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Diabetes by Air, Land, and Sea: Effect of Deployments on HbA1c and BMI

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ABSTRACT

Introduction

Service members (SMs) in the United States (U.S.) Armed Forces have diabetes mellitus at a rate of 2–3%. Despite having a chronic medical condition, they have deployed to environments with limited medical support. Given the scarcity of data describing how they fare in these settings, we conducted a retrospective study analyzing the changes in glycated hemoglobin (HbA1c) and body mass index (BMI) before and after deployment.

Materials and Methods

SMs from the U.S. Army, Air Force, Navy, and Marine Corps with diabetes who deployed overseas were identified through the Military Health System (MHS) Management Analysis and Reporting Tool and the Defense Manpower Data Center. Laboratory and pharmaceutical data were obtained from the MHS Composite Health Care System and the Pharmacy Data Transaction Service, respectively. Paired *t*-tests were conducted to calculate changes in HbA1c and BMI before and after deployment.

Results

SMs with diabetes completed 11,325 deployments of greater than 90 days from 2005 to 2017. Of these, 474 (4.2%) SMs had both HbA1c and BMI measurements within 90 days prior to departure and within 90 days of return. Most (84.2%) required diabetes medications: metformin in 67.3%, sulfonylureas in 19.0%, dipeptidyl peptidase-4 inhibitors in 13.9%, and insulin in 5.5%. Most SMs deployed with an HbA1c $< 7.0\%$ (67.1%), with a mean predeployment HbA1c of 6.8%. Twenty percent deployed with an HbA1c between 7.0 and 7.9%, 7.2% deployed with an HbA1c between 8.0 and 8.9%, and 5.7% deployed with an HbA1c of 9.0% or higher. In the overall population and within each military service, there was no significant change in HbA1c before and after deployment. However, those with predeployment HbA1c $< 7.0\%$ experienced a rise in HbA1c from 6.2 to 6.5% ($P < 0.001$), whereas those with predeployment HbA1c values $\geq 7.0\%$ experienced a decline from 8.0 to 7.5% ($P < 0.001$). Those who deployed between 91 and 135 days had a decline in HbA1c from 7.1 to 6.7% ($P = 0.010$), but no significant changes were demonstrated in those with longer deployment durations. BMI declined from 29.6 to 29.3 kg/m^2 ($P < 0.001$), with other significant changes seen among those in the Army, Navy, and deployment durations up to 315 days.

Conclusions

Most SMs had an HbA1c $< 7.0\%$, suggesting that military providers appropriately selected well-managed SMs for deployment. HbA1c did not seem to deteriorate during deployment, but they also did not improve despite a reduction in BMI. Concerning trends included the deployment of some SMs with much higher HbA1c, utilization of medications with adverse safety profiles, and the lack of HbA1c and BMI evaluation proximal to deployment departures and returns. However, for SMs meeting adequate glycemic targets, we demonstrated that HbA1c remained stable, supporting the notion that some SMs may safely deploy with diabetes. Improvement in BMI may compensate for factors promoting hyperglycemia in a deployed setting, such as changes in diet and medication availability. Future research should analyze in a prospective fashion, where a more complete array of diabetes and readiness-related measures to comprehensively evaluate the safety of deploying SMs with diabetes.

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The views expressed are solely those of the authors and do not reflect the official policy or position of the U.S. Army, U.S. Navy, U.S. Air Force, the Department of Defense, or the U.S. Government.

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INTRODUCTION

Continuation of military service is possible among active duty service members (SMs) in the United States (U.S.) Armed Forces when they develop chronic medical conditions, such as diabetes mellitus (henceforth "diabetes"). Multiple factors affect this decision, including occupation and severity of disease. A study from 2006 to 2010 examining prevalence of diabetes among SMs demonstrated that, among those age 45–64, 2.9% of men and 2.2% of women had diabetes.[1] Although most military providers are aware that duty restrictions and retainability standards apply for any SM with a chronic medical condition, it is not as ubiquitously known that some have not only been retained in active duty but have also deployed. A waiver enabling deployment is permissible as outlined in the Department of Defense Instruction (DoDI) 6490.07 whereby select members with diabetes can participate in "contingency deployments." DoDI 6490.07 defines "contingency deployments" as "a deployment that is limited to outside the continental U.S., over 30 days in duration, and in a location with medical support from only nonfixed (temporary) military medical treatment facilities."[2] The DoDI requires a minimum of a medical record review by a trained DoD healthcare provider to determine whether a SM with a chronic medical condition can deploy based on the severity and stability of the condition, as well as the environment and other anticipated requirements in deployment. It is logical that diabetes is specifically identified in the DoDI as a high-risk condition since both disease decompensation and certain diabetes medications can cause incapacitation.

The deliberations surrounding the decision to deploy a SM with diabetes may be a difficult one for a military provider, compounded by the scarcity of data depicting how SMs with diabetes fare in deployment. There are multiple factors to consider, including the achievement of glycemic targets prior to deployment, potential for decompensation, presence of comorbidities, and safety profiles of medications. Our group has previously published findings on the pre and postdeployment glycated hemoglobin (HbA1c) among U.S. Air Force SMs with diabetes[3], but similar studies and data on other services are lacking. In this study, we analyzed HbA1c values and body mass indices (BMI) before and after an overseas deployment among SMs from the U.S. Army, Air Force, Navy, and Marine Corps.

METHODS

Data were gathered from the Military Health System (MHS) Management Analysis and Reporting Tool, which contains administrative healthcare records from inpatient and outpatient military treatment facilities and civilian facilities where the SMs received treatment funded by TRICARE. Additional MHS data were collected from the Defense Manpower Data Center and the Pharmacy Data Transaction Service. Laboratory data were retrieved from the MHS Composite Health Care System.

The cohort was selected to include active duty SMs from the U.S. Army, Air Force, Navy, and Marine Corps with at least one deployment lasting greater than 90 days between January 1, 2005 and December 31, 2017, and a diabetes diagnosis during the deployment dates. The diabetes diagnosis was gathered from claims and/or encounter data as documented through the Healthcare Effectiveness Data and Information Set. The first day of the first month that a SM registered a diagnosis of diabetes was considered the first day that a SM had diabetes. Only deployments that began after that day were included in this analysis. For the purpose of this analysis, members of reserve units (Army Reserve, Army National Guard, Air Force Reserve, Air National Guard, Naval Reserve, and Marine Corps Reserve) were considered active duty members of their respective branches while they were activated. SMs who became pregnant or received a pregnancy related diagnosis between 6 months before their deployment began and 6 months after their deployment ended were excluded from our analysis.

BMI measurements and blood samples for HbA1c were obtained at military treatment facilities for either pre or postdeployment medical evaluations, or other healthcare encounters that may or may not have been related to deployment. Only BMI and HbA1c results recorded in the period of 90 days before deployment or 90 days after return were included. If more than one measurement were collected in the pre or postdeployment periods, the maximum value in each period was used for the analysis.

ICD-9 and ICD-10 diagnosis codes were used to determine the presence of comorbidities within the 90-day period before deployment. Similarly, therapeutic class codes from the American Hospital Formulary Service were used to determine the presence of a prescription for diabetes-related medications in the 90-day period before deployment. These flags were computed for each individual and each deployment.

Data were gathered using Microsoft SQL Server 2012. Analysis was conducted using R version 3.5.2. To build a description of the population, univariate measures were made for each of the recorded measures. Pairwise *t*-tests were then used to determine if there were changes in HbA1c and BMI scores in the periods before or after deployment.

RESULTS

From 2005 to 2017, SMs with diabetes from the U.S. Army, Air Force, Navy, and Marine Corps participated in 11,325 deployments lasting greater than 90 days. Our analysis focused on those who had both an HbA1c and BMI checked within 90 days of deployment and within 90 days of return, of which 474 (4.2%) qualified (Fig. 1); their demographic information is presented in Table I. The majority of the total population (79.6%) lacked any HbA1c checks within the relevant time intervals and only 680 (6.0%) had an HbA1c checked at both intervals. The most common age group was 41–50 years old, followed by 31–40 years old. The

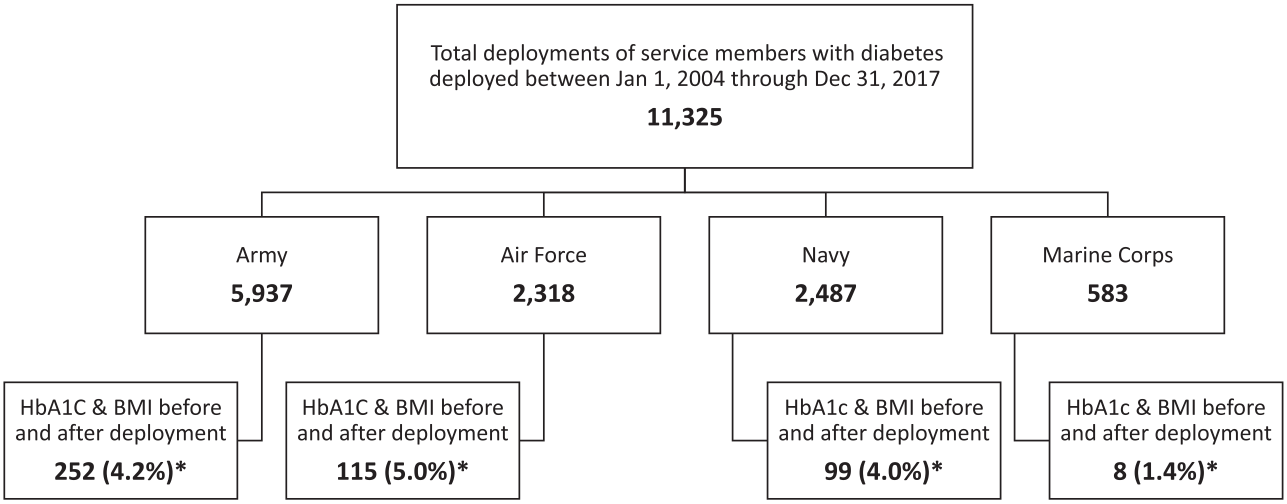

FIGURE 1. Case selection for analysis, by service, followed by presence of HbA1c and BMI data. *percentage by service.

preponderance of male and enlisted SMs were expected given the gender and rank distribution of the U.S. Armed Forces. Those in the Army deployed for an average duration of 284 days, Air Force personnel for 169 days, Navy personnel for 203 days, and Marines Corps personnel for 198 days.

The majority of the population required diabetes medications (84.2%), of which metformin was the most common (67.3%), followed by sulfonylureas (19.0%) and dipeptidyl peptidase-4 (DPP-4) inhibitors (13.9%). Insulin-users comprised 5.5% of the population. Approximately, a third had comorbid hypertension and/or hyperlipidemia, but only 1.0% or less had any microvascular complications. In comparison to this group, those who lacked any HbA1c data had lower rates of hypertension (5%) and hyperlipidemia (5%). Likewise, rates of microvascular complications were <1%.

The mean predeployment HbA1c and BMI were 6.8 and 29.6 kg/m^2, respectively. The majority (67.1%) deployed with HbA1c < 7.0%, but with a BMI in the overweight or obese range. For the total population, there was no significant change in HbA1c pre and postdeployment (P = 0.885). Likewise, no significant change in HbA1c was seen when the population was analyzed separately based on military service (Fig. 2). However, when the population was dichotomized into those with HbA1c < 7.0% and ≥7.0%, statistically significant changes emerged. Those with a predeployment HbA1c < 7.0% experience a statistically significant rise in HbA1c (6.2–6.5%, P < 0.001), whereas those with HbA1c ≥ 7.0% experienced a statistically significant decline (8.0–7.5%, P < 0.001).

Among the 680 SMs who had a pre and postdeployment HbA1c only (no BMI), the mean HbA1c remained at 6.9% (P = 0.471). When categorized by service, however, Army SMs demonstrated a significant rise in HbA1c from 6.8 to 7.0% (P = 0.021), which differed from the findings within the population with both HbA1c and BMI data. Otherwise, there were no significant changes within the other services (Air Force, 6.8–6.6%, P = 0.142; Navy, 7.1–6.9%, P = 0.086; and Marines, 7.2–8.0%, P = 0.056).

For the total population, there was a statistically significant decline in BMI (29.6 to 29.3 kg/m^2, P < 0.001). Members from the Army and Navy appear to have driven this decline (30.1–29.7 kg/m^2, P < 0.001 and 29.8–29.3 kg/m^2, P = 0.047, respectively), whereas no significant change in BMI was seen from those in the Air Force (28.8–28.5 kg/m^2, P = 0.228) and the Marine Corps (27.7–26.8 kg/m^2, P = 0.114) (Fig. 3).

HbA1c and BMI were also analyzed based on the following deployment durations: 91–135 days, 136–225 days, 226–315 days, and>315 days. The number of SMs in each category was 80, 198, 82, and 114, respectively. HbA1c declined from 7.1 to 6.7% (P = 0.010) in those who deployed for 90–135 days, but other duration categories did not demonstrate any significant changes. In the latter categories, both mean pre and postdeployment HbA1c remained less than 7.0%. BMI declined significantly in all categories of deployment durations except for greater than 315 days (91–135 days: 29.4–29.1 kg/m^2, P = 0.042; 136–225 days: 29.9–29.4 kg/m^2, P = 0.029; 226–315 days: 29.9–29.4 kg/m^2, P = 0.009; and >315 days: 30.0–29.7 kg/m^2, P = 0.085).

DISCUSSION

In this retrospective analysis of HbA1c levels and BMI obtained before and after overseas deployments among active duty SMs with diabetes, we found no significant change in HbA1c and a significant decline in BMI among those with available data. Recognizing that medical deployment screenings may have relied on HbA1c checks only, we also analyzed those with HbA1c but lacking BMI data. Like the findings of SMs with both HbA1c and BMI, no significant difference emerged except for those in the Army who experienced a rise in HbA1c.

TABLE I. Characteristics of the Study Sample with Paired Pre- and Post-HbA1c and BMI Prior to Deployment

Variable	Overall		Army		Air Force		Navy		Marine Corps	
	N	(%)	*N*	(%)	*N*	(%)	*N*	(%)	*N*	(%)
Total	474		252		115		99		8	
Gender										
Male	400	(84.4)	209	(82.9)	96	(83.5)	87	(87.9)	8	(100)
Female	74	(15.6)	43	(17.1)	19	(16.5)	12	(12.1)	0	(0)
Age groups										
18–30	29	(6.1)	14	(5.6)	9	(7.8)	5	(5.1)	1	(12.5)
31–40	169	(35.7)	74	(29.4)	51	(44.3)	38	(38.4)	6	(75)
41–50	230	(48.5)	131	(52.0)	45	(39.1)	53	(53.5)	1	(12.5)
50+	46	(9.7)	33	(13.1)	10	(8.7)	3	(3.0)	0	(0)
Rank category										
Officer	119	(25.1)	72	(28.6)	26	(22.6)	18	(18.2)	3	(37.5)
Enlisted	347	(73.2)	176	(69.8)	88	(76.5)	78	(78.8)	5	(62.5)
Unknown	8	(1.7)	4	(1.6)	1	(0.9)	3	(3.0)	0	(0)
Comorbidities										
Hypertension	151	(31.9)	73	(29.0)	38	(33.0)	37	(37.4)	3	(37.5)
Lipid disorders	172	(36.3)	82	(32.5)	39	(33.9)	48	(48.5)	3	(37.5)
Retinopathy	5	(1.1)	4	(1.6)	1	(0.9)	0	(0)	0	(0)
Nephropathy	1	(0.2)	1	(0.4)	0	(0)	0	(0)	0	(0)
Neuropathy	4	(0.8)	4	(1.6)	0	(0)	0	(0)	0	(0)
Prescriptions (therapeutic class)										
Biguanide*	319	(67.3)	165	(65.5)	71	(61.7)	79	(79.8)	4	(50.0)
Sulfonylurea	90	(19.0)	41	(16.3)	22	(19.1)	26	(26.3)	1	(12.5)
DPP4-inhibitor†	66	(13.9)	32	(12.7)	21	(18.3)	12	(12.1)	1	(12.5)
Thiazolidinedione	56	(11.8)	21	(8.3)	11	(9.6)	21	(21.2)	3	(37.5)
Insulin	26	(5.5)	17	(6.7)	5	(4.3)	3	(3.0)	1	(12.5)
Incretin mimetic#	9	(1.9)	7	(2.8)	1	(0.9)	1	(1.0)	0	(0)
Meglinitide	1	(0.2)	0	(0)	0	(0)	1	(1.0)	0	(0)
Amylin mimetic	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
SGLT-2 inhibitor‡	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
HbA1c										
<7%	318	(67.1)	170	(67.5)	84	(73.0)	58	(58.6)	6	(75.0)
7–7.9%	95	(20.0)	49	(19.4)	19	(16.5)	27	(27.3)	0	(0)
8–8.9%	34	(7.2)	21	(8.3)	7	(6.1)	4	(4.0)	2	(25.0)
≥9%	27	(5.7)	12	(4.8)	5	(4.3)	10	(10.1)	0	(0)
BMI (kg/m^2)										
18.5–24.9	61	(12.9)	24	(9.5)	23	(20.0)	12	(12.1)	2	(25.0)
25–29.9	212	(44.7)	113	(44.8)	51	(44.3)	45	(45.5)	3	(37.5)
≥30	201	(42.4)	115	(45.6)	41	(35.7)	42	(42.4)	3	(37.5)

*Also known as metformin.
†Dipeptidyl peptidase-4.
#Also known as glucagon-like peptide 1 receptor agonists.
‡Sodium-glucose transport protein 2.

Most of the SMs deployed with an HbA1c < 7.0% and did not have microvascular complications, suggesting that, from a glycemic standpoint, military providers were discriminating SMs appropriately for deployment. An HbA1c < 7.0% is an appropriate target according to prevailing diabetes clinical practice guidelines and expert opinion from military endocrinologists,[4–7] especially prior to deployment given the uncertainty of clinical surveillance availability. As such, only those who participated in the shortest duration category (91–135 days) had a mean predeployment HbA1c that was >7.0%, which may reflect limitations that were made for this group during the deployment screening process. Nevertheless, the mean HbA1c in this group was just above goal at 7.1% and declined to a mean HbA1c of 6.7% at the end of the deployment, providing further insight for the military provider who may make deployment clearance decisions for SMs with HbA1c above ideal targets.

The vast majority of SMs required a medication for diabetes, including a few on insulin, which is a medication of special interest in a deployed setting due to its refrigerated storage requirements and potential to cause hypoglycemia. The second most common medication type, sulfonylureas, is also unfavorable due to its association with hypoglycemia, but its prevalence was expected given the prevailing prescribing practices during our study interval.[8,9] However, metformin's place as the most common prescribed medication is in keeping

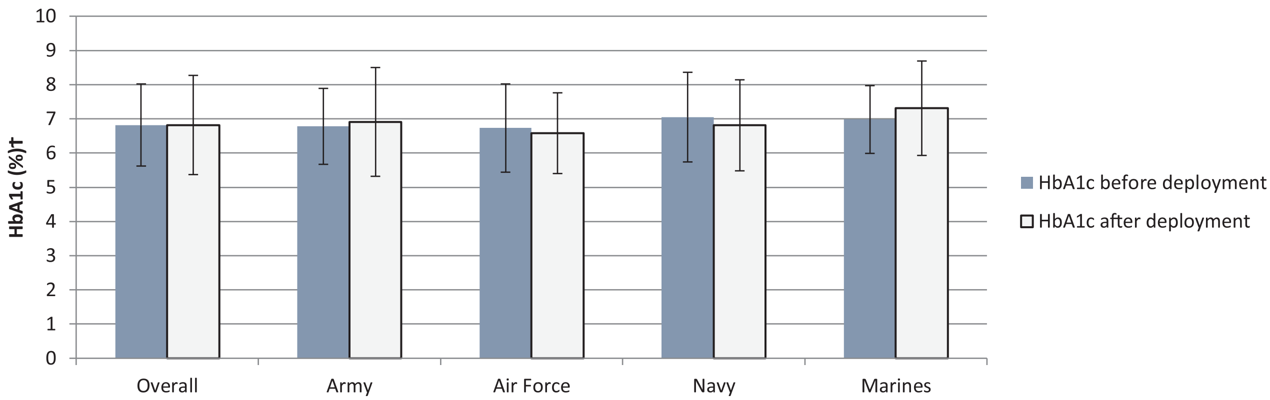

FIGURE 2. HbA1c before and after deployment. Data represent mean HbA1c +/− SD. †[10.93 × HbA1c%]–23.5 = mmol/mol.

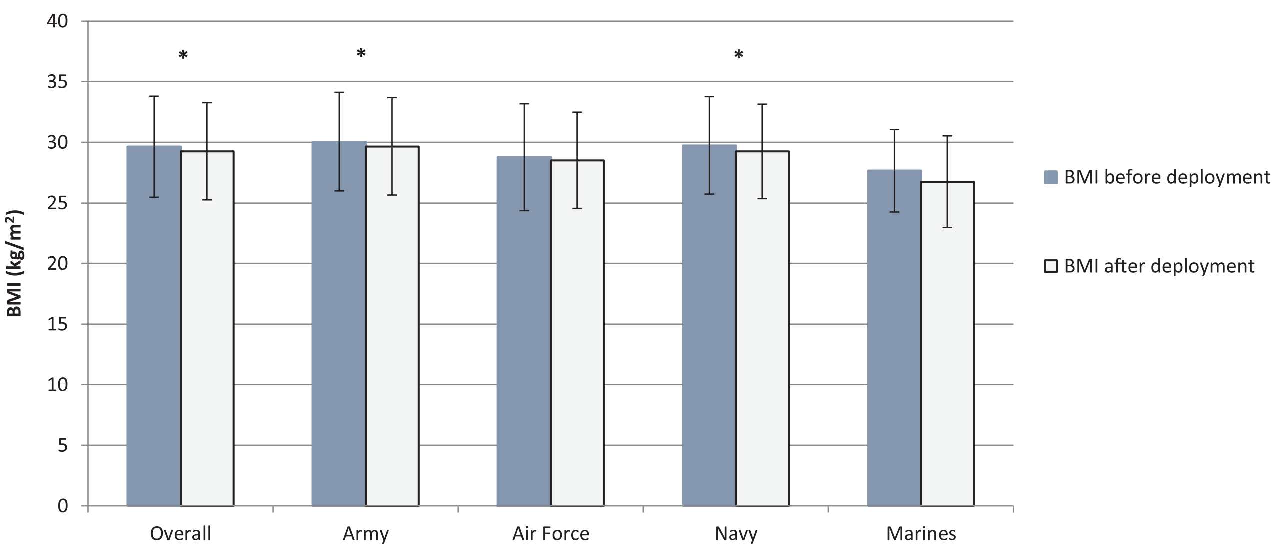

FIGURE 3. BMI before and after deployment. Data represents mean BMI +/− SD. $^{*}P < 0.05$.

with clinical practice guidelines given its high efficacy, oral delivery, and favorable safety profile.[4–6] The paucity of SMs on DPP4-inhibitors, glucagon-like peptide 1 receptor agonists (GLP-1 RA, also called incretin mimetic), and sodium-glucose transport protein 2 (SGLT2) inhibitors was likely due to their novelty and injectable delivery in the case of GLP-1 RA.[8,9]

The results of this study differed from a prior retrospective analysis conducted by the same authors comprised of U.S. Air Force personnel only. In contrast to the current study, that study demonstrated a statistically significant improvement in HbA1c after deployment. However, BMI reduction was concordant.[3] The discordance in HbA1c results, even when comparing the Air Force cohort only, was likely related to the differences in population selection methodology and data analysis. In the previous study, the analysis was not limited to those with concurrent HbA1c and BMI data; having either a pre- and post-HbA1c or a pre- and post-BMI satisfied the inclusion criteria. Change in HbA1c was analyzed without regard for BMI and vice versa. However, in the current study, the analysis was limited to those with concurrent pre- and post-HbA1c and BMI data. Additionally, the current study limited the population to those who deployed overseas, whereas that information was not available in the prior study. By excluding those who deployed within the continental U.S., we avoided the inclusion of a group who had access to diabetes care comparable to in-garrison care, which could have skewed the analysis.

Few other reports exist depicting how SMs with diabetes manage their condition while performing military-related activities. Medical staff from the armed forces of the U.S., Canada, Finland, and Israel has published case reports and small observational studies on glycemic control during various military activities, ranging from basic military training to combat aviation.[10–15] A study from Finland followed newly accessed SMs with type 1 diabetes over a 12-month period and reported a modest, but statistically significant, increase in HbA1c by 0.6% ($P = 0.007$).[14] A diabetes telemedicine clinic at Fort Bragg, North Carolina, described their experiences providing remote management of U.S. Army soldiers with type 1 diabetes on insulin pumps or multidose injections, some of whom performed highly strenuous activities such as specialized parachute jumps and field training. After a mean follow-up of 17 months, the soldiers experienced a remarkable decline in mean HbA1c from 9.6 to 6.6%. However, their telemedicine model, which provided patients with 24/7 remote access and up to daily review of glucose data, would have been very difficult to replicate in a deployment or a general in-garrison clinical setting.[15] Although the relevant body of literature is highly variegated, it universally emphasizes that participation in military activities is possible with comprehensive patient education, assiduous preparation and self-care, and timely clinical surveillance.

The statistically significant reduction in BMI observed in the current study was consistent with the prior study conducted by the authors among Air Force personnel.[3] Several other studies have also examined body composition changes after deployments among SMs, with the most contemporary studies deriving experiences from deployments to the Middle East.[16–23] In reviewing these studies, however, no clear pattern emerges regarding changes in BMI, lean mass, or fat mass after a deployment. Substantial heterogeneity in physical activity, diet, combat tasks, deployment durations, and measurement methods precludes the possibility of arriving at any conclusion that can explain or predict changes in BMI after a deployment. In the diabetes population, however, we have now demonstrated in two studies that BMI tends to decline over deployments, which we generally view as salutary. In this study, we demonstrated a sustainment in BMI reduction for those who deployed up to 315 days. With predeployment mean BMIs in the overweight range, even a modest reduction in BMI might have prevented a decrement in glycemic control or compensated for factors promoting hyperglycemia in a deployed setting, such as changes in diet, changes in physical activities, variations in sleep patterns, or lack of timely access to medications and refills.

We must acknowledge that our study reveals many findings of considerable significance with potential impact on military policy. First and foremost, it is astounding that over the course of 13 years, there have been 11,325 deployments involving a SM who carried the diagnosis of diabetes mellitus. The magnitude of this number flies counters to the notion that many assume to be true, and that diabetes is a disqualifying condition for service in military deployments. It clearly is not. Second, the fact that the military endocrinology community is largely unaware of any adverse clinical patterns involving SMs who deployed with diabetes suggests that the great majority are able to function well in the deployed setting. Third, it is concerning that of the large number of deployments, only 474 (4.2%) of these SMs had an HbA1c and BMI drawn within 90 days prior to and after deployment. There is room for improvement in how we care for our SMs with diabetes, both in how we prepare them for deployments and how we ensure that they receive appropriate care when they return. A medical assessment that includes standard of care lab work for SMs with diabetes (and other chronic conditions) should be routine practice pre and postdeployment. Fourth, it is noteworthy that most SMs with diabetes are deploying with medications, which are relatively safe. Metformin is a preferred agent in type 2 diabetes as it is rarely associated with hypoglycemia. There were only a few deployed members (5.5% of the analysis group) using insulin, which should be reserved only in situations with reliable and predictable resources for refills and refrigerated storage. Choi's report, however, suggests that SMs using insulin can perform well with robust support in a variety of military scenarios.[15]

While this is the first study to our knowledge looking this broadly at the scope of diabetes in relation to military deployments, we acknowledge several limitations of our analysis. First, since our study included only those SMs with diabetes who had both HbA1c and BMI within 90 days pre and postdeployment, our analysis only represents a small proportion (4.2%) of the entire group of SMs who deployed with this condition. Extracting those with HbA1c data only, without BMI, expanded the population by only 1.8%. Therefore, we cannot assume that our results are representative of the entire group. It is impossible to truly know the impact of deployment on diabetes with the limited information that we were able to obtain. Even so, by reporting our observations, it is our hope that pre and postdeployment practices will evolve such that we can accumulate more data in the future. It is important that medical questions surrounding SMs with chronic diseases (like diabetes) who deploy can be definitively answered. Second, our study did not differentiate between deployed locations due to policies limiting access to such data. Some settings are more austere than others, and we were not able to control for this variability in our data set. Certainly, a centrally located medical center with full resources in a deployed setting may be suitable for a SM who uses insulin, and this environment is very different from a remotely placed forward operating location. Third, our study did not account for SM specialty codes. A soldier who travels and engages in enemy combat operations has different requirements, requiring different limitations, from a uniformed support member that remains in secure areas "behind the wire." Accordingly, our study limitations highlight opportunities for future study.

CONCLUSION

This study provides insight to a readiness issue regarding the safety of deploying SMs with diabetes, which has previously been an unexplored area of military medicine. While hesitancy to deploy this population is prudent, we demonstrated that HbA1c did not seem to deteriorate after a wide variety of deployment types and durations. It is encouraging to discover that most SMs with diabetes deployed with an HbA1c $< 7.0\%$, which is deemed to reflect the achievement of satisfactory glycemic targets. Although it is commonly expected that

HbA1c would decline in a population who improved their BMI, it was not realized in our study population. This paradox could be due to multiple factors, such as daily routine changes and physiologic variations that occur in a deployed setting. Concerning trends included deployment of some SMs with much higher HbA1c, utilization of medications with less desirable safety profiles, and the lack of HbA1c and BMI evaluation proximal to the time of deployment departure and return. However, for SMs meeting adequate glycemic targets, we demonstrated that HbA1c remained stable, supporting the notion that certain SMs may safely deploy with diabetes. Future research endeavors should analyze in a prospective fashion, where a more complete array of diabetes and readiness-related measures to comprehensively evaluate the safety of deploying SMs with diabetes.

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