



Newly Reported Hypertension After Military Combat Deployment in a Large Population-Based Study

Nisara S. Granado

Tyler C. Smith

Besa Smith

G. Marie Swanson

Edward J. Boyko

Robin B. Harris

Timothy S. Wells

Eyal Shahar

Margaret A.K. Ryan

for the Millennium Cohort Study Team



Naval Health Research Center

Report No. 08-23

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government. Approved for public release: distribution is unlimited.

This research was conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

*Naval Health Research Center
140 Sylvester Road
San Diego, California 92106-3521*

Newly Reported Hypertension After Military Combat Deployment in a Large Population-Based Study

Nisara S. Granado, Tyler C. Smith, G. Marie Swanson, Robin B. Harris, Eyal Shahar, Besa Smith, Edward J. Boyko, Timothy S. Wells, Margaret A.K. Ryan, for the Millennium Cohort Study Team

Abstract—High-stress situations, such as combat deployments, are a potential risk factor for hypertension. Although stress is postulated to increase blood pressure, the underlying role of stress on hypertension is not well established. We sought to determine the relations between combat deployment-induced stress and hypertension. The Millennium Cohort baseline questionnaire (2001–2003) was completed by 77 047 US active-duty and Reserve/National Guard members. Follow-up was completed by 55 021 responders $\approx$ 3 years later (2004–2006). Multivariable logistic regression was used to estimate the 3-year risk of newly reported hypertension, adjusting for general and mental health, demographics, and occupational and behavioral characteristics. After applying exclusion criteria, our analyses included 36 061 service members. Subanalyses of deployers included 8829 participants. Newly reported hypertension was identified in 6.9% of the cohort between baseline and follow-up, many of whom had deployed on military operations in support of the conflicts in Iraq and Afghanistan. After adjusting, deployers who experienced no combat exposures were less likely to report hypertension than nondeployers (odds ratio: 0.77; 95% CI: 0.67 to 0.89). Among deployers, those reporting multiple combat exposures were 1.33 times more likely to report hypertension compared with noncombat deployers (95% CI: 1.07 to 1.65). Although military deployers, in general, had a lower incidence of hypertension than nondeployers, deployment with multiple stressful combat exposures appeared to be a unique risk factor for newly reported hypertension. (*Hypertension*. 2009;54:966-973.)

Key Words: hypertension ■ incidence ■ stressful events ■ cohort studies ■ military personnel

Military deployment may present profound psychological and physical stressors to deployers, such as exposure to life-threatening situations, dead or maimed bodies, and suboptimal living conditions. Although stress related to high-pressure work, natural disasters, and missile attacks has been associated with increased myocardial infarction and other cardiovascular risk,¹ the underlying role of deployment-induced stress or combat-related violence on hypertension is not well established.

Stress is postulated to increase blood pressure through the release of corticoids and inhibition of prostaglandin synthesis, which regulates blood pressure; the sudden rise in dopamine that increases coronary blood flow; or perhaps by altering electrolytes and increasing sodium, thereby aggravating hy-

pertension.^{2–4} Violence is thought to sustain nighttime blood pressure through mechanisms related to elevated sympathetic nervous system response.⁵ Several studies have linked acute stress from life-threatening situations, such as earthquake shock and combat, with elevated blood pressure, although this effect was temporary, lasting only hours to weeks.^{6–8} However, acute stress responses reported after terrorist attacks were shown to increase physician-diagnosed hypertension by 115% at 1 year and 75% at 2 years.⁹ Individuals with sustained nighttime blood pressure ($<10\%$ decrease from awake to sleep) were 3.5 times as likely to have personally seen violence (attacks, abuse, or crime) than those with a drop in nighttime blood pressure.¹⁰ Previous findings have shown no association between stress, as assessed by military deploy-

Received March 11, 2009; first decision April 3, 2009; revision accepted August 20, 2009.

From the Department of Defense Center for Deployment Health Research (N.S.G., T.C.S., B.S.), Naval Health Research Center, San Diego, Calif; Department of Public Health (G.M.S.), Indiana University School of Medicine, Indianapolis, Ind; Mel and Enid Zuckerman College of Public Health (R.B.H., E.S.), University of Arizona, Tucson, Ariz; Seattle Epidemiologic Research and Information Center (E.J.B.), Veterans' Affairs Puget Sound Health Care System, Seattle, Wash; Air Force Research Laboratory (T.S.W.), Wright-Patterson Air Force Base, Dayton, Ohio; Occupational Health Department (M.A.K.R.), Naval Hospital Camp Pendleton, Camp Pendleton, Calif.

This represents the Naval Health Research Center report 08-42, supported by the Department of Defense, under work unit No. 60002. The views expressed in this article are those of the authors and do not reflect the official policy or position of the US Department of the Navy, US Department of the Army, US Department of the Air Force, US Department of Defense, US Department of Veterans' Affairs, the US Government, or the University of Arizona. This research has been conducted in compliance with all applicable federal regulations governing the protection of human subjects in research (Protocol NHRC.2001.0007) and in compliance with the institutional review boards of the Naval Health Research Center and the University of Arizona. In addition, the funding organization had no role in the design and conduct of the study; collection, analysis, or preparation of data; or preparation, review, or approval of the manuscript.

Correspondence to Nisara S. Granado, Department of Defense Center for Deployment Health Research, Naval Health Research Center, 140 Sylvester Rd, San Diego, CA 92106-3521. E-mail nisara.granado@med.navy.mil

© 2009 American Heart Association, Inc.

Hypertension is available at <http://hyper.ahajournals.org>

DOI: 10.1161/HYPERTENSIONAHA.109.132555

ment to the 1991 Gulf War or Vietnam War, and hypertension,^{11–14} yet these studies were cross-sectional in nature, and hypertension may have resolved before evaluation. The Millennium Cohort Study is well positioned to evaluate potential associations and address concerns over the long-term health consequences related to the current operations in Iraq and Afghanistan.^{15–17} This is the first study to prospectively investigate the relations between military deployments and newly reported hypertension in a large population-based cohort, many of whose members were deployed with reported combat exposures.

Methods

Original Cohort

The Millennium Cohort invited a population-based random sample of the 2.2 million US military members who were serving as of October 1, 2000,¹⁵ oversampling for previous deployers to Southwest Asia, Bosnia, or Kosovo (1998–2000); Reserve and National Guard members; and women to ensure adequate power in stratified analyses.¹⁵ The Millennium Cohort Study baseline questionnaire was completed by 77 047 consenting enrollees (July 2001 to June 2003), whereas 55 021 responded to the follow-up questionnaire $\approx$ 3 years later (June 2004 to February 2006). More details on the original cohort are available elsewhere.¹⁵

Study Population

In the current analyses, participants were limited to consenting service members who completed both baseline and follow-up questionnaires. Excluded were individuals who reported ever having hypertension at baseline ($n=5753$), service members previously deployed and returned before baseline questionnaire submission ($n=1960$), and persons who completed either questionnaire while still deployed ($n=2924$). In an attempt to reduce confounding from pregnancy-related hypertension, women who reported having no menstrual period because of pregnancy or recent birth and women who reported giving birth in the previous 3 years ($n=3409$) were excluded. Additional exclusions were missing outcome and covariate data ($n=4874$) and individuals with the reported year of hypertension onset before deployment ($n=40$). The final study population included 36 061 participants. Subanalyses evaluated deployers only, which included 8829 participants. This study was conducted in accordance with ethical and institutional guidelines with informed consent and was approved by the institutional review boards of the University of Arizona and the Naval Health Research Center.

Hypertension Outcome

“Newly reported hypertension” included individuals who reported hypertension at follow-up but not at baseline, while ensuring that the year of hypertension onset, if available, was reported after deployment among those who deployed during this period. The Millennium Cohort Study baseline questionnaire asked, “Has your doctor or other health professional EVER told you that you have any of the following conditions? . . . Hypertension (high blood pressure).” At follow-up, participants were asked the same question, but in the context of the last 3 years. A field was available for, “If YES, in what year were you first diagnosed?”

Deployment Data

Deployment data were obtained electronically from the Defense Manpower Data Center on the basis of inbound and outbound theater dates. Recent deployment in support of the conflicts in Iraq and Afghanistan was assessed as occurring after the baseline questionnaire and before follow-up. Combat exposures were evaluated at follow-up through self-report of personally witnessing or being exposed in the past 3 years to a person’s death because of war or disaster, physical abuse, dead or decomposing bodies, maimed soldiers or civilians, or prisoners of war or refugees. Single and

multiple exposures were assessed for each of the combat exposures described.

General/Mental Health and Behavioral Characteristics

Self-reported general health was assessed at baseline and characterized as excellent, very good, good, or fair/poor. Responses to the fair and poor categories were collapsed because of small cell counts. Mental component summary scores were evaluated at baseline through the Medical Outcomes Study short-form 36-item questionnaire for veterans.¹⁸

Average self-reported alcohol consumption in the past year at baseline was based on the Departments of Health and Human Services and Agriculture Dietary Guidelines for Americans.¹⁹ “Moderate drinking” was defined as an average alcohol consumption of 1 drink a day for women or 2 drinks a day for men, with 1 drink specified as either one 12-oz beer, one 4-oz glass of wine, or one 1.5-oz shot of liquor. Heavy drinking was defined as higher than this level, whereas low drinking levels or no alcohol consumption were assessed through self-report of <12 drinks of any type of alcoholic beverage in their entire life and/or in the past year.

Reports of physical activity and strength training were collected from the follow-up questionnaires. The variables were classified on the basis of the American College of Sports Medicine and the American Heart Association.²⁰ Participants who self-reported ≥ 150 minutes per week of moderate/light exercise (on the basis of 30 minutes per day, 5 days a week) and/or ≥ 60 minutes of vigorous exercise (on the basis of 20 minutes per day, 3 days a week) were considered physically active. Conducting 8 to 10 strength-training exercises was estimated at 30 minutes; therefore, individuals who self-reported ≥ 60 minutes per week of strength training or work that strengthened their muscles were considered to be engaged in active strength training.

Cigarette smoking was assessed using the baseline questionnaire and was categorized as nonsmoker, past smoker, and current smoker. Smoking status was based on self-report of lifetime smoking of ≥ 100 cigarettes (5 packs), a successful attempt to quit smoking, and cigarette use in the past year.

Demographic and Occupational Data

Demographic and occupational data were obtained electronically from the Defense Manpower Data Center and categorized as shown in Table 1. Body mass index scores were calculated from self-reported height and weight data collected from baseline questionnaires on the basis of the guidelines from the National Heart, Lung, and Blood Institute.²¹ Electronic outpatient and inpatient International Classification of Diseases, Ninth Revision, Clinical Modification codes were obtained from Department of Defense databases and civilian claims billed to the Department of Defense. Newly diagnosed hypertension codes were identified as ≥ 2 outpatient and/or ≥ 1 inpatient International Classification of Diseases, Ninth Revision, Clinical Modification code(s) from baseline to follow-up survey submission dates among active-duty participants only, because of unequal benefits in accessing the Department of Defense healthcare system among Reserve/National Guard members. To ensure adequate time for entry of codes into the databases, we also investigated 90 days after follow-up submission.

Statistical Analysis

Cumulative incidence of newly reported hypertension was calculated, in addition to κ coefficients and corresponding 95% CIs, to evaluate the agreement between self-report and hypertension diagnosis codes. Univariate analyses, including χ^2 tests of association, were conducted for the full model ($N=36\,061$) and the deployers-only model ($N=8829$). Initial model analyses assessed multicollinearity among all of the variables, which was deemed likely if the variance inflation factor was >4 , indicating high correlation. Potential confounders were retained in the adjusted model, in addition to variables of interest from literature review. Potential interactions were tested and considered significant at $P \leq 0.05$. Multivariable

Table 1. Characteristics of Millennium Cohort Study Participants by Military Deployment

Characteristics (N=36 061)	n (%)			
	Nondeployed (n=27 232)	No Combat (n=4385)	Deployed	
			Single (n=586)	Multiple (n=3858)
Sex*				
Male	20 363 (74.8)	3663 (83.5)	472 (80.5)	3329 (86.3)
Female	6869 (25.2)	722 (16.5)	114 (19.5)	529 (13.7)
Birth year*				
1960 and earlier	7552 (27.7)	830 (18.9)	100 (17.1)	564 (14.6)
1960–1969	11 379 (41.8)	1967 (44.9)	260 (44.4)	1493 (38.7)
1970–1979	7402 (27.2)	1388 (31.6)	197 (33.6)	1549 (40.2)
1980 and forward	899 (3.3)	200 (4.6)	29 (4.9)	252 (6.5)
Education*				
No high school diploma	1458 (5.4)	128 (2.9)	35 (6.0)	267 (6.9)
High school diploma	10 134 (37.2)	1382 (31.5)	223 (38.0)	1782 (46.2)
Some college	6824 (25.1)	1657 (37.8)	171 (29.2)	700 (18.1)
College graduate	5347 (19.6)	854 (19.5)	118 (20.1)	787 (20.4)
Advanced degree	3469 (12.7)	364 (8.3)	39 (6.7)	322 (8.4)
Marital status*				
Married	18 140 (66.6)	2953 (67.3)	361 (61.6)	2425 (62.8)
Single	7032 (25.8)	1139 (26.0)	183 (31.2)	1214 (31.5)
Other	2060 (7.6)	293 (6.7)	42 (7.2)	219 (5.7)
Race/ethnicity*				
Non-Hispanic white	19 787 (72.7)	3306 (75.4)	414 (70.6)	2647 (68.6)
Non-Hispanic black	2979 (10.9)	433 (9.9)	87 (14.9)	338 (8.8)
Asian/Pacific Islander	2315 (8.5)	310 (7.1)	35 (6.0)	545 (14.1)
Hispanic	1585 (5.8)	251 (5.7)	36 (6.1)	223 (5.8)
Other	566 (2.1)	85 (1.9)	14 (2.4)	105 (2.7)
Service component†				
Reserve/National Guard	12 896 (47.4)	1767 (40.3)	235 (40.1)	1458 (37.8)
Active duty	14 336 (52.6)	2618 (59.7)	351 (59.9)	2400 (62.2)
Military pay grade*				
Enlisted	19 371 (71.1)	3268 (74.5)	429 (73.2)	2727 (70.7)
Officer	7861 (28.9)	1117 (25.5)	157 (26.8)	1131 (29.3)
Service branch*				
Army	13 051 (47.9)	1121 (25.6)	259 (44.2)	2637 (68.3)
Air Force	7461 (27.4)	2297 (52.4)	220 (37.5)	705 (18.3)
Navy/Coast Guard	5535 (20.3)	818 (18.6)	89 (15.2)	235 (6.1)
Marine Corps	1185 (4.4)	149 (3.4)	18 (3.1)	281 (7.3)
Occupational category*				
Other occupations	18 373 (67.5)	3274 (74.7)	419 (71.5)	2260 (58.6)
Combat specialists	5496 (20.2)	951 (21.7)	128 (21.8)	1174 (30.4)
Healthcare specialists	3363 (12.3)	160 (3.6)	39 (6.7)	424 (11.0)
Body mass index†				
Underweight/normal	10 078 (37.0)	1588 (36.2)	221 (37.7)	1376 (35.7)
Overweight	14 294 (52.5)	2417 (55.1)	313 (53.4)	2152 (55.8)
Obese	2860 (10.5)	380 (8.7)	52 (8.9)	330 (8.5)

(Continued)

Table 1. Continued

Characteristics (N=36 061)	n (%)			
	Nondeployed (n=27 232)	No Combat (n=4385)	Deployed	
			Combat	
			Single (n=586)	Multiple (n=3858)
Alcohol consumption*				
None to low drinking	7485 (27.5)	1029 (23.5)	139 (23.7)	755 (19.6)
Moderate drinking	9199 (33.8)	1481 (33.8)	201 (34.3)	1269 (32.9)
Heavy drinking	10 548 (38.7)	1875 (42.7)	246 (42.0)	1834 (47.5)
Physical activity*				
Inactive	9434 (34.6)	1367 (31.2)	199 (34.0)	987 (25.6)
Active	17 798 (65.4)	3018 (68.8)	387 (66.0)	2871 (74.4)
Strength training*				
Inactive	14 975 (55.0)	2267 (51.7)	294 (50.2)	1518 (39.3)
Active	12 257 (45.0)	2118 (48.3)	292 (49.8)	2340 (60.7)
Smoking status*				
Nonsmoker	16 284 (59.8)	2673 (61.0)	370 (63.1)	2202 (57.1)
Past smoker	6669 (24.5)	996 (22.7)	138 (23.6)	885 (22.9)
Current smoker	4279 (15.7)	716 (16.3)	78 (13.3)	771 (20.0)
General health*				
Excellent	6212 (22.8)	1022 (23.3)	129 (22.0)	983 (25.5)
Very good	11 429 (42.0)	1885 (43.0)	245 (41.8)	1666 (43.2)
Good	7802 (28.6)	1280 (29.2)	178 (30.4)	1016 (26.3)
Fair/poor	1789 (6.6)	198 (4.5)	34 (5.8)	193 (5.0)
Mental component summary*				
>75th percentile	6847 (25.1)	1106 (25.2)	152 (25.9)	907 (23.5)
>50th to 75th percentile	6801 (25.0)	1119 (25.5)	139 (23.7)	965 (25.0)
>25th to 50th percentile	6732 (24.7)	1144 (26.1)	161 (27.5)	966 (25.1)
0 to 25th percentile	6852 (25.2)	1016 (23.2)	134 (22.9)	1020 (26.4)

* $\chi^2 P \leq 0.05$ in the full model (N=36 061) and in the deployers-only model (N=8829).

† $\chi^2 P \leq 0.05$ in the full model and $P > 0.05$ in the deployers-only model.

logistic regression was used to investigate relations between newly reported hypertension and combat deployment. Statistical analyses were performed using SAS software, version 9.2 (SAS Institute, Inc).

Results

Within ≈ 3 years between baseline and the follow-up questionnaire (average: 2.7 years), 25% were deployed in support of the operations in Iraq and Afghanistan, with half of those reporting combat exposures during deployment (Table 1). In the full model, compared with nondeployers, deployers without combat were proportionately more likely to be men, younger, have some college education, married, non-Hispanic white, on active duty, enlisted, in the Air Force, in occupations other than combat or health care, overweight, reporting heavy drinking, physically active, engaging in strength training, nonsmokers or current smokers, and reporting better general or mental health. In the deployers-only model, compared with noncombat deployers, multiple combat-exposed deployers were proportionately more likely to be men,

younger, less than some college educated, single, Asian/Pacific Islanders, an officer, in the Army or Marine Corps, combat or healthcare specialists, reporting heavy drinking, physically active, engaging in strength training, current smokers, reporting other than good general health, and in worse overall mental health.

Within ≈ 3 years between baseline and follow-up surveys, 2485 responders (6.9%) reported hypertension (Table 2). When newly reported hypertension was evaluated against objective hypertension diagnosis codes, there was moderate agreement ($\kappa=0.46$; 95% CI: 0.44 to 0.49). Including 90 days after follow-up submission to allow for adequate time for entry of code(s) did not change the agreement ($\kappa=0.49$; 95% CI: 0.47 to 0.52). In both the full and the deployers-only models, there was no variable with a variance inflation level of >4 , indicating no multicollinearity. Furthermore, interaction terms between deployment and sex, as well as alcohol consumption, were tested but were not statistically signifi-

Table 2. Approximate 3-Year Incidence and Adjusted Odds of Newly Reported Hypertension and Military Deployment Between Baseline (2001–2003) and Follow-Up (2004–2006)

Covariates (N=36 061)	Cumulative Incidence, %	Adjusted OR*	95% CI
Newly reported hypertension	6.9		
Deployment status			
Nondeployed	7.3		
Deployed no combat	5.4	0.77	0.67 to 0.89
Deployed single combat	5.5	0.78	0.54 to 1.13
Deployed multiple combat	6.1	0.98	0.84 to 1.13
Sex			
Male	7.4		
Female	5.0	0.72	0.63 to 0.81
Birth year			
1960 and earlier	10.8		
1960–1969	6.9	0.53	0.48 to 0.59
1970–1979	4.0	0.33	0.29 to 0.38
1980 and forward	2.8	0.30	0.21 to 0.43
Marital status			
Married	7.9		
Single	4.4	0.86	0.76 to 0.98
Other	7.2	0.95	0.80 to 1.11
Race/ethnicity			
Non-Hispanic white	6.4		
Non-Hispanic black	11.0	1.84	1.62 to 2.08
Asian/Pacific Islander	6.1	1.16	0.97 to 1.38
Hispanic	6.8	1.10	0.91 to 1.32
Other	7.3	1.20	0.90 to 1.59
Service component			
Reserve/National Guard	7.1		
Active duty	6.7	1.19	1.08 to 1.31
Military pay grade			
Enlisted	7.3		
Officer	5.8	0.82	0.70 to 0.96
Body mass index			
Normal/underweight	3.6		
Overweight	7.7	1.77	1.58 to 1.98
Obese	14.6	3.09	2.69 to 3.55
Physical activity			
Inactive	8.3		
Active	6.2	0.90	0.82 to 0.99
Strength training			
Inactive	7.8		
Active	5.9	0.86	0.78 to 0.94

(Continued)

Table 2. Continued

Covariates (N=36 061)	Cumulative Incidence, %	Adjusted OR*	95% CI
General health			
Excellent	4.5		
Very good	6.4	1.27	1.12 to 1.44
Good	9.0	1.67	1.45 to 1.91
Fair/poor	9.8	1.68	1.38 to 2.04

*Data are adjusted for above characteristics plus education, service branch, occupation, alcohol consumption, smoking status, and mental component summary.

cant. All of the results were adjusted for general and mental health, demographics, and occupational and behavioral characteristics. Compared with nondeployers, noncombat deployers were 0.77 times as likely to report hypertension (95% CI: 0.67 to 0.89). In addition, being a woman, younger, single, an officer, physically active, or conducting strength training was inversely associated with newly reported hypertension, whereas risk factors included being non-Hispanic black, on active duty, overweight or obese, and reporting poorer general health.

In subanalyses among deployers only, deployers with multiple combat exposures were 1.33 times more likely to report hypertension than noncombat deployers (95% CI: 1.07 to 1.65; Table 3). In addition, being younger, an officer, or a current smoker was inversely associated with incident hypertension, whereas risk factors included being non-Hispanic black or Hispanic, overweight or obese, and reporting poorer general and mental health. When each type of combat exposure was analyzed separately, personally witnessing or being exposed to a person's death because of war or disaster was statistically significantly associated with newly reported hypertension both at single (odds ratio [OR]: 1.50; 95% CI: 1.10 to 2.05) and multiple exposures (OR: 1.43; 95% CI: 1.12 to 1.83). Exposure to physical abuse, dead or decomposing bodies, maimed soldiers or civilians, or prisoners of war or refugees was not statistically significantly associated with newly reported hypertension.

Discussion

Over the $\approx$ 3-year period, newly reported hypertension was observed in 6.1% of deployers with multiple combat exposures and 6.9% overall in this large population-based cohort of young adults (mean age: 35 years). Newly reported hypertension was found to be higher among nondeployers than deployers. Although deployment in general appeared to be inversely associated with newly reported hypertension, deployers presumably are healthier than nondeployers, because service members must be medically cleared for deployment. Deployment alone may not capture the effects of stress associated with actual combat. Compared with noncombat deployers, deployers with multiple combat exposures were statistically significantly at higher risk of newly reported hypertension.

National statistics from 2003 to 2004 reported a higher prevalence of hypertension among non-Hispanic blacks than non-Hispanic whites (OR: 1.61; 95% CI: 1.30 to 1.99) but no

Table 3. Among Deployers: Approximate 3-Year Incidence and Adjusted Odds of Newly Reported Hypertension and Combat Exposures

Covariates (N=8829)	Cumulative Incidence, %	Adjusted OR*	95% CI
Newly reported hypertension	5.7		
Deployment status			
Deployed no combat	5.4		
Deployed single combat	5.5	1.02	0.69 to 1.51
Deployed multiple combat	6.1	1.33	1.07 to 1.65
Birth year			
1960 and before	9.6		
1960–1969	6.3	0.56	0.44 to 0.72
1970–1979	3.5	0.33	0.24 to 0.46
1980 and forward	2.5	0.26	0.13 to 0.51
Race/ethnicity			
Non-Hispanic white	5.1		
Non-Hispanic black	10.3	1.97	1.49 to 2.60
Asian/Pacific Islander	4.2	1.03	0.69 to 1.56
Hispanic	7.3	1.50	1.04 to 2.16
Other	5.9	1.12	0.61 to 2.06
Military pay grade			
Enlisted	6.1		
Officer	4.4	0.62	0.43 to 0.90
Body mass index			
Normal/underweight	2.9		
Overweight	6.5	1.92	1.50 to 2.47
Obese	12.2	3.33	2.42 to 4.59
Smoking status			
Nonsmoker	5.9		
Past smoker	6.3	0.95	0.76 to 1.19
Current smoker	4.2	0.70	0.52 to 0.94
General health			
Excellent	3.7		
Very good	5.5	1.33	1.01 to 1.75
Good	7.4	1.45	0.91 to 2.33
Fair/poor	7.1	1.76	1.12 to 2.76
Mental component summary			
>75th percentile	5.5		
>50th to 75th percentile	4.9	1.03	0.78 to 1.35
>25th to 50th percentile	5.5	1.15	0.88 to 1.50
0 to 25th percentile	6.8	1.41	1.08 to 1.86

*Data are adjusted for above characteristics plus sex, education, marital status, service component, service branch, occupation, alcohol consumption, physical activity, and strength training.

association between Mexican Americans and non-Hispanic whites (OR: 0.68; 95% CI: 0.43 to 1.08).²² In this study, non-Hispanic blacks had an 84% higher risk for newly reported hypertension than non-Hispanic whites, with no association between Hispanics and non-Hispanic whites.

Among deployers, similar trends were observed with 97% higher risk among non-Hispanic blacks than non-Hispanic whites, yet higher risk was also observed among Hispanics than non-Hispanic whites (50%).

Obese persons are at increased risk for developing hypertension, cardiovascular disease, and stroke.^{23,24} In the current study, obese individuals had a 3-fold higher risk of reporting hypertension than normal or underweight persons. Similar trends showing increased body mass index as a risk factor for hypertension have been identified in other prospective cohort studies.^{25,26}

Physical activity is especially important in promoting cardiovascular benefits, along with a reduction in high blood pressure.^{24,27} Strength training has been shown to complement aerobic exercise,²⁸ help facilitate weight control,²⁹ and be potentially beneficial in the management of hypertension.³⁰ In this study, individuals who were physically active and actively strength trained were at a decreased risk of newly reported hypertension. However, this association was only significant when nondeployers were included in the model. Although physical activity and strength training were not captured at baseline, excluding these variables from the model did not change the relations between deployment and newly reported hypertension. In addition, light-intensity exercise could not be distinguished; thus, including this subgroup in the “inactive” category may have potentially biased the results toward the null, thereby minimizing the association found.

Several studies have found current smoking to increase blood pressure and to be a risk factor for hypertension, possibly because of sympathetic activation and arterial stiffness.^{31–35} Contrarily, in the total sample of deployers and nondeployers, there was no association between cigarette smoking and newly reported hypertension. In the sample of deployers only, current smoking was inversely associated with newly reported hypertension. These findings may be attributable to differences between groups at baseline, in which current smokers were statistically significantly younger and less overweight/obese than past and nonsmokers. Vascular stiffness, which reportedly increases with age,³⁶ may be less prominent in the younger, although currently smoking population. In addition, potential confounding because of weight gain or loss may not have been fully adjusted in our model using baseline body mass index alone as a measurement of adiposity and body composition.

Limitations and Strengths

Limitations of this study include potential biases related to loss to follow-up and misclassification of exposures and outcome because of self-report. In addition, risk factors such as family history and high dietary salt were not measured. Although we do not expect family history to differ between deployers and nondeployers, because family history of disease is not a screening requirement for deployment, change in diet among deployers may differ from nondeployers. Selection bias could have occurred from individuals who were unable to submit the questionnaires while deployed to remote locations. For this reason, individuals who completed their questionnaire while deployed were excluded. Subanalyses of

current deployers or participants who completed either survey while deployed resulted in similar findings, with noncombat current deployers being less likely to report hypertension than nondeployers (OR: 0.54; 95% CI: 0.40 to 0.75) and current deployers with multiple combat exposures at increased risk for newly reported hypertension than noncombat deployers (OR: 1.30; 95% CI: 1.05 to 1.61). Conversely, current deployers with multiple combat exposures were statistically significantly less likely to report hypertension than nondeployers (OR: 0.61; 95% CI: 0.45 to 0.84). Misclassification bias may have occurred for some who did not have adequate time to be examined and diagnosed with hypertension on return from deployment. However, a subanalysis, in which only deployments completed ≥ 3 months before the follow-up questionnaire were conducted to allow for adequate diagnosis time, resulted in no difference in findings.

Self-reported hypertension and combat-related exposures may be prone to recall bias and may not represent the true measure of hypertension or combat exposures in the population. Medical charts were not available for analyses; however, electronic medical encounters were available with moderate agreement observed between self-report and hypertension codes. Although awareness of blood pressure measurements was not assessed, >99.8% of participants had ≥ 1 encounter within the military healthcare system, during which blood pressure is routinely measured.

Despite the limitations, the strength of this study lies in the prospective design, which allows for calculation of cumulative incidence and estimated risk of newly reported hypertension. Previous studies have shown these cohort data to be reliable and survey response to be uninfluenced by poor health status.^{15,17,37–43} We believe that these results are generalizable to the entire US military because of the large sample size and population-based random sampling methods used. To some extent, results may also be generalizable to any population of healthy young adults. Furthermore, a large sample size allows for subgroup comparisons, adequate power to detect statistically important differences, and the ability to adjust for potential confounding.

Perspectives

In this large population-based cohort, an estimated 6.9% of military service members reported hypertension within an ≈ 3 -year period. A lower incidence of newly reported hypertension was found among military deployers, likely because of deployers being healthier than nondeployers because of the medical clearance requirement for deployment. Deployers reporting multiple combat exposures, especially those who personally witnessed a death because of war or disaster, were at statistically significantly increased risk for newly reported hypertension. This may indicate a stress-induced hypertensive effect in an otherwise healthy population. Future studies evaluating military deployment and hypertension diagnosis through blood pressure measurements are recommended. Additional follow-up of this cohort will allow for better understanding of relations between military combat deployment and other occupational and psychosocial stressors with newly reported hypertension and other chronic health conditions.

Acknowledgments

In addition to the authors, the Millennium Cohort Study Team includes Paul Amoroso, Gina Creaven, James Davies, Lacy Farnell, Gary Gackstetter, Gregory Gray, Gia Gumbs, Tomoko Hooper, Isabel Jacobson, Kelly Jones, Molly Kelton, Cynthia LeardMann, Travis Leleu, Jamie McGrew, James Riddle, Katherine Snell, Steven Speigle, Kari Welch, Martin White, James Whitmer, and Charlene Wong.

We are indebted to the Millennium Cohort Study participants, without whom these analyses would not be possible. We appreciate the support from the Management Information Division, US Defense Manpower Data Center (Seaside, CA); Military Operational Medicine Research Program, United States Army Medical Research and Material Command (Ft Detrick, MD); Henry M. Jackson Foundation for the Advancement of Military Medicine (Rockville, MD); and Air Force Institute of Technology, Wright-Patterson Air Force Base (OH). In addition, we thank Michelle Stoia from the Naval Health Research Center (San Diego, CA).

Sources of Funding

The Millennium Cohort Study is funded through the Military Operational Medicine Research Program, United States Army Medical Research and Material Command (Fort Detrick, MD).

Disclosures

None.

References

1. Tofler GH, Muller JE. Triggering of acute cardiovascular disease and potential preventive strategies. *Circulation*. 2006;114:1863–1872.
2. Melby CL. Inhibition of prostaglandin synthesis: a possible mechanism for stress-induced hypertension. *Med Hypotheses*. 1983;10:445–449.
3. Kuchel O. Mental stress and hypertension, an evolutionary framework: some historical perspectives of the 1960 World Health Organization Prague hypertension meeting. *J Hypertens*. 2003;21:639–641.
4. Maboob T, Haleem DJ, Mumtaz M, Haleem M. Stress and hypertension: role of serum, red cell and tissue electrolytes. *Life Sci*. 1996;58:1587–1590.
5. Wilson DK, Kliever W, Sica DA. The relationship between exposure to violence and blood pressure mechanisms. *Curr Hypertens Rep*. 2004;6:321–326.
6. Miller G. Does war stress contribute to hypertension? *Aust Fam Physician*. 1993;22:707–710.
7. Parati G, Antonicelli R, Guazzarotti F, Paciaroni E, Mancia G. Cardiovascular effects of an earthquake: direct evidence by ambulatory blood pressure monitoring. *Hypertension*. 2001;38:1093–1095.
8. Saito K, Kim JJ, Maekawa K, Ikeda Y, Yokoyama M. The great Hanshin-Awaji earthquake aggravates blood pressure control in treated hypertensive patients. *Am J Hypertens*. 1997;10:217–212.
9. Holman EA, Silver RC, Poulin M, Anderson J, Gil-Rivas V, McIntosh DN. Terrorism, acute stress, and cardiovascular health: a 3-year national study following the September 11th attacks. *Arch Gen Psychiatry*. 2008;65:73–80.
10. Wilson DK, Kliever W, Teasley N, Plybon L, Sica DA. Violence exposure, catecholamine excretion, and blood pressure nondipping status in African American male versus female adolescents. *Psychosom Med*. 2002;64:906–915.
11. Eisen SA, Kang HK, Murphy FM, Blanchard MS, Reda DJ, Henderson WG, Toomey R, Jackson LW, Alpern R, Parks BJ, Klimas N, Hall C, Pak HS, Hunter J, Karlinksky J, Battistone MJ, Lyons MJ; for the Gulf War Study Participating Investigators. Gulf War veterans' health: medical evaluation of a U.S. cohort. *Ann Intern Med*. 2005;142:881–890.
12. Kang HK, Dalager NA, Needham LL, Patterson DG Jr, Lees PS, Yates K, Matanoski GM. Health status of Army Chemical Corps Vietnam veterans who sprayed defoliant in Vietnam. *Am J Ind Med*. 2006;49:875–884.
13. Smith TC, Gray GC, Weir JC, Heller JM, Ryan MA. Gulf War veterans and Iraqi nerve agents at Khamisiyah: postwar hospitalization data revisited. *Am J Epidemiol*. 2003;158:457–467.
14. Gray GC, Reed RJ, Kaiser KS, Smith TC, Gastanaga VM. Self-reported symptoms and medical conditions among 11,868 Gulf War-era veterans: the Seabee Health Study. *Am J Epidemiol*. 2002;155:1033–1044.

15. Ryan MA, Smith TC, Smith B, Amoroso P, Boyko EJ, Gray GC, Gackstetter GD, Riddle JR, Wells TS, Gumbs G, Corbeil TE, Hooper TI. Millennium Cohort: enrollment begins a 21-year contribution to understanding the impact of military service. *J Clin Epidemiol.* 2007;60:181–191.
16. Smith TC, Ryan MA, Wingard DL, Slymen DJ, Sallis JF, Kritiz-Silverstein D. New onset and persistent symptoms of post-traumatic stress disorder self reported after deployment and combat exposures: prospective population based US military cohort study. *BMJ.* 2008;336:366–371.
17. Riddle JR, Smith TC, Smith B, Corbeil TE, Engel CC, Wells TS, Hoge CW, Adkins J, Zamorski M, Blazer D. Millennium Cohort: the 2001–2003 baseline prevalence of mental disorders in the U.S. military. *J Clin Epidemiol.* 2007;60:192–201.
18. Ware JE Jr, Kosinski M. *SF-36® Physical and Mental Health Summary Scales: A Manual for Users of Version 1.* 2nd ed, Lincoln, RI: Quality-Metric Incorporated; 2001.
19. US Department of Agriculture/US Department of Health and Human Services. Home and Garden Bulletin No. 232. *Nutrition and Your Health: Dietary Guidelines for Americans.* 3rd ed. Washington, DC: US Government Printing Office; 1990.
20. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc.* 2007;39:1423–1434.
21. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res.* 1998;6(suppl 2):51S–209S.
22. Ong KL, Cheung BM, Man YB, Lau CP, Lam KS. Prevalence, awareness, treatment, and control of hypertension among United States adults 1999–2004. *Hypertension.* 2007;49:69–75.
23. Garrison RJ, Kannel WB, Stokes J III, Castelli W. Incidence and precursors of hypertension in young adults: the Framingham Offspring Study. *Prev Med.* 1987;16:235–251.
24. Glynn RJ, Rosner B. Comparison of risk factors for the competing risks of coronary heart disease, stroke, and venous thromboembolism. *Am J Epidemiol.* 2005;162:975–982.
25. Gelber RP, Gaziano JM, Manson JE, Buring JE, Sesso HD. A prospective study of body mass index and the risk of developing hypertension in men. *Am J Hypertens.* 2007;20:370–377.
26. Li L, Law C, Power C. Body mass index throughout the life-course and blood pressure in mid-adult life: a birth cohort study. *J Hypertens.* 2007;25:1215–1223.
27. Fagard RH, Cornelissen VA. Effect of exercise on blood pressure control in hypertensive patients. *Eur J Cardiovasc Prev Rehabil.* 2007;14:12–17.
28. Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, Limacher M, Piña IL, Stein RA, Williams M, Bazzarre T. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription—an advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; position paper endorsed by the American College of Sports Medicine. *Circulation.* 2000;101:828–833.
29. Braith RW, Stewart KJ. Resistance exercise training: its role in the prevention of cardiovascular disease. *Circulation.* 2006;113:2642–2650.
30. Fisher MM. The effect of resistance exercise on recovery blood pressure in normotensive and borderline hypertensive women. *J Strength Cond Res.* 2001;15:210–216.
31. Parikh NI, Pencina MJ, Wang TJ, Benjamin EJ, Lanier KJ, Levy D, D'Agostino RB, Kannel WB, Vasan RS. A risk score for predicting near-term incidence of hypertension: the Framingham Heart Study. *Ann Intern Med.* 2008;148:102–110.
32. Niskanen L, Laaksonen DE, Nyyssönen K, Punnonen K, Valkonen VP, Fuentes R, Tuomainen TP, Salonen R, Salonen JT. Inflammation, abdominal obesity, and smoking as predictors of hypertension. *Hypertension.* 2004;44:859–865.
33. Bowman TS, Gaziano JM, Buring JE, Sessa H. A prospective study of cigarette smoking and risk of incident hypertension in women. *J Am Coll Cardiol.* 2007;50:2085–2092.
34. Grassi G, Seravalle G, Calhoun DA, Bolla GB, Giannattasio C, Marabini M, Del Bo A, Mancia G. Mechanisms responsible for sympathetic activation by cigarette smoking in humans. *Circulation.* 1994;90:248–253.
35. Mahmud A, Feely J. Effect of smoking on arterial stiffness and pulse pressure amplification. *Hypertension.* 2003;41:183–187.
36. Benetos A, Waeber B, Izzo J, Mitchell G, Resnick L, Asmar R, Safar M. Influence of age, risk factors, and cardiovascular and renal disease on arterial stiffness: clinical applications. *Am J Hypertens.* 2002;15:1101–1108.
37. Smith B, Leard CA, Smith TC, Reed RJ, Ryan MA. Anthrax vaccination in the Millennium Cohort: validation and measures of health. *Am J Prev Med.* 2007;32:347–353.
38. Smith TC, Smith B, Jacobson IG, Corbeil TE, Ryan MA. Reliability of standard health assessment instruments in a large, population-based cohort study. *Ann Epidemiol.* 2007;17:525–532.
39. Chretien JP, Chu LK, Smith TC, Smith B, Ryan MA. Demographic and occupational predictors of early response to a mailed invitation to enroll in a longitudinal health study. *BMC Med Res Methodol.* 2007;7:6.
40. Smith TC, Jacobson IG, Smith B, Hooper TI, Ryan MA. The occupational role of women in military service: validation of occupation and prevalence of exposures in the Millennium Cohort Study. *Int J Environ Health Res.* 2007;17:271–284.
41. Smith B, Wingard DL, Ryan MA, Macera CA, Patterson TL, Slymen DJ. U.S. military deployment during 2001–2006: comparison of subjective and objective data sources in a large prospective health study. *Ann Epidemiol.* 2007;17:976–982.
42. Smith B, Smith TC, Gray GC, Ryan MA. When epidemiology meets the Internet: Web-based surveys in the Millennium Cohort Study. *Am J Epidemiol.* 2007;166:1345–1354.
43. Wells TS, Jacobson IG, Smith TC, Spooner CN, Smith B, Reed RJ, Amoroso PJ, Ryan MA. Prior health care utilization as a potential determinant of enrollment in a 21-year prospective study, the Millennium Cohort Study. *Eur J Epidemiol.* 2008;23:79–87.

Newly Reported Hypertension After Military Combat Deployment in a Large Population-Based Study

Nisara S. Granado, Tyler C. Smith, G. Marie Swanson, Robin B. Harris, Eyal Shahar, Besa Smith, Edward J. Boyko, Timothy S. Wells and Margaret A.K. Ryan
for the Millennium Cohort Study Team

Hypertension. 2009;54:966-973; originally published online September 14, 2009;

doi: 10.1161/HYPERTENSIONAHA.109.132555

Hypertension is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Copyright © 2009 American Heart Association, Inc. All rights reserved.

Print ISSN: 0194-911X. Online ISSN: 1524-4563

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://hyper.ahajournals.org/content/54/5/966>

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Hypertension* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the [Permissions and Rights Question and Answer](#) document.

Reprints: Information about reprints can be found online at:
<http://www.lww.com/reprints>

Subscriptions: Information about subscribing to *Hypertension* is online at:
<http://hyper.ahajournals.org/subscriptions/>

REPORT DOCUMENTATION PAGE

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB Control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD MM YY) 11 07 08		2. REPORT TYPE Journal		3. DATES COVERED (from – to) Nov 2007 – Jul 2008	
4. TITLE AND SUBTITLE Newly Reported Hypertension after Military Cohort: Deployment in a Large Population-based Study				5a. Contract Number: 5b. Grant Number: 5c. Program Element Number: 5d. Project Number: 5e. Task Number: 5f. Work Unit Number: 60002	
6. AUTHORS Nisara S. Granado, Tyler C Smith, G. Marie Swanson, Robin B. Harris, Eyal Shahar, Besa Smith, Edward J. Boyko, Timothy S. Wells, & Margaret A.K. Ryan for the Millennium Cohort Study Team					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commanding Officer Naval Health Research Center 140 Sylvester Rd San Diego, CA 92106-3521					
8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) Commanding Officer Naval Medical Research Center 503 Robert Grant Ave Silver Spring, MD 20910-7500				9. PERFORMING ORGANIZATION REPORT NUMBER Report No. 08-23	
				10. SPONSOR/MONITOR'S ACRONYM(S) NMRC/BUMED	
				11. SPONSOR/MONITOR'S REPORT NUMBER(s)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES <u>Hypertension</u> , 2009, <u>54</u> , 966-973					
14. ABSTRACT					
Objective: We sought to determine the prevalence of hypertension and the reliability of self-report from a large, population-based cohort, compared with electronic medical diagnosis and record of prescriptions dispensed to active-duty US military personnel. Research Design: Self-reported hypertension from baseline Millennium Cohort data were used in addition to hypertensive outpatient and inpatient diagnoses, and antihypertensive medications dispensed from US Department of Defense pharmacy records to determine the prevalence of hypertension among US service members. Percent agreement and kappa statistics were calculated to evaluate overall agreement between self-report and other sources of hypertension assessment. Results: The prevalence of hypertension was 5.0% from provider diagnosis, 7.0% based on antihypertensive medication dispensed, 10.0% from self-report, and 13.3% using any of the 3 sources. There was moderate agreement between self-reported and electronically recorded diagnosed hypertension (kappa = 0.50; 95% confidence interval [CI], 0.49-0.52), and self-report and at least 1 antihypertensive medication dispensed in the pharmacy system (kappa = 0.49; 95% CI, 0.47-0.50). When self-report was compared with the combined provider diagnoses plus antihypertensive medication dispensed, there was moderate agreement (kappa = 0.48; 95% CI, 0.46-0.50). Conclusions: Information gained from electronic medical records can complement self-report when identifying hypertensive patients in the absence of blood pressure measurements. Moderate agreement was observed between self-report and diagnosis, antihypertensive medication dispensed, and combined diagnosis plus antihypertensive medication dispensed.					
15. SUBJECT TERMS hypertension, antihypertensive agents, military personnel, prevalence, reproducibility of results					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	18a. NAME OF RESPONSIBLE PERSON
a. REPORT UNCL	b. ABSTRACT UNCL	c. THIS PAGE UNCL	UNCL	9	Commanding Officer
					18b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: (619) 553-8429