



Original article

Healthy behaviors and incidence of overweight and obesity in military veterans



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ABSTRACT

Purpose: Research suggests that U.S. veterans have a higher obesity prevalence than nonveterans and that weight gain is high after military discharge. Few studies have assessed the joint effects of health behaviors on obesity risk.

Methods: We prospectively assessed the incidence of overweight and obesity in relation to multiple behaviors among U.S. veterans, with follow-up beginning 2–3 years after military discharge. Self-reported physical activity, sedentary time, fast-food intake, sleep duration, smoking status, and alcohol use were categorized as “healthy” based on recommendations or prior literature. Multivariable Cox models were used to estimate relative risks (RRs) and 95% confidence intervals (CIs) for overweight/obesity (body mass index [BMI] ≥ 25 kg/m²) and obesity (BMI ≥ 30 kg/m²) in relation to healthy behaviors.

Results: Among 11,025 participants with baseline BMI of 18.5–24.9 kg/m², those reporting at least five of six healthy behaviors had 36% lower overweight/obesity risk compared with those reporting 0 or one healthy behavior (RR, 0.64; 95% CI, 0.54–0.74). Among 17,583 participants with baseline BMI of 25.0–29.9 kg/m², obesity risk was 38% lower for those with at least five of six relative to 0 or one healthy behavior (RR, 0.62; 95% CI, 0.54–0.72).

Conclusions: Self-reporting multiple healthy behaviors was associated with reduced overweight/obesity rates. Further research is warranted to determine whether interventions targeting several health behaviors may be more effective in reducing obesity among military veterans than interventions targeting one behavior.

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Overweight and obesity are leading preventable causes of death in the United States, with only smoking and hypertension responsible for more preventable deaths [1]. Consistent with national trends in the civilian population, the prevalence of overweight and obesity has increased in the U.S. military and veteran populations, with studies suggesting that veterans may have a higher prevalence

of overweight and obesity than their nonveteran counterparts [2–5].

Findings from the Millennium Cohort Study suggest that rates of weight gain may be high after discharge from the military [6]. Previous work in this population indicates there are substantial reductions in moderate-to-vigorous physical activity after military discharge [7]. Other factors, such as a lack of a military service requirement to maintain body and fitness standards, change in daily routine or food environment, and stress or disability arising from military service, may also contribute to weight gain [3].

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Despite a well-established link between specific individual health behaviors and risk of developing obesity, very few prospective studies have investigated the combined role of multiple health behaviors and weight gain [8]. In addition, there is limited research on factors that may influence obesity risk after discharge from the military, a high-risk period for weight gain [9]. The MOVE! Weight Management Program, implemented by the Veterans Health Administration in 2006, targets behavioral strategies for changes in diet and physical activity [9]. Such interventions could benefit from a better understanding of how changes across a wider array of weight-related behaviors simultaneously may influence obesity risk.

The objective of this study was to prospectively examine the incidence of overweight and obesity in relation to multiple health behaviors in combination—physical activity, sedentary time, fast-food consumption, sleep duration, smoking status, and alcohol use—in a large cohort of U.S. veterans recently discharged from military service.

Methods

Study population

The Millennium Cohort Study is an ongoing prospective cohort study designed to investigate the health effects associated with military service, as described previously [10]. Briefly, beginning in 2001, four panels of participants were enrolled approximately every 3 years (2001, 2004, 2007, and 2011). The study enrolled a total of 201,619 military personnel from all service branches, including active duty, Reserve, and National Guard personnel. Participants are followed via self-administered surveys approximately every 3 years, regardless of military status at the time of follow-up. All participants provided written informed consent at enrollment. The study was approved by the Naval Health Research Center Institutional Review Board (protocol number NHRC.2000.0007).

We restricted the analysis to participants from the first three enrollment panels who had been discharged from military service before 2013 and had completed at least two surveys after military discharge ($n = 43,222$). Baseline for the present study was the date the first survey was completed after discharge. Eligible participants must have been of normal weight (body mass index [BMI] 18.5–24.9 kg/m²) or overweight (BMI 25.0–29.9 kg/m²) at the time they completed their first postdischarge survey. We excluded participants who at study baseline had BMI less than 18.5 kg/m² ($n = 259$), BMI 30.0 kg/m² or greater ($n = 12,485$), or missing BMI ($n = 81$). After further excluding participants who were missing current weight on all follow-up surveys ($n = 467$), who were missing data on health behaviors at study baseline ($n = 904$), or who reported a recent pregnancy at baseline or on all follow-up surveys ($n = 418$), the present analysis included 11,025 participants with normal weight at baseline (5650 men and 5375 women) and 17,583 participants in the overweight range at baseline (13,638 men and 3945 women).

Measures

The primary endpoints were incident overweight and obesity. Participants reported height and current body weight on the enrollment and all follow-up surveys. BMI was calculated as weight in kilograms divided by squared height in meters. Incidence of overweight/obesity was classified as transitioning to a BMI of 25 kg/m² or greater at follow-up, and incidence of obesity as a BMI of 30.0 kg/m² or greater at follow-up.

The enrollment and follow-up surveys collected information on service-related experiences and behavioral, physical, and mental

health. The primary exposures of interest were postmilitary health behaviors (physical activity, sedentary time, fast-food consumption, sleep duration, smoking status, and alcohol use) reported after leaving service. Physical activity was measured as self-reported minutes per week of moderate or light (e.g., walking, cleaning, or slow jogging) and vigorous activity (e.g., running, active sports, marching, or biking) in a typical week. Sedentary time was measured as self-reported hours per day spent “sitting and watching TV or videos or using a computer in a typical day.” Fast-food consumption was classified as times per week a participant reported eating “from a fast food restaurant (like hamburgers, tacos, or pizza)” on average. Sleep duration was measured as self-reported hours of sleep in an average 24-hour period over the past month. Participants were classified as ever smokers if they reported that they had smoked at least 100 cigarettes (five packs) in their lifetime; smokers were classified as former smokers if they reported having quit successfully or not having smoked in the past year. Alcohol consumption was measured as self-reported drinks per week by summing the number of drinks consumed on each day of the week in the last week.

Each behavior was categorized as “healthy” based on recommendations or prior literature. For physical activity, the healthy category was defined according to national guidelines, which recommend at least 75 min/wk of activity of vigorous intensity, at least 150 min/wk of activity of moderate intensity, or an equivalent combination of the two [11]. For sedentary time, there are no national guidelines; based on findings that mortality rates were appreciably higher above a threshold of more than 7 h/d, healthy was defined as 7 h/d or less [12,13]. For fast-food consumption, healthy was defined as less than 1 time per week, based on findings that frequenting a fast-food restaurant at least once a week is associated with greater weight gain [14]. For sleep duration, healthy was defined as 7–9 h/d, consistent with recommendations by the National Sleep Foundation [15]. For smoking, healthy was defined as not currently smoking to focus on modifiable factors [8]. For alcohol use, healthy was defined as light to moderate intake of at least one drink per week, and for men, up to 14 drinks per week, and for women, up to seven drinks per week [16]; the reference category included heavy drinkers (>14 drinks per week for men; >7 drinks per week for women) as well as abstainers (<1 drink per week), based on evidence that moderate drinkers experience the least weight gain [17–19].

For the purposes of stratified analyses, participants were classified as having prior depression if they reported that a health professional had ever told them that they had depression or if they screened positive using the Patient Health Questionnaire 8-item screening tool [20,21]. Participants were classified as having prior post-traumatic stress disorder (PTSD) if they reported that a health professional had ever told them that they had PTSD or if they screened positive using the PTSD Patient Checklist—Civilian Version [22,23]. Data on demographic and military service-related characteristics were also obtained from electronic personnel files of the Defense Manpower Data Center.

Statistical analysis

Participants accrued follow-up time from the completion of the first survey after discharge from military service until either the midpoint of a subsequent survey cycle in which a participant became newly overweight or obese (depending on the outcome of interest), loss to follow-up, or the end of follow-up for the 2014–2016 survey cycle, whichever occurred first. Participants who transitioned to a lower BMI category continued to accrue follow-up time until they became an event of interest or were censored. Cases and person-time for each health behavior were allocated in a time-

dependent manner over follow-up. Women who were pregnant during follow-up did not contribute person-time to the survey cycle in which they gave birth.

Multivariable relative risks (RRs) and 95% confidence intervals (CIs) were estimated with Cox proportional hazards models. All models were adjusted for age, sex, enrollment panel, race/ethnicity (non-Hispanic White, non-Hispanic Black, or Other), marital status (never married; currently married; or divorced, separated, or widowed), former service component (active duty; or Reserve or National Guard), service branch (Army; Navy or Coast Guard; Marine Corps; or Air Force), rank (enlisted or officer), length of service (<4, 4–7, 8–19, or ≥20 years), and time since discharge (<2, 2–3, 4–5, or ≥6 years). All variables that may have changed over time (e.g., physical activity and marital status) were updated as time-dependent variables in the analysis.

We estimated population attributable risk percentages (PAR%), which correspond to the proportion of cases of overweight or obesity in this population that theoretically would not have occurred if all participants had been in the healthy category. The PAR% and 95% CIs were calculated using the methods (and %PAR SAS macro) published by Spiegelman et al [24].

All analyses were stratified by BMI at study baseline (normal weight, 18.5–24.9 kg/m²; overweight, 25.0–29.9 kg/m²), and within strata were adjusted for 1 kg/m² levels of baseline BMI (e.g., <21, 21.0–21.9, and 22.0–22.9 kg/m²). Additional subgroup

analyses were stratified by sex, race/ethnicity, service branch, length of service, and history of depression or PTSD; these analyses focused on the majority of participants who were overweight at baseline, based on considerations of statistical power. Tests for heterogeneity were performed using a likelihood ratio test that compared models with and without interaction terms. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC).

Results

At study baseline, the mean age of the population was 41.1 years (SD = 10.9), mean length of military service was 16.4 years (SD = 10.0), and mean time since discharge from the military was 2.5 years (SD = 1.9). The majority of the study population was male (67%), non-Hispanic White (79%), and previously in the Army (44%) or Air Force (28%). [Supplemental Table 1](#) presents participant characteristics according to the number of healthy behaviors at baseline.

During a mean length of follow-up of 6.1 years (SD = 2.9), 3979 (36%) initially normal-weight participants became overweight or obese, and 4995 (26%) initially overweight participants became obese.

For each of the six individual health behaviors, multivariable RR estimates for incident overweight/obesity and obesity were generally modest in magnitude ([Table 1](#)). For incident overweight/

Table 1
Association between each healthy behavior and incident overweight/obesity and obesity

Characteristic	Incidence of overweight/obesity			Incidence of obesity		
	Cases	Person-years	RR* (95% CI)	Cases	Person-years	RR* (95% CI)
Normal weight at study baseline						
Physical activity (min/wk)						
<150	1687	19,251	1.00 (ref)	194	26,810	1.00 (ref)
≥150	2292	29,562	0.94 (0.88–1.01)	179	38,790	0.70 (0.57–0.87)
Sedentary time (h/d)						
>7	887	9840	1.00 (ref)	101	13,874	1.00 (ref)
≤7	3092	38,973	0.91 (0.84–0.98)	272	51,726	0.84 (0.66–1.07)
Fast-food consumption (times/wk)						
≥1	3025	35,356	1.00 (ref)	299	48,417	1.00 (ref)
<1	954	13,457	0.91 (0.84–0.98)	74	17,183	0.80 (0.62–1.04)
Sleep duration (h/d)						
<7 or >9	2053	21,290	1.00 (ref)	228	29,642	1.00 (ref)
7–9	1926	27,523	0.82 (0.77–0.88)	145	35,958	0.66 (0.53–0.82)
Smoking status						
Current	687	7679	1.00 (ref)	85	10,169	1.00 (ref)
Never or former	3292	41,134	0.91 (0.83–0.99)	288	55,431	0.78 (0.60–1.01)
Alcohol use						
Abstainer or heavy drinker	2001	23,676	1.00 (ref)	225	32,143	1.00 (ref)
Moderate drinker [†]	1978	25,137	0.95 (0.89–1.01)	148	33,457	0.71 (0.57–0.88)
Overweight at study baseline						
Physical activity (min/wk)						
<150				2194	39,733	1.00 (ref)
≥150				2428	52,822	0.92 (0.87–0.98)
Sedentary time (h/d)						
>7				1159	19,785	1.00 (ref)
≤7				3463	72,771	0.91 (0.84–0.97)
Fast-food consumption (times/wk)						
≥1				3866	73,955	1.00 (ref)
<1				756	18,600	0.87 (0.80–0.95)
Sleep duration (h/d)						
<7 or >9				2596	44,416	1.00 (ref)
7–9				2026	48,140	0.85 (0.79–0.90)
Smoking status						
Current				715	12,271	1.00 (ref)
Never or former				3907	80,285	0.95 (0.87–1.03)
Alcohol use						
Abstainer or heavy drinker				2363	43,032	1.00 (ref)
Moderate drinker [†]				2259	49,523	0.90 (0.85–0.96)

* RRs adjusted for age, sex, enrollment panel, time since discharge, length of service, former service component, service branch, officer rank, race/ethnicity, marital status, study baseline body mass index, and each of the other health behaviors.

[†] Moderate alcohol use is defined as 1–14 drinks per week (for men) or 1–7 drinks per week (for women).

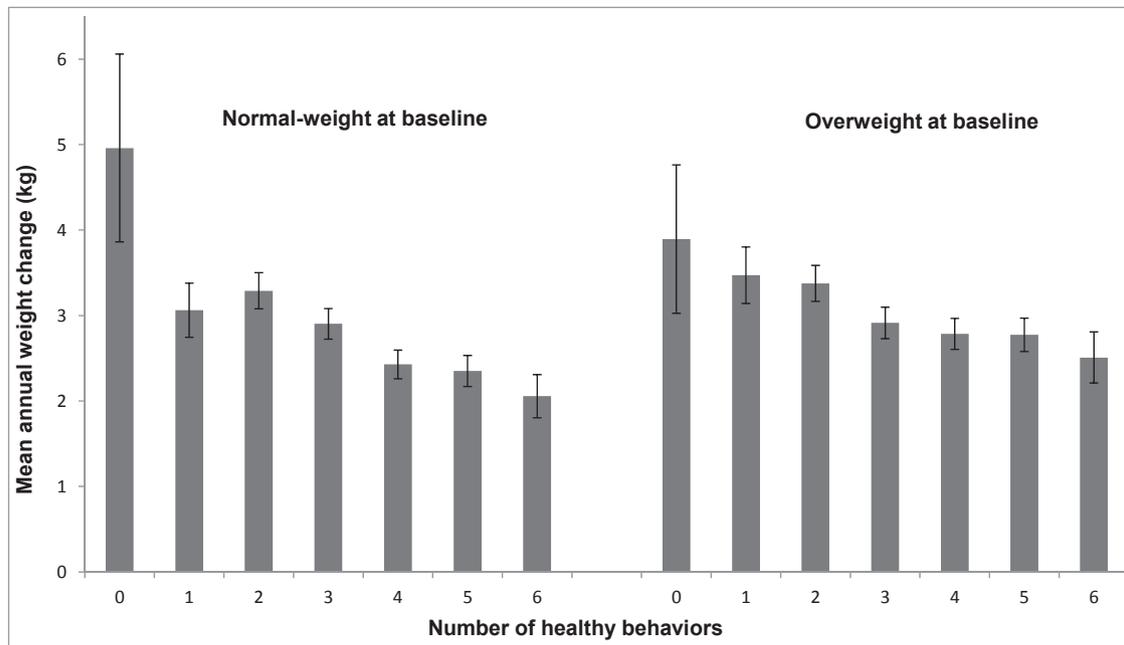


Fig. 1. Mean annual weight change (kilogram) by number of healthy behaviors, stratified by body mass index category at study baseline. Adjusted for age, sex, enrollment panel, time since discharge, length of service, former service component, service branch, officer rank, race/ethnicity, marital status, and study baseline body mass index.

obesity, the RR estimates were 0.94 (95% CI, 0.88–1.01) for regular physical activity, 0.91 (95% CI, 0.84–0.98) for low sedentary time, 0.91 (95% CI, 0.84–0.98) for low fast-food consumption, 0.82 (95% CI, 0.77–0.88) for moderate sleep duration, 0.91 (95% CI, 0.83–0.99) for not currently smoking, and 0.95 (95% CI, 0.89–1.01) for moderate alcohol use. The corresponding RRs for incident obesity, among those who were overweight at baseline, were similar (Table 1). The RR estimates for incident obesity, among those with normal weight at baseline, tended to be stronger in magnitude but less precise because of fewer individuals who transitioned from normal weight to obese during follow-up.

Among participants who were normal weight at baseline, mean annual weight gain ranged from 5.0 kg for the 0.6% of participants with 0 healthy behaviors to 2.1 kg for the 4.6% of participants with all six healthy behaviors assessed (Fig. 1). Among participants who were overweight at baseline, mean annual weight gain ranged from 3.9 to 2.5 kg for those with 0 (0.5%) and those with all six healthy behaviors (3.0%), respectively; during the 6 years of follow-up, on average, this difference in weight gain equated to 8.4 kg.

To examine RRs according to the number of healthy behaviors, extreme high and low categories were collapsed to maintain more than 5% of participants in all categories (Table 2). An increasing number of healthy behaviors was associated with progressively lower rates of overweight and obesity (all P for trend <.0001). Among participants with normal weight at baseline, those with at least five of six healthy behaviors had 36% lower overweight/obesity risk (RR, 0.64; 95% CI, 0.54–0.74) and 61% lower obesity risk (RR, 0.39; 95% CI, 0.24–0.63) compared with those with only 0 or 1 healthy behavior. Among participants who were overweight at baseline, those with at least five of six healthy behaviors had 38% lower obesity risk (RR, 0.62; 95% CI, 0.54–0.72) compared with those with only 0 or 1 healthy behaviors.

When modeling the number of healthy behaviors as an ordinal variable, incidence of overweight/obesity was 10% lower (RR, 0.90; 95% CI, 0.88–0.93), and incidence of obesity was 26% lower (RR, 0.74; 95% CI, 0.67–0.80) for each additional healthy behavior reported among participants who were normal weight at baseline (data not shown). Among those who were overweight at baseline,

Table 2
Association between number of healthy behaviors and incident overweight/obesity and obesity

Number of healthy behaviors*	Incidence of overweight/obesity			Incidence of obesity		
	Cases	Person-years	RR† (95% CI)	Cases	Person-years	RR† (95% CI)
Normal weight at study baseline						
0 or 1	250	2356	1.00 (ref)	33	3493	1.00 (ref)
2	682	7103	0.88 (0.75–1.02)	112	9882	1.21 (0.81–1.80)
3	1128	12,595	0.80 (0.69–0.92)	104	17,492	0.67 (0.44–1.00)
4	1158	14,576	0.73 (0.63–0.85)	83	19,531	0.49 (0.32–0.74)
5 or 6	761	12,183	0.64 (0.54–0.74)	41	15,203	0.39 (0.24–0.63)
P -trend			<.0001			<.0001
Overweight at study baseline						
0 or 1				346	4396	1.00 (ref)
2				940	14,643	0.88 (0.77–1.00)
3				1428	26,589	0.79 (0.70–0.89)
4				1253	28,397	0.71 (0.62–0.80)
5 or 6				655	18,530	0.62 (0.54–0.72)
P -trend						<.0001

* Healthy behaviors were physical activity, sedentary time, fast-food consumption, sleep duration, smoking status, and alcohol use.

† RRs adjusted for age, sex, enrollment panel, time since discharge, length of service, former service component, service branch, officer rank, race/ethnicity, marital status, and study baseline body mass index.

Table 3
Association between number of healthy behaviors and incident obesity among those who were overweight at baseline[†]

Stratum	Number of healthy behaviors [‡]					P trend	P heterogeneity
	0 or 1	2	3	4	5 or 6		
Sex							.15
Men							
Cases/PY	235/3211	647/11,254	997/21,112	918/23,260	493/15,541		
IR [‡]	73.2	57.5	47.2	39.5	31.7		
RR* (95% CI)	1.00 (ref)	0.83 (0.71–0.96)	0.73 (0.63–0.84)	0.66 (0.57–0.76)	0.59 (0.50–0.69)	<.0001	
Women							
Cases/PY	111/1185	293/3389	431/5478	335/5136	162/2989		
IR	93.7	86.5	78.7	65.2	54.2		
RR* (95% CI)	1.00 (ref)	0.97 (0.77–1.22)	0.93 (0.74–1.16)	0.82 (0.65–1.03)	0.73 (0.56–0.94)	.0009	
Race/ethnicity							.12
White, non-Hispanic							
Cases/PY	251/3335	707/10,948	1079/20,198	965/22,818	559/15,742		
IR	75.3	64.6	53.4	42.3	35.5		
RR* (95% CI)	1.00 (ref)	0.92 (0.79–1.07)	0.82 (0.71–0.94)	0.71 (0.61–0.82)	0.65 (0.55–0.76)	<.0001	
Black, non-Hispanic							
Cases/PY	58/606	135/1979	197/3243	142/2737	31/1237		
IR	95.7	68.2	60.7	51.9	25.1		
RR* (95% CI)	1.00 (ref)	0.81 (0.56–1.16)	0.80 (0.56–1.13)	0.69 (0.48–0.99)	0.36 (0.22–0.60)	.0002	
Other							
Cases/PY	37/456	98/1716	152/3148	146/2842	65/1550		
IR	81.1	57.1	48.3	51.4	41.9		
RR* (95% CI)	1.00 (ref)	0.73 (0.47–1.15)	0.71 (0.46–1.08)	0.76 (0.50–1.17)	0.68 (0.43–1.09)	.37	
Service branch							.08
Army							
Cases/PY	193/2316	466/7239	660/12,120	523/11,987	268/7474		
IR	83.3	64.4	54.5	43.6	35.9		
RR* (95% CI)	1.00 (ref)	0.79 (0.66–0.95)	0.71 (0.60–0.84)	0.65 (0.55–0.78)	0.58 (0.48–0.71)	<.0001	
Navy or Coast Guard							
Cases/PY	57/755	158/2671	277/5110	288/5830	151/3917		
IR	75.5	59.2	54.2	49.4	38.5		
RR* (95% CI)	1.00 (ref)	0.98 (0.69–1.38)	0.90 (0.65–1.25)	0.90 (0.65–1.24)	0.79 (0.55–1.11)	.08	
Marine Corps							
Cases/PY	25/362	77/1138	122/1823	97/1959	59/1398		
IR	69.1	67.7	66.9	49.5	42.2		
RR* (95% CI)	1.00 (ref)	0.96 (0.57–1.61)	0.93 (0.57–1.53)	0.70 (0.42–1.16)	0.64 (0.38–1.09)	.007	
Air Force							
Cases/PY	71/964	239/3595	369/7536	345/8621	177/5740		
IR	73.7	66.5	49.0	40.0	30.8		
RR* (95% CI)	1.00 (ref)	0.94 (0.71–1.26)	0.78 (0.59–1.03)	0.68 (0.51–0.89)	0.53 (0.39–0.71)	<.0001	
Length of service							.008
<20 y							
Cases/PY	191/2141	474/6463	690/10,504	629/10,646	312/6826		
IR	89.2	73.3	65.7	59.1	45.7		
RR* (95% CI)	1.00 (ref)	0.88 (0.73–1.05)	0.82 (0.69–0.98)	0.81 (0.68–0.96)	0.68 (0.56–0.83)	<.0001	
≥20 y							
Cases/PY	155/2255	466/8181	738/16,085	624/17,750	343/11,704		
IR	68.7	57.0	45.9	35.2	29.3		
RR* (95% CI)	1.00 (ref)	0.86 (0.72–1.04)	0.74 (0.62–0.89)	0.62 (0.51–0.74)	0.56 (0.46–0.69)	<.0001	
History of depression or PTSD							.003
No							
Cases/PY	150/2194	561/9109	901/18,938	895/22,533	515/15,723		
IR	68.4	61.6	47.6	39.7	32.8		
RR* (95% CI)	1.00 (ref)	0.93 (0.77–1.13)	0.74 (0.62–0.89)	0.66 (0.55–0.80)	0.61 (0.50–0.73)	<.0001	
Yes							
Cases/PY	196/2202	379/5534	527/7651	358/5864	140/2807		
IR	89.0	68.5	68.9	61.1	49.9		
RR* (95% CI)	1.00 (ref)	0.81 (0.67–0.98)	0.85 (0.71–1.02)	0.81 (0.67–0.98)	0.67 (0.53–0.84)	.007	

IR = incidence rate; PY = person-years.

* RRs adjusted for age, sex, enrollment panel, time since discharge, length of service, former service component, service branch, officer rank, race/ethnicity, marital status, and study baseline body mass index.

[†] Healthy behaviors were physical activity, sedentary time, fast-food consumption, sleep duration, smoking status, and alcohol use.[‡] Incidence rate per 1000 person-years.

incidence was 10% lower for each additional healthy behavior (RR, 0.90; 95% CI, 0.87–0.92).

Among those with normal weight at baseline, self-reporting none of the six healthy behaviors was associated with a PAR% of 23% (95% CI, 9%–35%) for incident overweight/obesity and 68% (95% CI, 24%–89%) for obesity. Among those who were overweight, the corresponding PAR% for incident obesity was 28% (95% CI, 11%–43%). That is, if all participants who were overweight at baseline

had been in the healthy category for all behaviors examined, the incidence of obesity would be reduced by 28%.

In stratified analyses focused on incident obesity in relation to number of healthy behaviors among those who were overweight at baseline, there was evidence of a strong inverse trend among men, non-Hispanic Whites, and those who were in the Army and Air Force (all *P* for trend <.0001), which were the larger subgroups included in the study population; the associations within the other

strata by sex, race/ethnicity, and service branch were less precise and generally weaker in magnitude (Table 3). Although the inverse association between number of healthy behaviors and obesity rates was evident across strata of length of military service and history of depression or PTSD, the trend was more pronounced among those with at least 20 years of service (P for heterogeneity = .008) and among those without a history of depression or PTSD (P for heterogeneity = .003).

Discussion

In this large prospective study of U.S. veterans recently discharged from military service, individual healthy behaviors—regular exercise, lower sedentary time, limited fast-food consumption, sufficient sleep duration, not currently smoking, and moderate alcohol use—were each independently associated with modestly lower risk of overweight and obesity during an average of 6 years of follow-up. Progressively lower rates of overweight and obesity were evident for an increasing number of healthy behaviors. We estimated that 23% of the cases who transitioned from normal to overweight and 28% of those who transitioned from overweight to obese could have been prevented if the six unhealthy behaviors we examined were eliminated from this study population. Similarly, we estimated that participants with none of the healthy behaviors gained, on average, 8 kg more than participants with all six healthy behaviors over 6 years of follow-up.

To our knowledge, this is the first prospective study to report on the association between multiple health behaviors in combination and risk of overweight and obesity. One previous prospective study, which specifically investigated changes in weight and waist circumference as continuous outcomes, found that a combination of healthy behaviors was associated with lower weight gain and smaller increase in waist circumference; these associations were appreciably stronger than the modest associations for the individual health behaviors that were assessed (physical activity, diet, and smoking) [8]. Never smoking was most strongly associated with less weight gain among men. In the present study, given that never smoking is a nonmodifiable factor for ever smokers, we assessed noncurrent smoking and observed similar evidence of an inverse association with risk of obesity.

A larger number of studies have reported on the association between multiple health behaviors and obesity-related chronic diseases such as type II diabetes; these studies have consistently concluded that a combination of multiple healthy behaviors is associated with a markedly reduced incidence of type II diabetes and have shown that BMI in the overweight and obese range is the single most important risk factor [25–28].

In contrast to the present study, the aforementioned studies of weight gain and type II diabetes did not examine sedentary behavior or sleep [8,25–28]. Independent of physical activity, sedentary time has been associated with increased weight gain and obesity risk [29], although relatively few prospective studies have examined this association [30]. Although the RR estimates we observed for incident overweight and obesity in relation to each individual health behavior were relatively modest, the point estimates that were strongest in magnitude were those associated with a sufficient amount of sleep (7–9 h/d). A systematic review found that a number of prospective studies have shown short sleep duration to be associated with greater weight gain; experimental studies suggest that sleep deprivation may lead to weight gain through increased caloric intake or reduced physical activity [31]. More limited evidence suggests that long sleep duration may also be associated with increased obesity risk [32].

In subgroup analyses, we found that the inverse relationship between an increasing number of healthy behaviors and incidence

of obesity appeared to be more pronounced among older veterans who had served in the military for at least 20 years and among those without a history of depression or PTSD. Recent findings from the Veterans Health Administration indicate that obesity prevalence is appreciably higher than average among specific subpopulations including younger male veterans and veterans with a mental health condition [5]. Tailored intensive interventions may be warranted for vulnerable populations at highest risk of obesity and subsequent obesity-related chronic disease.

Study limitations include the use of self-reported measures of body size, which tends to result in underestimates of BMI [33]; therefore, obesity rates may have been underestimated. In addition, BMI does not account for muscle mass or body fat. Using BMI can misclassify fit participants with greater muscle mass as overweight or obese. This source of misclassification may be particularly relevant in a study population of recent veterans. The eligible study population must have completed at least two follow-up surveys after leaving the military; previous work in this cohort identified characteristics associated with nonresponse during follow-up (e.g., male gender, younger age, and lower education) but found no appreciable nonresponse bias [34]. We did not have a comprehensive measure of overall diet; however, fast-food consumption may be considered a proxy for higher energy intake and poorer diet quality [35,36]. PAR% estimates are dependent on the prevalence of risk factors in the target population and may not be comparable across studies with different distributions of health behaviors. Because data on self-reported health behaviors were collected approximately every 3 years, we were unable to capture seasonal or short-term changes; the “healthy” category of each behavior included a heterogeneous group of participants, including both those whose behaviors persisted between surveys and those who only recently made a healthy behavior change. This misclassification may have attenuated any observed associations between health behaviors and obesity risk.

In summary, our findings provide evidence that a substantial proportion of U.S. veterans could avoid becoming overweight or obese through adherence to a combination of healthy behaviors. Interventions targeting changes in multiple health behaviors simultaneously, particularly during a high-risk period of weight gain, may be more effective than those targeting a single behavior in reducing obesity rates at a population level.

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Appendix

Supplemental Table 1

Participant characteristics by number of healthy behaviors, stratified by baseline BMI category^{*†}

	Number of healthy behaviors									
	Normal weight at baseline (n = 11,025)					Overweight at baseline (n = 17,583)				
	0 or 1	2	3	4	5 or 6	0 or 1	2	3	4	5 or 6
Participants, n (%)	569 (5)	1694 (15)	2947 (27)	3302 (30)	2513 (23)	909 (5)	2897 (17)	5156 (29)	5281 (30)	3340 (19)
Age, y, mean (SD)	37.4 (10.6)	37.9 (10.3)	38.2 (10.7)	39.0 (11.0)	40.3 (11.4)	39.7 (9.8)	41.0 (10.0)	42.4 (10.7)	43.0 (10.7)	44.2 (11.2)
Length of service, y, mean (SD)	12.6 (9.5)	13.5 (9.2)	13.5 (9.4)	14.2 (9.7)	14.9 (10.1)	15.5 (9.1)	16.5 (9.6)	17.7 (9.9)	18.3 (10.0)	19.2 (10.4)
Years since separation, mean (SD)	2.8 (2.2)	2.7 (2.1)	2.8 (2.1)	2.6 (2.0)	2.5 (1.9)	2.6 (1.9)	2.4 (1.9)	2.4 (1.8)	2.4 (1.8)	2.5 (1.9)
Female (%)	42	48	48	49	51	30	25	23	22	19
White, non-Hispanic (%)	74	74	76	80	86	76	75	76	80	85
Married (%)	50	57	60	65	65	63	68	71	73	74
Officer rank (%)	9	15	22	30	40	13	20	22	27	33
Former active duty (%)	49	42	39	38	37	48	45	44	44	43
Former service branch (%)										
Army	53	49	46	42	39	52	49	46	42	43
Navy or Coast Guard	18	18	19	21	23	17	17	19	21	22
Marine Corps	8	9	8	8	8	8	7	8	8	9
Air Force	22	25	27	29	31	24	27	28	30	30
BMI, kg/m ² , mean (SD)	22.6 (1.7)	22.7 (1.6)	22.8 (1.6)	22.8 (1.6)	22.7 (1.6)	27.3 (1.4)	27.4 (1.4)	27.4 (1.4)	27.3 (1.4)	27.2 (1.3)
Vigorous physical activity, min/wk, mean (SD)	7.0 (74)	49.5 (254)	82.4 (284)	118 (285)	138 (230)	10 (71)	39 (192)	78 (254)	117 (277)	143 (277)
Moderate physical activity, min/wk, mean (SD)	56.0 (140)	170 (506)	232 (547)	289 (555)	290 (498)	59 (163)	117 (338)	211 (492)	268 (533)	313 (524)
Sedentary time, h/d, mean (SD)	7.9 (4.0)	5.8 (3.7)	4.7 (3.2)	3.8 (2.6)	3.2 (2.0)	8.2 (3.7)	5.8 (3.6)	4.7 (3.2)	3.9 (2.6)	3.3 (1.9)
Sleep, h/d, mean (SD)	6.2 (2.1)	6.2 (1.8)	6.7 (1.6)	7.0 (1.3)	7.4 (0.9)	5.9 (1.7)	6.1 (1.6)	6.5 (1.5)	6.8 (1.2)	7.3 (0.9)
Fast food intake, times/wk, mean (SD)	2.1 (1.6)	1.8 (1.4)	1.6 (1.4)	1.3 (1.3)	0.7 (1.2)	2.1 (1.5)	1.9 (1.4)	1.7 (1.4)	1.5 (1.4)	0.9 (1.2)
Alcohol, drinks/wk, mean (SD)	8.1 (15)	6.4 (14)	5.0 (10)	4.2 (7)	4.3 (4)	8.2 (19)	6.3 (12)	5.2 (10)	4.8 (7)	4.7 (5)
Current smoker (%)	68	34	18	7	1	58	28	15	5	1
Prior history of PTSD (%)	37	28	21	14	10	37	26	19	13	9
Prior history of depression (%)	47	38	28	21	18	43	31	24	17	14

* All values are means and proportions standardized to the age distribution of the study population at the start of follow-up. All characteristics are assessed at the start of follow-up of the analysis, which corresponds to the first survey completed after separation from military service.

† Healthy categories are defined as: ≥ 75 min/wk of vigorous physical activity or ≥ 150 min/wk of moderate physical activity (or an equivalent combination), < 8 h/d of sedentary time, < 1 time/week of fast food consumption, 7–9 h/d of sleep, not currently smoking, and 1–14 drinks/week (for men) or 1–7 drinks/week (for women).