM staff and directly impacted the delay in reporting details of this outbreak according to DoD policy until the outbreak was nearly over. An approved theater outbreak response plan is needed in order to help mitigate and prevent future outbreaks in theater. Such a plan should be centrally drafted at the level of the medical brigade, not by each unit or location. A general response plan should be encouraged for each location, but the PM assets and expertise required to manage an outbreak may not always be available at each location.

The physicians at the 75th Combat Support Hospital who evaluated and treated the index patient released him to return to his billeting. However, in a deployed environment, a significant consideration is to protect the force by removing patients who are potentially infectious from the general population. Although the theater PM physician and 223rd PM commander were able to identify and readmit the index case within 2 hours of his ED discharge, it is unknown how many others the index case may have exposed during this time, especially given the poor cleaning procedures being utilized during that period. A theater outbreak response plan must include specifics for protecting the health of other service members when one of them is ill and may be highly infectious.

Laboratory capabilities are limited throughout the theater. For most diseases requiring laboratory support, specimens are sent to Landstuhl Regional Medical Center for processing, which can cause a significant delay in diagnosis and treatment. However, for this outbreak, the use of the BioFire® system allowed for immediate testing of specimens in Camp Arifjan. As a result of this outbreak, the theater medical command learned the value of the rapid nucleic acid detection system and acquired additional systems for hospitals and traveling PM teams throughout the theater.

PM assets of the medical brigade, namely the theater PM physician and the commander of the PM detachment, advised the medical brigade commander to recommend to the installation commander the 3 major actions that resulted in control of the norovirus outbreak. Those actions were 1) the halting of flights in and out of Camp Arifjan; 2) the isolation of infected, symptomatic patients and the quarantine of recovering and exposed service members; and 3) the restriction of movement of service members to prevent spread of infection to others outside the quarantine area.

At the time of the Camp Arifjan outbreak, an additional outbreak thought to be due to norovirus occurred in a classified country, where 13 soldiers were identified with symptoms consistent with norovirus. On 27 May, a PM surveillance laboratory team and the theater PM physician were forward deployed to determine the root cause of that outbreak. A link between the 2 outbreaks could not be proven.

Given the number of service members located at Camp Arifjan at the time and the high attack rate of norovirus, the case count could have been in the thousands. Despite the successful response, this outbreak highlighted the need for a theater outbreak response plan, which should include details on responding to infectious patients in the deployed environment and frequent education and review of proper cleaning techniques and personal hygiene. This outbreak also demonstrated the importance of inclusion of the medical brigade PM teams for any outbreak investigations in theater. The epidemic curve suggests this was a point source epidemic, originating from the index case and then further spreading via person-to-person contact and contaminated environmental surfaces, including latrines. Because of the efforts of the public health teams, the outbreak response was successful in limiting the breadth and duration of the outbreak.

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REFERENCES

1. Armed Forces Health Surveillance Branch. Gastrointestinal infections, active component, U.S. Armed Forces, 2002–2012. *MSMR*. 2013;20(10):7–11.
2. Armed Forces Health Surveillance Branch. Surveillance snapshot: Norovirus outbreaks among military forces, 2008–2016. *MSMR*. 2017;24(7):30.
3. Armed Forces Health Surveillance Branch. Historical perspective: Norovirus gastroenteritis outbreaks in military forces. *MSMR*. 2011;18(11):7–8.
4. Darling ND, Poss DE, Brooks KM, et al. Brief report: Laboratory characterization of noroviruses identified in specimens from Military Health System beneficiaries during an outbreak in Germany, 2016–2017. *MSMR*. 2017;24(7):2–29.
5. Kasper MR, Lescano AG, Lucas C, et al. Diarrhea outbreak during U.S. military training in El Salvador. *PLoS ONE*. 2012;7(7).
6. Putnam SD, Sanders JW, Frenck RW, et al. Self-reported description of diarrhea among military populations in Operations Iraqi Freedom and Enduring Freedom. *J Travel Med*. 2006;13(2):92–99.
7. Riddle MS, Martin GJ, Murray CK, et al. Management of acute diarrheal illness during redeployment: a deployment health guideline and expert panel report. *Mil Med*. 2017;182(9):34–52.
8. Centers for Disease Control and Prevention. Updated norovirus outbreak management and disease prevention guidelines. *MMWR Recomm Rep*. 2011;4(60):1–18.
9. Centers for Disease Control and Prevention. Norovirus. https://www.cdc.gov/norovirus/about/index.html. Accessed 3 June 2019.
10. Ambrose J, Kebisek J, Gibson K, White D. Gaps in reportable medical event surveillance across the Department of Defense and recommended tools to improve surveillance practices. *MSMR*. 2019. In press.

Outbreak of Cyclosporiasis in a U.S. Air Force Training Population, Joint Base San Antonio–Lackland, TX, 2018

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Diarrheal illnesses have an enormous impact on military operations in the deployed and training environments. While bacteria and viruses are the usual causes of gastrointestinal disease outbreaks, 2 Joint Base San Antonio–Lackland, TX, training populations experienced an outbreak of diarrheal illness caused by the parasite *Cyclospora cayetanensis* in June and July 2018. Cases were identified from outpatient medical records and responses to patient questionnaires. A confirmed case was defined by diarrhea and laboratory confirmation, and patients without a positive lab were classified as suspected cases. In cluster 1, 46 suspected and 7 confirmed cases occurred among technical training students who reported symptom onset from 12 June to 21 June. In cluster 2, 18 suspected and 14 confirmed cases in basic military training trainees reported symptom onset from 29 June to 8 July. Numerous lessons from cluster 1 were applied to cluster 2. Crucial lessons learned during this cyclosporiasis outbreak included the importance of maintaining clinical suspicion for cyclosporiasis in persistent gastrointestinal illness and obtaining confirmatory laboratory testing for expedited diagnosis and treatment.

WHAT ARE THE NEW FINDINGS?

Diarrheal disease due to the protozoan *Cyclospora cayetanensis* had not been previously reported among American military trainees in the U.S. This report describes the life cycle of the protozoan and highlights the difficult nature of source finding and the importance of clinical suspicion for cyclosporiasis in persistent gastrointestinal illness.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Up to 60% of deployed U.S. troops have reported episodes of diarrhea during their deployment. The main causes of these diarrheal illnesses are bacterial and viral, but *C. cayetanensis* may cause protracted, relapsing gastroenteritis impacting operational readiness and mission effectiveness. This report shares recommendations for future cyclosporiasis outbreak investigations.

Diarrheal illnesses have an enormous impact on military operations. Historically, up to 60% of deployed U.S. troops have reported episodes of diarrhea during their deployment.[1–3] Understandably, diarrheal illness negatively impacts operational readiness and mission effectiveness in deployment locations, as it results in increased healthcare service use, loss of man-hours, and transient critical shortages.[4] However, this negative impact is also readily apparent within the unique environment of military training. Moreover, although the majority of military gastrointestinal outbreaks in both the deployed and training environments have been bacterial (e.g., *Escherichia coli*) or viral (e.g., norovirus) in origin,[5–7] recent outbreaks in the U.S. civilian population as well as an outbreak in military training facilities in El Salvador indicate that the protozoan *Cyclospora cayetanensis* may also pose a threat.[8]

C. cayetanensis is a coccidian protozoan parasite that causes protracted, relapsing gastroenteritis known as cyclosporiasis.[9] Cyclosporiasis is a waterborne and foodborne illness associated with contaminated water or fresh produce, usually imported. The illness has an average incubation period of 7 days, and symptoms can last up to 6 weeks. Excreted oocysts require 1 to 2 weeks outside the human host to undergo sporulation before becoming infectious[9]; therefore, person-to-person transmission is unlikely. While the course of illness can be self-limited, treatment with trimethoprim-sulfamethoxazole can shorten the duration of illness and oocyte excretion.[9]

From 2000 through 2016, the Centers for Disease Control and Prevention (CDC) tracked 33 U.S. outbreaks of cyclosporiasis.[10] In 2017, CDC received notification of 1,065 laboratory-confirmed cases of cyclosporiasis from 40 states, including cases associated with international travel.[11] This report describes an outbreak of diarrheal disease caused by *C. cayetanensis* among U.S. military technical school students (cluster 1) and basic military trainees (cluster 2) at Joint Base San Antonio–Lackland (JBSA–Lackland), TX, during June and July 2018. These outbreaks were unrelated to the 2 national outbreaks of cyclosporiasis that occurred during the same time period.

METHODS

Setting

JBSA–Lackland is the only location for U.S. Air Force basic military training (BMT). Recruits come from all parts of the U.S. and from numerous international locations for 7.5 weeks of BMT. At any given time, there are 5,000 to 8,000 BMT trainees distributed across 6 training squadrons. The squadrons are divided into 40- to 50-member training flights. Members of each flight share a common dormitory room and perform all training activities as a unit. Contact between trainees of differing flights is limited to shared common touch surface areas in the Dining Facilities Administration Center (DFAC), classroom hallways, and stairwells. All meals are eaten in DFACs except for a prepackaged meal upon arrival to JBSA–Lackland and meals during the last week of training, when off-base privileges are granted.

Once trainees graduate BMT, they begin technical training. The duration of technical training may range from 2 weeks to 2 years. At any given time, there are approximately 3,000 technical students on JBSA–Lackland. Two technical students share a dormitory room, with 4 students sharing a restroom. These students eat the majority of their meals in the DFACs and gain privileges to go off base as they progress through training.

Medical care for trainees is provided at the Reid Health Services Center during regular business hours or at the Family Emergency Center at Wilford Hall Ambulatory Surgical Center after hours. On average, 2 to 3 trainees per day present to Reid Health Services Center with nausea, vomiting, and/or diarrhea.

Case identification

Cases were identified from review of outpatient medical records from Reid Health Services Center and administered questionnaires. In cluster 1 (technical trainees), 2 teams with reported cases were administered an open-ended questionnaire, and in cluster 2 (BMT trainees), the flight with the greatest number of confirmed cases was administered a questionnaire that gathered information about fresh vegetables and fruits known to have been consumed during training.

For the purposes of this outbreak investigation, a confirmed case of cyclosporiasis was defined by the presence of diarrhea with or without vomiting between 12 June and 8 July 2018 accompanied by a positive gastrointestinal pathogen polymerase chain reaction (PCR) for *Cyclospora* in a stool specimen. Without a positive lab, a case was classified as a suspected case. Bivariate analysis was carried out to determine whether associations existed between food exposures and illness. Statistical analysis was performed using OpenEpi v3.01.[12] One-tailed p values <.01 were considered statistically significant.

RESULTS

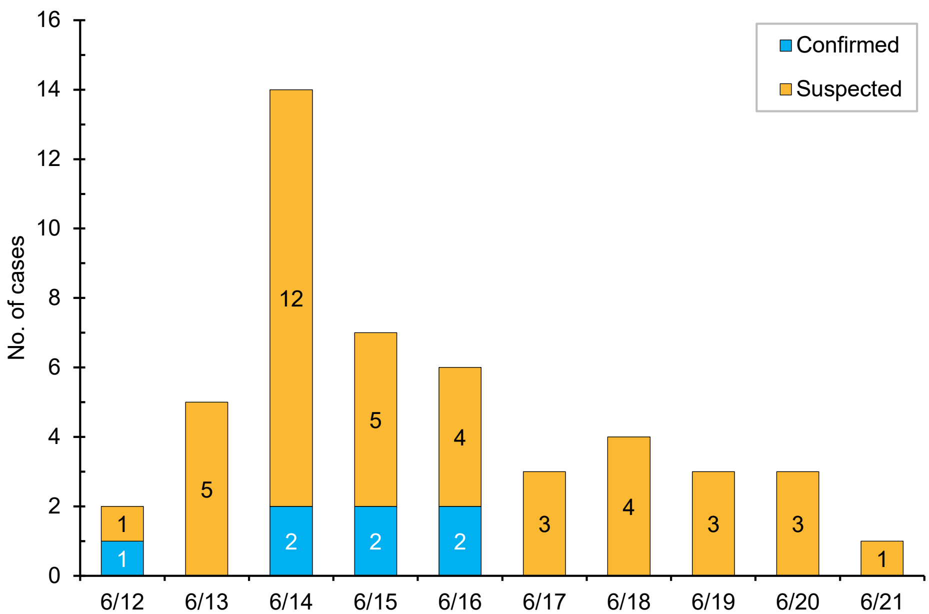
Two distinct clusters of cyclosporiasis cases occurred between 12 June and 8 July 2018. Cluster 1 (n=53) occurred among technical training students who reported with symptoms from 12 June through 21 June and included 46 suspected and 7 confirmed cases **(Figure 1)**. Five of the suspected cases did not have documented onset dates. Diarrhea was reported by 100% of cluster 1 cases, with 45% reporting vomiting, and 64% reporting nausea **(data not shown)**. Cluster 2 (n=32) occurred among BMT trainees and included 18 suspected and 14 confirmed cases who reported symptom onset between 29 June and 8 July **(Figure 2)**. Of the 18 suspected cases, 5 cases did not have documented onset dates. In this cluster of 32 cases, 100% reported diarrhea, 44% reported vomiting, and 72% reported nausea **(data not shown)**. One additional confirmed BMT case was reported, but it did not occur in the timeframe of either cluster and was not considered in the analysis.

In cluster 1, the first technical student sought medical care on 13 June for diarrhea; 3 additional students followed on 14 June, and 7 followed on 15 June. The earliest report of symptom onset was on 12 June. At this point, a gastrointestinal disease cluster was suspected in 2 technical training squadrons and gastrointestinal pathogen panel PCRs were ordered. One stool sample was returned to the clinic for testing and tested positive for *Cyclospora* on 19 June. The next positive *Cyclospora* PCR was reported on 21 June. One suspected case tested positive for *Salmonella*. Reported symptom onset peaked 14 June and continued through 21 June **(Figure 1)**. In addition to identifying cases in the clinic, investigators conducted mass briefings from 22 June through 28 June, during which questionnaires were administered to members of 2 technical squadrons to elicit information on food and water exposures. However, data obtained from this open-ended questionnaire lacked the specificity needed to examine associations between exposures to potential food sources and illness.

In cluster 2, the first trainee sought medical care on 30 June, and 5 more trainees sought care on 2 July; the earliest report of symptom onset was on 29 June. Gastrointestinal pathogen panel PCRs were already being ordered on all patients with gastrointestinal symptoms visiting the clinic. Three positive *Cyclospora* PCRs were reported on 3 July, 2 of which belonged to 1 flight. Reported symptom onset peaked on 1 July and continued through 8 July **(Figure 2)**. On 6 July, questionnaires were administered to the trainees in the flight with the most laboratory-confirmed cyclosporiasis cases (n=6). The questionnaire captured information on the fresh food items eaten after arrival at San Antonio, TX. Among the 49 trainees who responded to the BMT questionnaire, 2 additional suspected cases were identified. None of the suspected or confirmed cases from this flight reported departing from the Midwest states that were experiencing a contemporaneous cyclosporiasis outbreak (i.e., IA, IL, MN, and WI). Bivariate analysis of data from the 49 questionnaire respondents demonstrated statistically significant positive associations between confirmed cases and 4 exposures: blueberries (odds ratio [OR]=25.51; p=.001), blackberries (OR=23.11; p=.001), cherry tomatoes (OR=11.25; p=.006), and oranges (OR=11.20; p=.004) **(Table 1)**. No statistically significant associations were identified between other possible food exposures and illness.

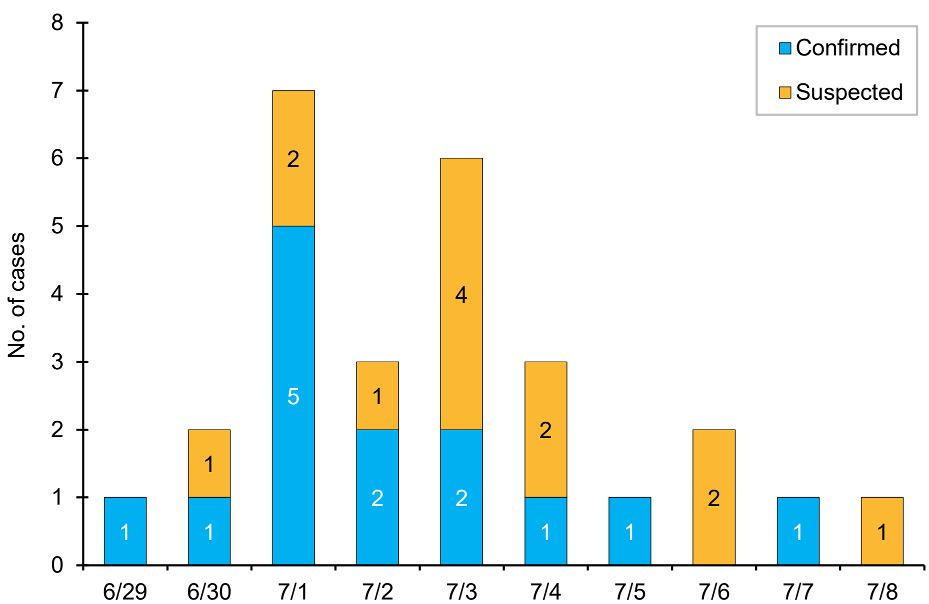
Public health investigations were performed at training facilities and DFACs. No DFAC food workers who served confirmed cases reported illness during the outbreak. During inspections of the DFACs, there were no discrepancies noted with respect to *Cyclospora*. Food vendors that service all DFACs at JBSA–Lackland were questioned, and no concerns other than this outbreak were brought to investigators' attention.

FIGURE 1. Symptom onset among cases in cluster 1 (technical training students)



Note: 5 suspected cases did not have documented dates of onset.
No., number.

FIGURE 2. Symptom onset among cases in cluster 2 (basic military training)



Note: 5 suspected cases did not have documented dates of onset.
No., number.

EDITORIAL COMMENT

During the months of June and July 2018, JBSA–Lackland experienced 2 clusters of cyclosporiasis affecting 2 technical training squadrons and (primarily) 1 BMT flight. Investigations of these clusters did not reveal a specific source of infection; therefore, at the time of the outbreak, there were no known connections to the larger national outbreaks related to Del Monte Fresh Produce vegetable trays or salads from McDonald's restaurants distributed by Fresh Express that were contemporaneously occurring.[13,14] At the time of this publication, there were no further confirmed cases of cyclosporiasis in the JBSA–Lackland training population.

Similar to many CDC-reported cyclosporiasis outbreaks, even though there were statistically significant associations with some food items (i.e., blueberries, blackberries, oranges, and cherry tomatoes), a source of the pathogen could not be conclusively determined despite a 2-week food history questionnaire, detailed interviews, and DFAC inspections.[10] Potable water and DFAC food from shared sources serve all of the training and permanent populations on JBSA–Lackland. Yet these clusters of cyclosporiasis were restricted to a few specific squadrons and flights. Because of the restricted nature of the outbreak, source exposure was presumed to be most likely through a contaminated batch of produce, and therefore potable water sources were not examined.

Lessons from the investigation response to cluster 1 were implemented in cluster 2. For example, the questionnaire used during cluster 1 did not have enough granularity to determine food associations; therefore, during cluster 2, the investigative team designed a questionnaire based on DFAC menus. Outbreak response also shifted from an early emphasis on treatment to confirmatory testing, providing more accurate case counts and distinction of gastroenteritis due to other potential pathogens (e.g., *Salmonella*). Lastly, the emphasis on diagnostic testing during cluster 2 resulted in fewer courses of antimicrobial treatment for presumptive diagnoses of cyclosporiasis.

Despite unique opportunities during the investigation of cluster 2 (e.g., control of food and a known cohort), no definitive source of infection was found. The typically long incubation period for cyclosporiasis and delays between symptom onset and diagnosis confirmation represented challenges to identifying the *Cyclospora* source. In addition, food recall was likely low, even with a comprehensive questionnaire listing fresh food from the DFAC. Even though specific foods were identified, food testing was not feasible because of the short shelf life and immediate use of fresh foods. Moreover, given that *Cyclospora* has relatively recently emerged in the U.S. (outbreaks have only been reported since the 1990s),[10] clinical suspicion of this uncommon parasite as a cause for acute gastrointestinal illness is low. Testing posed another challenge; *Cyclospora* was not a component of routine ova and parasite testing and had to

TABLE. Attack rates of confirmed illness based on food exposures in the 49 BMT trainee respondents

	Food item eaten			Food item not eaten				
	No. ill	Total	Attack rate	No. ill	Total	Attack rate	OR	p-value[a]
Blueberries[b]	9	26	34.6%	0	23	0.0%	25.51	.001
Blackberries[b]	9	27	33.3%	0	22	0.0%	23.11	.001
Oranges	7	17	41.2%	2	34	5.9%	11.20	.004
Cherry tomatoes	5	9	55.6%	4	40	10.0%	11.25	.006
Cucumber	5	10	50.0%	4	39	10.3%	8.75	.011
Green peas	4	7	57.1%	5	42	11.9%	9.87	.016
Honeydew	6	17	35.3%	3	32	9.4%	5.27	.035
Tropical fruit	4	9	44.4%	5	40	12.5%	5.60	.046
Cantaloupe	7	25	28.0%	2	24	8.3%	4.28	.078
Pineapple	8	32	25.0%	1	17	5.9%	5.73	.101
Fresh pears	5	17	29.4%	4	32	12.5%	2.92	.143
Green pepper	3	8	37.5%	6	41	14.6%	3.50	.151
Applesauce	2	21	9.5%	7	28	25.0%	0.32	.156
Broccoli	4	14	28.6%	5	35	14.3%	2.40	.220
Green apple	2	5	40.0%	7	44	15.9%	3.52	.224
Red onion	2	6	33.3%	7	43	16.3%	2.57	.302
Celery	1	2	50.0%	8	47	17.0%	4.88	.337
Mushrooms	1	2	50.0%	8	47	17.0%	4.88	.337
Packaged pears	4	17	23.5%	5	32	15.6%	1.66	.377
Spinach	2	7	28.6%	7	42	16.7%	2.00	.381
Fruit cocktail	4	18	22.2%	5	31	16.1%	1.49	.433
Peaches	3	20	15.0%	6	29	20.7%	0.68	.455
Carrots	2	14	14.3%	7	35	20.0%	0.67	.493
Red grapes	8	41	19.5%	1	8	12.5%	1.70	.543
Olives	1	4	25.0%	8	45	17.8%	1.54	.569
Green grapes	2	12	16.7%	7	37	18.9%	0.86	.617
Romaine lettuce	3	16	18.8%	6	33	18.2%	1.04	.624
Red apple	3	16	18.8%	6	33	18.2%	1.04	.624
Iceberg lettuce	4	22	18.2%	5	27	18.5%	0.98	.635
Cabbage	0	0	0.0%	0	0	0.0%	.	.
Banana	9	45	20.0%	0	4	0.0%	.	.

BMT, basic military training; No., number; OR, odds ratio.

[a]1-tailed p-values <.01 were considered statistically significant.

[b]When cell sizes equaled zero, 0.5 was added to each of the cells (Pagano M, Gauvreau K. *Principles of Biostatistic*. 2nd ed. Chapman and Hall: Belmont, CA).

be requested specifically. Therefore, providers relied on molecular methods in diagnosing cyclosporiasis, and at the onset of the outbreak, the local supplies of testing kits were quickly depleted. Perhaps the most important challenge in determining the source of the outbreak was the low case numbers, which prevented conclusive determination of a source despite observed associations with blueberries, blackberries, cherry tomatoes, and oranges.

The JBSA–Lackland Public Health Flight and Preventive Medicine team collaborated with county, state, and national agencies and shared lessons learned. Perhaps the most crucial lessons learned were the importance of clinical suspicion for cyclosporiasis in persistent gastrointestinal illness and the importance of confirmatory laboratory testing for expedited diagnosis and treatment.

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REFERENCES

1. Sanders JW, Putnam SD, Gould P, et al. Diarrheal illness among deployed U.S. military personnel during Operation Bright Star 2001—Egypt. *Diagn Microbiol Infect Dis*. 2005;52(2):85–90.
2. Sanders JW, Putnam SD, Riddle MS, Tribble DR. Military importance of diarrhea: lessons from the Middle East. *Curr Opin Gastroenterol*. 2005;21(1):9–14.
3. Monteville MR, Riddle MS, Baht U, et al. Incidence, etiology, and impact of diarrhea among deployed US military personnel in support of Operation Iraqi Freedom and Operation Enduring Freedom. *Am J Trop Med Hyg*. 2006;75(4):762–767.
4. Sanders JW, Putnam SD, Frankart C, et al. Impact of illness and non-combat injury during Operations Iraqi Freedom and Enduring Freedom (Afghanistan). *Am J Trop Med Hyg*. 2005;73(4):713–719.
5. Bohnker BK, Thornton S. Explosive outbreaks of gastroenteritis in the shipboard environment attributed to norovirus [Letter to the Editor]. *Mil Med*. 2003;168(5):iv.
6. Riddle MS, Smoak BL, Thornton SA, Bresee JS, Faix DJ, Putnam SD. Epidemic infectious gastrointestinal illness aboard U.S. Navy ships deployed to the Middle East during peacetime operations—2000–2001. *BMC Gastroenterol*. 2006;6(9).
7. Riddle MS, Sanders JW, Putnam SD, Tribble DR. Incidence, etiology, and impact of diarrhea among long-term travelers (US military and similar populations): a systematic review. *Am J Trop Med Hyg*. 2006;74(5):891–900.
8. Kasper MR, Lescano AG, Lucas C, et al. Diarrhea outbreak during U.S. military training in El Salvador. *PloS One*. 2012;7(7):e40404.
9. Ortega YR, Sanchez R. Update on *Cyclospora cayetanensis*, a food-borne and waterborne parasite. Clin Microbiol Rev. 2010;23(1):218–234.
10. Centers for Disease Control and Prevention. U.S. Foodorne Outbreaks of Cyclosporiasis—2000–2016. https://www.cdc.gov/parasites/cyclosporiasis/outbreaks/foodborneoutbreaks.html. Accessed 24 September 2018.
11. Centers for Disease Control and Prevention. Cyclosporiasis Outbreak Investigations—United States, 2017. https://www.cdc.gov/parasites/cyclosporiasis/outbreaks/2017/index.html. Accessed 24 September 2018.
12. Sullivan KM, Dean A, Soe MM. OpenEpi: a web-based epidemiologic and statistical calculator for public health. *Public Health Rep*. 2009;124(3):471–474.
13. Centers for Disease Control and Prevention. Multistate Outbreak of Cyclosporiasis Linked to Del Monte Fresh Produce Vegetable Trays—United States, 2018: Final Update. https://www.cdc.gov/parasites/cyclosporiasis/outbreaks/2018/a-062018/index.html. Accessed 24 September 2018.
14. Centers for Disease Control and Prevention. Multistate Outbreak of Cyclosporiasis Linked to Fresh Express Salad Mix Sold at McDonald's Restaurants—United States, 2018: Final Update. https://www.cdc.gov/parasites/cyclosporiasis/outbreaks/2018/b-071318/index.html. Accessed 24 September 2018.

Surveillance Snapshot: Human Papillomavirus Vaccination Among U.S. Active Component Service Members in the Millennium Cohort Study, 2006–2017

Rayna K. Matsuno, PhD, MPH; Ben Porter, PhD; Steven Warner, MPH; Natalie Wells, MD, MPH (CDR, USN) for the Millennium Cohort Study Team

FIGURE 1. Percentages of all eligible service women (n=22,387) who initiated (n=8,453), completed (n=5,179), and adhered (n=3,400) to guidelines for HPV vaccination, active component, U.S. Armed Forces, 2006–2017

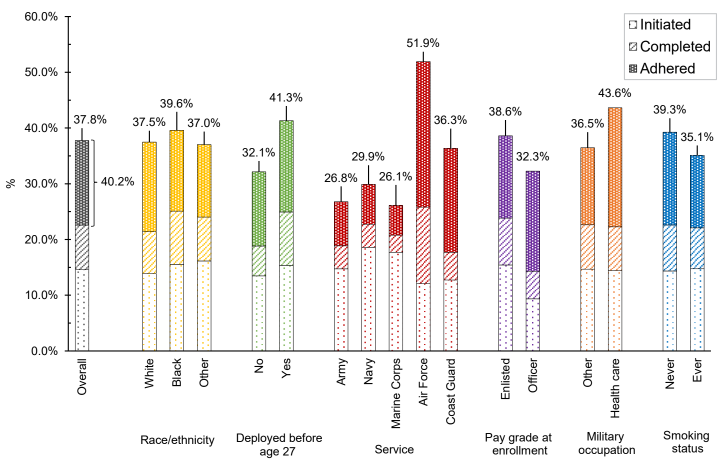
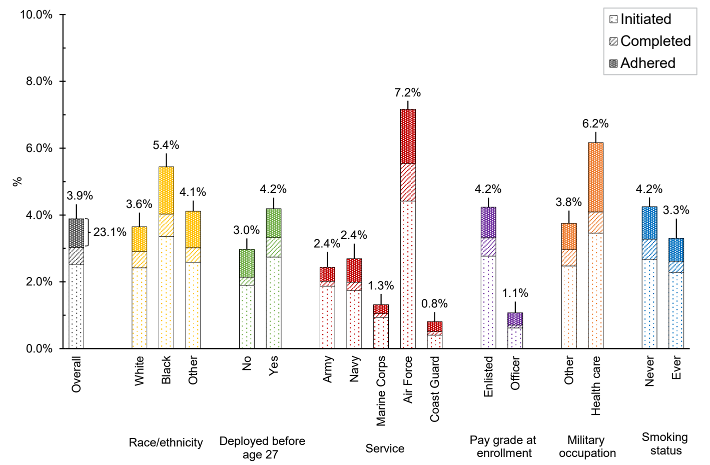


FIGURE 2. Percentages of all eligible service men (n=31,705) who initiated (n=1,231), completed (n=429), and adhered (n=272) to guidelines for HPV vaccination, active component, U.S. Armed Forces, 2009–2017



The U.S. Millennium Cohort Study is a population-based prospective study that includes over 200,000 current and prior U.S. military service members.[1,2] The cohort includes 4 panels of participants, the first of which was enrolled in 2001; subsequent panels were enrolled in 2004, 2007, and 2011. Questionnaires were sent to participants every 3 years to collect information on service-related experiences as well as mental, physical, and behavioral health. As such, the Millennium Cohort Study is uniquely positioned to leverage both administrative and self-reported data to help understand the effects of military service on the health of its members.

The analysis was restricted to active component members under age 26 in 2006 (women) or 2009 (men). The primary outcomes were human papillomavirus (HPV) vaccine initiation, completion (3 doses), and adherence (3 doses within 1 year). Medical encounter and central immunization databases were used to identify those who had received the HPV vaccine through June 2017. The analysis sample included 22,387 female and 31,705 male Millennium Cohort Study participants.

Overall, among service women in the analysis sample, 37.8% initiated the HPV vaccine and 40.2% of initiators were adherent **(Figure 1)**. Among service men in the analysis sample, 3.9% initiated the vaccine and 23.1% of initiators were adherent **(Figure 2)**. Compared to their respective counterparts, members of the Air Force and those in healthcare occupations had higher percentages of initiation and adherence. Initiation and adherence percentages were lower among self-reported ever smokers (cigarette) compared to never smokers. No differences were observed for other selected measures such as depression, panic or anxiety, or problem drinking **(data not shown)**.

REFERENCES

1. Gray GC, Chesbrough KB, Ryan MA, et al. The Millennium Cohort Study: a 21-year prospective cohort study of 140,000 military personnel. *Mil Med*. 2002;167(6):483–488.

2. Ryan MA, Smith TC, Smith B, et al. Millennium Cohort: enrollment begins a 21-year contribution to understanding the impact of military service. *J Clin Epidemiol*. 2007;60(2):181–191.

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The study protocol was approved by the Naval Health Research Center Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects. Research data were derived from an approved Naval Health Research Center, Institutional Review Board protocol number NHRC.2000.0007.

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Female Infertility, Active Component Service Women, U.S. Armed Forces, 2013–2018

Shauna Stahlman, PhD, MPH; Michael Fan, PhD

This report presents the incidence and prevalence of diagnosed female infertility among active component service women. During 2013–2018, 8,744 active component women of childbearing potential were diagnosed with infertility for the first time, resulting in an overall incidence of 79.3 cases per 10,000 person-years (p-yrs). Compared to their respective counterparts, women in their 30s, non-Hispanic blacks, those in healthcare and pilot/air crew occupations, Army personnel, and those who were married had the highest incidence rates. The incidence of diagnosed female infertility decreased from 85.1 per 10,000 p-yrs in 2013 to 63.6 per 10,000 p-yrs in 2018 despite a concurrent increase in the rate of fertility testing. During the surveillance period, the average annual prevalence of diagnosed female infertility was 1.6%. Of the service women who were diagnosed with infertility for the first time during the surveillance period, 1,808 (20.7%) delivered a live birth within 2 years after the incident infertility diagnosis. Current findings indicate that the prevalence of diagnosed female infertility among active component service women is lower than estimates of self-reported infertility from surveys of U.S. civilians and service women.

WHAT ARE THE NEW FINDINGS?

The prevalence of diagnosed infertility among female active component service members is low compared to estimates of self-reported infertility obtained from U.S. national and military surveys. The incidence of diagnosed female infertility decreased between 2013 and 2018 despite a concurrent increase in the rate of fertility testing.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Although the incidence, prevalence, and burden of diagnosed infertility among active component service women are relatively small, there are some subgroups of women who are at higher risk. It is important to identify the underlying physical cause of infertility in order to administer proper treatment and prevent additional sequelae.

Clinical infertility is the failure of a woman of childbearing age to become pregnant after 1 year of regular, unprotected sexual intercourse.[1] The reasons for infertility can involve 1 or both partners, but in some cases no cause can be identified. Ovulation disorders are estimated to account for one-third of infertility cases, and they often present with irregular periods (oligomenorrhea) or the absence of periods (amenorrhea).[2] The most common cause of infertility related to anovulation is polycystic ovary syndrome, a hormone imbalance that can prevent the ovaries from releasing eggs.[3] Other causes of infertility include fallopian tube damage or blockage, uterine or cervical abnormalities, hypothalamic-pituitary hormone imbalances, endometriosis, and primary ovarian insufficiency (i.e., premature menopause).[3]

Tubal infertility from blocked or swollen fallopian tubes can be caused by previous sexually transmitted infections (STIs), pelvic inflammatory disease (PID), or history of a ruptured appendix or abdominal surgery.[1] Uterine or cervical abnormalities include structural abnormalities or the growth of benign tumors called fibroids, which can interfere with the passage and implantation of the fertilized egg within the uterus.[1] Hypothalamic-pituitary hormone imbalances such as hypogonadotrophic hypogonadism can be caused by excessive exercise, being underweight, or both.[2] Endometriosis occurs when endometrial tissue implants and grows outside of the uterus, affecting the function of the female genital organs.[4] Causes of premature menopause can include genetic disorders, immunological and metabolic disorders, smoking, and use of chemotherapeutic drugs.[5]

Because ovarian function as well as the number and quality of eggs released decreases with advancing age, age may be an increasingly important factor contributing to rates of infertility in the U.S., as many women are delaying pregnancies to their 30s and 40s. In 2017, approximately 10% of all firstborn children in the U.S. were born to women aged 35 years or older, and about one-third were born to women aged 30 years or older.[6] This trend has also been observed among women serving in the U.S. military. Among female service members, the highest live birth rates during 2012–2016 were observed among women aged 30–34 years, and the prevalence of pregnancy among women aged 35–39 years increased from 10.7% in 2012 to 11.7% in 2016.[7]

In 2018, the Service Women's Action Network (SWAN) conducted an online survey focused on reproductive health services in the military. Of the 799 total survey respondents, 277 (34.7%) were active duty. Of the active duty service women who answered questions about infertility, 37% said that they had trouble getting pregnant when actively trying to do so.[8] The results of this survey caused concern among military leadership, as the findings suggested a much higher prevalence of female infertility among service women compared to the Centers for Disease Control and Prevention's (CDC's) national prevalence estimate. According to the CDC's 2011–2015 National Survey of Family Growth, the prevalence of infertility among married women 15–44 years old was 6.7%; 12.1% of women aged 15–44 years reported impaired fecundity.[9] The CDC defined infertility as a self-report of at least 1 year of failed attempts for married/cohabitating partners at getting pregnant when neither the respondent nor her current husband/cohabiting partner was surgically sterile and when the couple had been sexually active each month without contraception.[9] Impaired fecundity was defined as self-reported problems getting pregnant and carrying a baby to term regardless of marital/cohabitating status.[9] It has been suggested that service women may be at increased risk for infertility because of exposures to environmental toxins as well as traumas and/or stressors experienced during deployments.[8,10,11] In addition, relatively higher levels of tobacco use, alcohol use, and PID also may put service women at greater risk for infertility than the national female population.[12–14]

This report estimates the incidence, prevalence, and burden of medical encounters due to diagnosed infertility among active component service women in the U.S. Armed Forces between 2013 and 2018.

METHODS

The surveillance period was 1 January 2013 through 31 December 2018. The surveillance population consisted of all active component service women of childbearing potential who served in the Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. Women of childbearing potential were defined as women aged 17–49 years without any history of hysterectomy or permanent sterilization. History of hysterectomy and/or permanent sterilization was defined by having a qualifying diagnostic or procedural code for hysterectomy or permanent sterilization in any position of an inpatient or outpatient record. These diagnostic and procedural codes have been previously described.[7,15] All data used for the analyses were abstracted from records routinely maintained in the Defense Medical Surveillance System (DMSS) for health surveillance purposes.

An incident case of infertility was defined by having at least 2 outpatient medical encounters with an infertility diagnosis (International Classification of Diseases, 9th Revision [ICD-9] code 628.*; International Classification of Diseases, 10th Revision [ICD-10] code N97.*) in the first or second diagnostic position or by having an inpatient encounter with an infertility diagnosis in the first diagnostic position. An individual could be counted as a case of infertility only once. The incident date was the date of the first qualifying medical encounter. The type of infertility (anovulation, tubal origin, uterine origin, other, or unspecified) was assigned according to the most specific type that was diagnosed in any inpatient or outpatient encounter record during the case's military service **(Table 1)**. Anovulation was considered the most specific type, followed by tubal origin, uterine origin, other, and unspecified.

For incidence calculations, person-time was censored at the time of the first hysterectomy or permanent sterilization diagnosis, when the service member turned 50 years old, or at the time of the first infertility diagnosis, whichever came first. Person-time for prevalent cases and for women not of childbearing potential was removed from the study population. Incidence was calculated per 10,000 person-years (p-yrs).

To be counted as a prevalent case of infertility, the woman of childbearing potential had to 1) be in active component military service during the calendar year of interest, 2) qualify as an incident case of infertility in the year of interest or any year prior (including before 2013), and 3) have an inpatient or outpatient encounter for any infertility type in any diagnostic position during the year of interest. The denominator for prevalence calculations was the total number of women of childbearing potential in active component service during that year. Prevalence rates were calculated per 10,000 persons.

The burden of medical encounters for infertility was analyzed by calculating the total number of inpatient and outpatient encounters with a primary diagnosis of infertility among all active component service women (including both prevalent and incident cases of infertility). The total numbers of individuals affected and the total number of hospital bed days for infertility were also calculated according to standard *MSMR* burden methodology.[16]

To assess the impact that fertility testing may have had on incidence of diagnosed infertility, the rate of fertility testing among all active component women (not just women of childbearing potential) was measured during the surveillance period. Fertility testing was defined by the presence of an inpatient or outpatient encounter with a diagnosis of fertility testing (ICD-9: V26.21;

TABLE 1. ICD-9/ICD-10 codes for female infertility

ICD-9	ICD-10	Description
628.0	N97.0	Infertility associated with anovulation
628.2	N97.1	Infertility of tubal origin (block, occlusion, stenosis of fallopian tubes)
628.3	N97.2	Infertility of uterine origin (congenital anomaly of uterus, nonimplantation)
628.1, 628.4, 628.8	N97.8	Infertility of other specified origin (pituitary-hypothalamic, cervical or vaginal, age-related, etc.)
628.9	N97.9	Infertility of unspecified origin

ICD, International Classification of Diseases.

ICD-10: Z31.41) in any diagnostic position. One test per person per day was counted. The denominator was person-time for all female active component service members during the surveillance period.

Finally, incident infertility cases were followed for up to 2 years to measure subsequent live birth deliveries. Live birth deliveries were defined by having a hospitalization with a live birth delivery-related diagnosis (ICD-9: V27* [excluding V271, V274, V277] and ICD-10: Z37* [excluding Z371, Z374, and Z377]) in any diagnostic position.

RESULTS

Incidence

During the surveillance period, 8,744 active component women of childbearing potential were diagnosed with infertility for the first time. The crude overall incidence was 79.3 per 10,000 p-yrs **(Table 2)**. Infertility of unspecified origin was the most commonly diagnosed type (35.0 per 10,000 p-yrs), followed by other specified origin (21.3 per 10,000 p-yrs), anovulation (14.0 per 10,000 p-yrs), tubal origin (7.8 per 10,000 p-yrs), and uterine origin (1.2 per 10,000 p-yrs). Annual incidence rates of diagnosed infertility (of any origin) decreased by 25.3% from 2013 through 2018 mainly because of decreasing rates of infertility of unspecified origin **(Figure 1)**. Incidence of diagnoses of infertility of other specified origins increased between 2013 and 2017 and then dropped in 2018.

Overall rates of incident infertility diagnoses were highest among women in their 30s and lowest among those in the youngest (<20 years; 6.8 per 10,000 p-yrs) and oldest (45–49 years; 19.1 per 10,000 p-yrs) age groups **(Table 2, Figure 2)**. Annual rates of any infertility diagnosis decreased among service women in all age groups during the surveillance period; however, the smallest decrease occurred among women less than 20 years old **(Figure 2)**. For most age groups, the incidence of infertility diagnosis peaked in 2017.

Infertility due to unspecified origin was the most frequently diagnosed type of infertility among service women in all age groups, and infertility of uterine origin was the least frequently diagnosed type **(Figure 3)**. Other specified origin was the next most frequently diagnosed type, except among women in their 20s, for whom the most frequently diagnosed type was anovulation. Among the other 3 types of infertility, anovulation was the most common cause among women under 40 years old. However, infertility due to tubal and uterine origins was more common among women in their 30s and 40s compared to women under 30 years old.

Overall incidence rates of infertility diagnoses of any type were highest among non-Hispanic black service members (95.0 per 10,000 p-yrs) compared to women in other race/ethnicity groups **(Table 2)**. Compared to other racial/ethnicity groups, non-Hispanic black women had the highest rates of diagnoses of all types of infertility **(Figure 4)**.

Overall rates of incident infertility diagnoses were highest among service women in the Army (101.7 per 10,000 p-yrs) and lowest among women in the Marine Corps (50.4 per 10,000 p-yrs) **(Table 2)**. Senior enlisted service women had higher incidence rates than junior enlisted personnel, and senior officers had higher rates than junior officers. Compared to other occupations, service women in healthcare occupations had the highest incidence of diagnosed infertility (107.7 per 10,000 p-yrs), followed by pilots/air crew (92.2 per 10,000 p-yrs). The rate of incident infertility diagnoses among married service women was nearly 6 times that of unmarried service women and more than twice that of those with "other" marital statuses.

Prevalence

The average annual prevalence of diagnosed female infertility of any type during the surveillance period was 163 per 10,000 persons, or 1.6% **(Figure 5)**. The annual prevalence of all types of diagnosed infertility decreased during the surveillance period, except for infertility of other specified origin, which increased between 2013 and 2017.

Burden

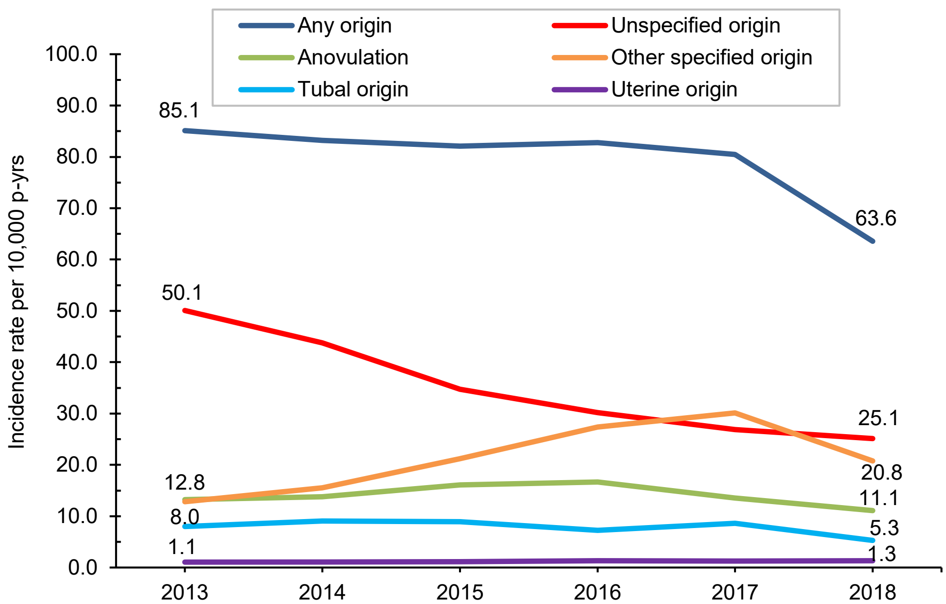
There were 65,524 total medical encounters and 120 hospital bed days for female infertility during the surveillance period **(data not shown)**. Annual numbers

TABLE 2. Incidence of infertility by type and demographic and military characteristics, active component service women of childbearing potential, U.S. Armed Forces, 2013–2018

	No.	Rate[a]
Total	8,744	79.3
Type of infertility		
Anovulation	1,546	14.0
Tubal origin[b]	862	7.8
Uterine origin[c]	130	1.2
Other specified origin	2,352	21.3
Unspecified origin	3,854	35.0
Age group (years)		
<20	65	6.8
20–24	1,858	46.9
25–29	2,593	89.7
30–34	2,368	140.4
35–39	1,436	153.6
40–44	391	94.8
45–49	33	19.1
Race/ethnicity		
Non-Hispanic white	3,636	74.6
Non-Hispanic black	2,600	95.0
Hispanic	1,340	72.4
Asian/Pacific Islander	386	79.4
Other/unknown	782	73.2
Service		
Army	3,711	101.7
Navy	2,168	66.3
Air Force	2,439	75.0
Marine Corps	426	50.4
Rank		
Junior enlisted (E1–E4)	3,029	55.4
Senior enlisted (E5–E9)	3,451	96.7
Junior officer (O1–O3, W01-W03)	1,501	100.4
Senior officer (O4–O10, W04–W05)	763	156.1
Occupation		
Combat-specific[d]	152	63.2
Motor transport	250	70.4
Pilot/air crew	154	92.2
Repair/engineering	1,539	66.4
Communications/intelligence	2,943	84.1
Healthcare	2,169	107.7
Other/unknown	1,537	63.4
Marital status		
Married	6,771	145.5
Unmarried	1,362	25.1
Other	611	65.7

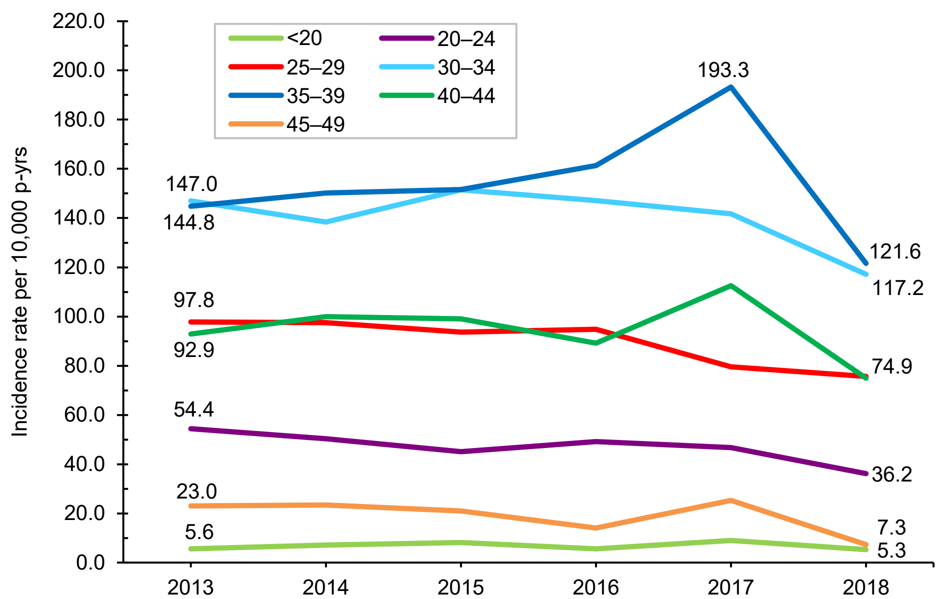
[a]Rates per 10,000 person-years.
[b]Block, occlusion, or stenosis of the fallopian tubes.
[c]Structural abnormality of the uterus or nonimplantation (includes fibroids).
[d]Infantry/artillery/combat engineering/armor.
No., number.

FIGURE 1. Annual incidence rates of female infertility diagnoses, active component service women of childbearing potential, 2013–2018



P-yrs, person-years.

FIGURE 2. Annual incidence rates of female infertility diagnoses by age group, active component service women of childbearing potential, 2013–2018



P-yrs, person-years.

of medical encounters during which infertility was reported as a primary (first-listed) diagnoses and the numbers of individuals affected by infertility remained relatively stable during the period **(Figure 6)**. However, the ratio of medical encounters to individuals affected decreased from 2.9 in 2013 to 2.7 in 2018. In 2018, there were 9,892 outpatient encounters for female infertility, which represents 7.3% of all outpatient encounters for conditions affecting the genitourinary system among active component service women in that year **(data not shown)**.[17]

Fertility testing

During the surveillance period, annual rates for female fertility testing increased 29.8%, from 62.2 per 10,000 p-yrs in 2013 to 80.7 per 10,000 p-yrs in 2018 **(Figure 7)**.

Live births after infertility diagnosis

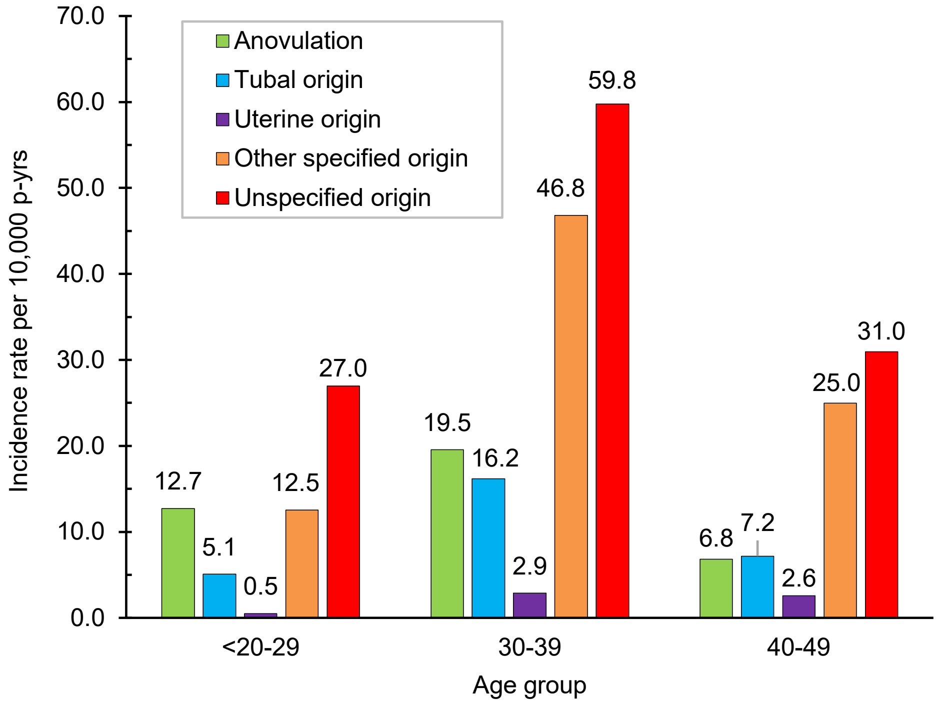
Of the 8,744 service women who were diagnosed with infertility for the first time during the surveillance period, 651 (7.5%) had a hospitalization for a live birth within 1 year after the incident infertility diagnosis **(data not shown)**. In total, 1,808 (20.7%) had a hospitalization for a live birth within 2 years after the incident infertility diagnosis.

EDITORIAL COMMENT

The findings of this report show that the incidence of diagnosed female infertility among active component U.S. service members between 2013 and 2018 was 79.3 per 10,000 p-yrs. The findings also show that rates were highest among women in their 30s and non-Hispanic black women. The most common types of diagnoses of infertility due to specific causes were related to anovulation or of tubal origin. These results are broadly similar to an earlier *MSMR* analysis of female infertility during 2000–2012.[18] Findings from the current analysis show that the overall incidence of diagnosed female infertility decreased between 2013 and 2018 despite a concurrent increase in the rate of fertility testing. In addition, the average annual prevalence of diagnosed female infertility was 163 per 10,000, or 1.6%.

The prevalence of diagnosed infertility among service women from this report (1.6%) is lower than the national self-reported infertility prevalence (6.7%) and much lower than the self-reported estimate among active duty service members in the 2018 SWAN study (37%). Diagnoses of infertility in this report may underestimate the true rate of infertility to the extent that affected service women did not seek care for infertility or sought care outside of the Military Health System. In contrast, the 2018 SWAN study's survey of a nonrepresentative sample of active duty service

FIGURE 3. Incidence rates of female infertility diagnoses by type and age group, active component service women of childbearing potential, 2013–2018

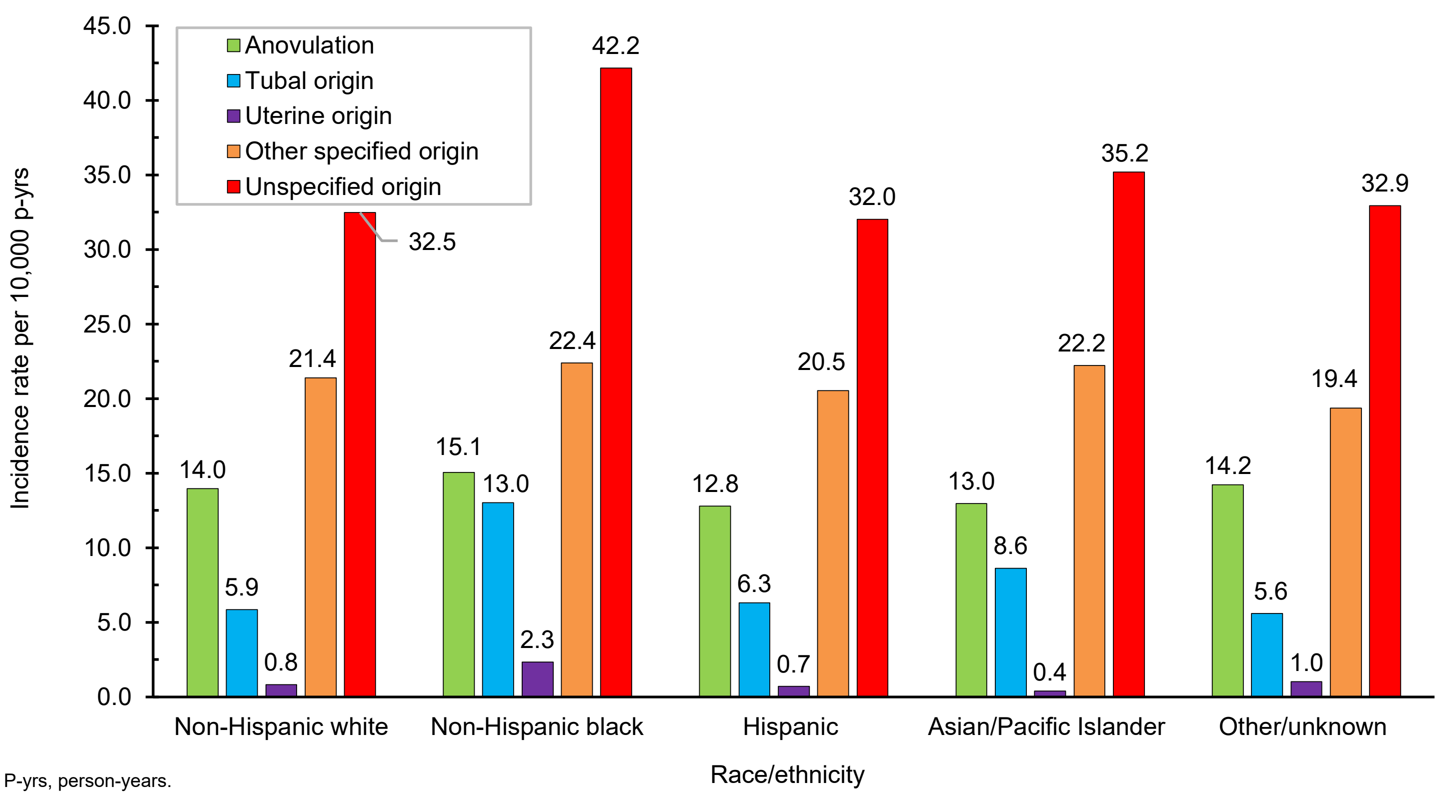


P-yrs, person-years.

women likely introduced selection bias in favor of those who had negative experiences related to fertility, which would overestimate the prevalence of infertility.

This report also showed that among women diagnosed with incident infertility, about one-fifth (20.7%) had a live birth within 2 years following the diagnosis. Overall, about 50% of female infertility cases in the U.S. are successfully treated.[19] Women with infertility related to ovulation problems are most likely to benefit from treatment. However, successful treatment depends on several factors, including the underlying cause of infertility, age, history of prior pregnancies, and duration of infertility problems. Women in active military service may receive diagnostic services to identify physical causes of infertility and some medically necessary treatments (e.g., hormonal therapy, corrective surgery, or antibiotics).[20] However, TriCare only covers non-coital reproductive therapies (e.g., artificial insemination or in vitro fertilization

FIGURE 4. Incidence of infertility by type and race/ethnicity, active component service women of childbearing potential, U.S. Armed Forces, 2013–2018



P-yrs, person-years.

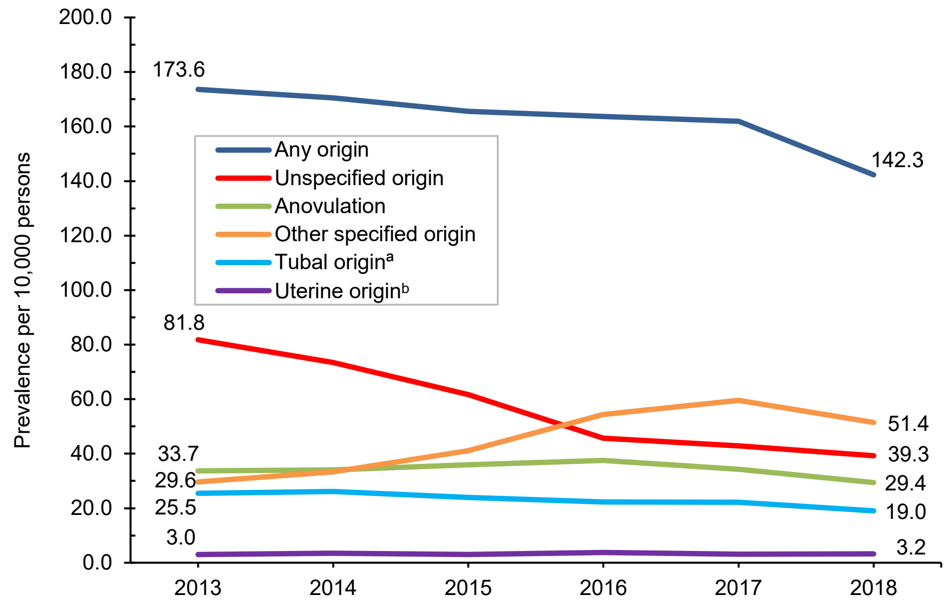
[IVF]) for service members who lost their natural reproductive abilities because of illnesses or injuries related to active service. Although TriCare does not cover IVF, there are military treatment facilities that offer low-cost IVF treatment through medical training programs.

Between 2000 and 2012, the highest incidence of infertility among service members was among women aged 30–34 years. However, during 2013–2018, the highest incidence was among women aged 35–39 years, followed closely by women aged 30–34 years. This shift was likely influenced by the increasing rates of clinical care seeking for infertility among women delaying pregnancy until older ages. Similar to the previous report, infertility due to anovulation was more common in younger compared to older age groups, whereas infertility with tubal or uterine origin was more common in older compared to younger age groups. These different distributions of diagnoses in relation to age likely reflect the different pathophysiologic mechanisms associated with various types of infertility.

The finding that the overall incidence of diagnosed infertility was higher among non-Hispanic black service women is consistent with surveillance data indicating a relatively high incidence of risk factors for infertility including STIs, PID, and uterine fibroids among non-Hispanics blacks compared to those in other race/ethnicity groups.[13,21,22] Overall incidence was also higher among healthcare personnel and pilots/air crew. Healthcare personnel may be more likely to self-diagnose or seek care, which could result in surveillance bias. In contrast, there is some indication that pilots and flight attendants may be at higher risk for reproductive health concerns because of cosmic ionizing radiation, circadian rhythm disruption, and physical job demands.[23] Finally, the finding of higher incidence of diagnosed infertility among married service women is likely influenced by greater healthcare seeking for family planning and even possibly the definition of infertility itself, which the CDC defines as 1 year of failed attempts for married or cohabitating partners at getting pregnant.[9]

There are several limitations to this analysis. As previously described, diagnoses of infertility may underestimate the true incidence and prevalence of this condition. In addition, the percentage of women who gave birth following incident infertility diagnoses is also likely an underestimate because women who gave birth after leaving military service are not captured. Furthermore, the current analysis did not explicitly capture recurrent pregnancy loss (ICD-9: 629.81, 646.3*; ICD-10: N96, O26.2*), which could be considered a type of infertility. However, some individuals diagnosed with recurrent pregnancy loss may have received a diagnosis

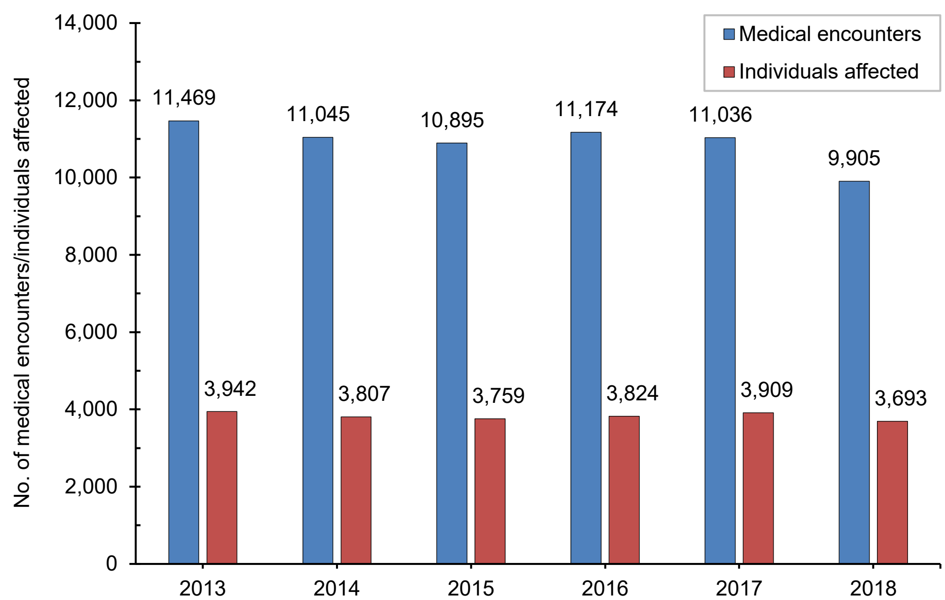
FIGURE 5. Prevalence of infertility by type, active component service women of childbearing potential, U.S. Armed Forces, 2013–2018



[a]Block, occlusion, or stenosis of the fallopian tubes.

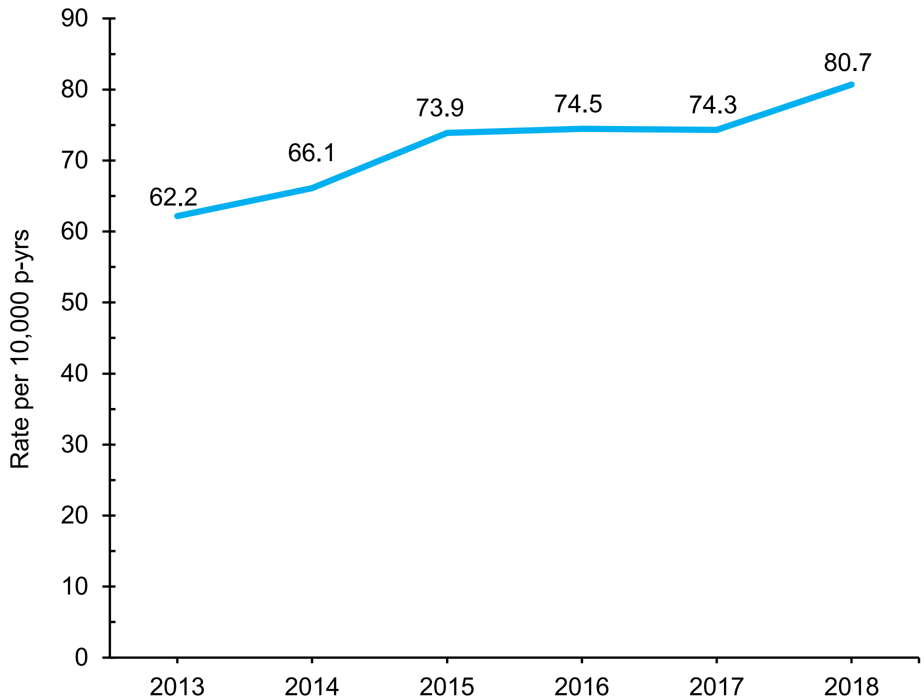
[b]Structural abnormality of the uterus or nonimplantation (includes fibroids).

FIGURE 6. Numbers of medical encounters for infertility and numbers of individuals affected, active component service women, 2013–2018



No., number.

FIGURE 7. Annual rates of fertility testing, active component service women, U.S. Armed Forces, 2013–2018



P-yrs, person-years.

of "unspecified infertility" and would have been included in the current analysis.

Despite these limitations, this report provides an update on the incidence and prevalence of diagnosed infertility among active component service women. In contrast to recent survey findings, this report indicates that the incidence and prevalence of diagnosed female infertility are low compared to the self-reported prevalence in the U.S. general population.

REFERENCES

1. Centers for Disease Control and Prevention. Reproductive Health. Infertility FAQs. https://www.cdc.gov/reproductivehealth/infertility/index.htm. Accessed 14 April 2019.
2. Hamilton-Fairley D, Taylor A. Anovulation. *BMJ*. 2003;327(7414):546–549.
3. U.S. Department of Health and Human Services. Office of Women's Health. Infertility. https://www.womenshealth.gov/a-z-topics/infertility. Accessed 14 April 2019.
4. Senapati S, Bamhart K. Managing endometriosis-associated infertility. *Clin Obstet Gynecol*. 2011;54(4):720–726.
5. Okeke TC, Anyaehie UB, Ezenyeaku CC. Premature menopause. *Ann Med Health Sci Res*. 2013;3(1):90–95.
6. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK, Drake P. Births: Final data for 2017. National Vital Statistics Reports; vol 67 no 8. Hyattsville, MD: National Center for Health Statistics. 2018.
7. Stahlman S, Witkop CT, Clark LL, and Taubman SB. Pregnancies and live births, active component service women, U.S. Armed Forces, 2012–2016. *MSMR*. 2017;24(11):2–9.
8. Service Women Action Network (SWAN). Access to reproductive health care: the experience of military women. https://www.servicewomen.org/wp-content/uploads/2018/12/2018ReproReport_SWAN-2.pdf. Accessed 14 April 2019.
9. Centers for Disease Control and Prevention. National Center for Health Statistics. Key Statistics from the National Survey of Family Growth–I Listing. https://www.cdc.gov/nchs/nsfg/key_statistics/i.htm. Accessed 14 April 2019.
10. Rooney KL, Domar AD. The relationship between stress and infertility. *Dialogues Clin Neurosci.* 2018 Mar;20(1):41–47.
11. Armed Forces Health Surveillance Center. Health of women after wartime deployments: correlates of risk for selected medical conditions among females after initial and repeat deployments to Afghanistan and Iraq, active component, U.S. Armed Forces. *MSMR*. 2012;19(7):2–10.
12. Van Heertum K, Rossi B. Alcohol and fertility: how much is too much? *Fertil Res Pract.* 2017;3:10.
13. McKee DL, Hu Z, Stahlman S. Incidence and sequelae of acute pelvic inflammatory disease among active component females, U.S. Armed Forces, 1996–2016. *MSMR*. 2018;25(10):2–8.
14. Stahlman S, Oetting AA. Mental health disorders and mental health problems, active component, U.S. Armed Forces, 2007–2016. *MSMR*. 2018;25(3):2–11.
15. Stahlman S, Witkop CT, Clark LL, and Taubman SB. Contraception among active component service women, U.S. Armed Forces, 2012–2016. *MSMR*. 2017;24(11):10–21.
16. Armed Forces Health Surveillance Branch. Absolute and relative morbidity burdens attributable to various illnesses and injuries, active component, U.S. Armed Forces, 2018. *MSMR*. 2019;26(5):2–9.
17. Armed Forces Health Surveillance Branch. Ambulatory visits, active component, U.S. Armed Forces, 2018. *MSMR*. 2019;26(5):18–24.
18. Armed Forces Health Surveillance Center. Female infertility, active component service women, U.S. Armed Forces, 2000–2012. *MSMR*. 2013;20(9):8–12.
19. Jose-Miller AB, Boyden JW, Frey KA. Infertility. *Am Fam Physician*. 2007;75(6):849–56.
20. TriCare. Assisted Reproductive Services. https://www.tricare.mil/CoveredServices/IsItCovered/AssistedReproductiveServices. Accessed 30 April 2019.
21. Stahlman S, Seliga N, Oetting AA. Sexually transmitted infections, active component, U.S. Armed Forces, 2010–2018. *MSMR*. 2019;26(3):2–10.
22. Armed Forces Health Surveillance Center. Uterine fibroids, active component females, U.S. Armed Forces, 2001–2010. *MSMR*. 2011;18(12):10–3.
23. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health. Aircrew Safety and Health: Reproductive Health. https://www.cdc.gov/niosh/topics/aircrew/reproductivehealth.html. Accessed 30 April 2019.

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