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Increased blood pressures in veterans with post traumatic stress disorder: A case-control study

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Abstract

Objective: Veterans of war affected by posttraumatic stress disorder (PTSD) are at increased risk for cardiovascular diseases. We aimed to compare brachial and central blood pressures between veterans with PTSD and controls.

Method: In this case-control study on veterans of Iran–Iraq war, 50 veterans with PTSD and 50 veterans as controls were selected from an outpatient clinic and matched for age ±3 years. Exclusion criteria were malignancies, severe anatomical defects such as amputated extremities, history of PTSD before serving in war, comorbid psychiatric disorders other than anxiety or depressive disorders. Detailed history was taken concerning medical and social aspects. Beck Depression Inventory was used for depressive symptoms. Brachial blood pressures were measured using both auscultatory and oscillometric devices. Measures of central hemodynamics were estimated accordingly. Data on lipid profile were collected either through medical records or newly required lab tests.

Results: Brachial systolic, diastolic, and pulse pressures as well as estimated central systolic and diastolic pressures were significantly higher in the PTSD group. Beck Depression Inventory scores, frequency of diabetes mellitus, and hypertension were

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significantly higher in the PTSD group. PTSD status was an independent predictor of both brachial and central systolic and diastolic pressures.
Conclusions: We demonstrated increased measures of blood pressure in veterans with PTSD independent of depression and other risk factors. Further research is warranted to confirm our results.

Keywords
post traumatic stress disorder, depression, cardiovascular disease, blood pressure, veterans

Introduction

Mental health problems have been a major concern in the US military, especially in veterans,[1–4] with combined prevalence of 20%–30% for post traumatic stress disorder (PTSD) and depression.[3–5] PTSD develops due to exposure to an extreme stressor or a traumatic event and is characterized by re-experiencing of the event, avoidance of the reminders of the event, and hyper arousal, which affect a person's function both in personal life and social situations.[6,7] PTSD is also associated with substantial increased risk for other comorbid mental disorders especially depression in veterans.[8]

On the other hand, cardiovascular diseases are the leading cause of mortality in male veterans referring to healthcare settings, and higher cardiovascular risk factors such as obesity and hypertension are detected in these individuals compared with the general population.[9] There is a growing body of evidence on the association of PTSD with cardiovascular diseases and risk factors. Higher rates of ischemic heart disease and hypertension were reported in prisoners of World War II affected by PTSD.[10] Furthermore, PTSD was also associated with myocardial infarction and coronary heart disease (CHD) in male veterans.[11] Interestingly, a 13-year longitudinal cohort reported more than twice increased risk of CHD in veteran twins of Vietnam era who were discordant for the history of PTSD.[12] It is suggested that the increased rate of heart disease in patients with PTSD can in part be explained by the association of PTSD with cardiovascular risk factors particularly hypertension.[13] In line with this hypothesis, more severe atherosclerosis is reported in veterans with PTSD compared to veterans without PTSD.[14] Also, increased arterial stiffness is observed in people affected by PTSD as the result of deportation in childhood compared to the non-PTSD controls without the history of deportation.[15]

There are biological explanations for the higher rate of cardiovascular risk factors (e.g., blood pressures) in patients with PTSD which involve neuroendocrine, sympathetic, immunologic, and metabolic systems.[16,17] As a well-documented explanation, adrenergic axis is under longstanding stimulation in patients with PTSD. In line with this explanation, increased plasma levels of

noradrenaline and increased excretion of noradrenaline metabolites in 24 h urine of patients with PTSD has been detected in comparison to the non-patient individuals or patients with other psychiatric disorders.[18]

It is strongly suggested that further research on cardiovascular diseases in patients with PTSD account for the role of depression.[19] In fact, previous research showed increased prevalence of uncontrolled hypertension in patients with depression which has been attributed to decreased treatment compliance.[20] Also, it seems that the autonomic system and hypothalamus-pituitary-adrenal axis play the principal role in the increased risk of cardiovascular disorders among patients with depression.[21] In this regard, Kibler et al.[22] found significantly higher odds ratios for prevalence of hypertension in patients with comorbid PTSD depression and patients with only PTSD, compared to the patients with only depression and the control group; however, they considered history of hypertension rather than objective measures of blood pressure.

Overall, cardiometabolic diseases have not been emphasized proportionately to their high impact on the well-being of individuals affected by PTSD, including veterans,[16] while treating the cardiometabolic diseases can help regulating neuropsychologic function in patients with PTSD.[16] In this case-control study, we aimed to compare brachial and central measures of blood pressure between PTSD affected and non-PTSD veterans of Iran-Iraq war. We also compared potential hypertension risk factors (i.e., age, BMI, diabetes, smoking, ischemic heart disease, and depression) between these two groups and accounted for their confounding effects on the predicting power of PTSD status for blood pressure measures in the final analysis.

Method

Study design and population

In this case-control study, 100 male veterans of Iran-Iraq war, including 50 individuals with PTSD and 50 individuals as controls, were selected through convenience sampling from both active and retired members of military services referring to outpatient psychiatry clinic of Besat Medical Center, Aja University of Medical Sciences, Tehran, Iran, 2014–2015. Cases and controls were matched based on age ± 3 years. Exclusion criteria were malignancies, severe anatomical defects such as amputated extremities, history of PTSD before serving in Iran-Iraq war, and concurrent psychiatric disorders other than anxiety or depressive disorders. It was also required that all participants have a minimum deployment duration of three months. They could be under treatment with routine psychiatric and anti-hypertensive medications at the time of participation in study. Participants were selected based on the diagnostic interview according to DSM-IV-TR criteria[23] by one of the authors as a military psychiatrist experienced in PTSD diagnosis in veteran patients for more than 10 years.

Measures

A detailed history was taken from each participant including social and medical aspects as well as war-related injuries and hospitalizations. Exposure to chemical warfare during the war was confirmed according to both participants' claims and medical records. History of chronic diseases including hypertension, CHD, cerebral vascular disease, and diabetes was taken according to the participants' claims, medical records, and current medical treatments, if applicable.

Beck Depression Inventory II was filled by the participants after offering related explanations by a trained and experienced author. The author was responsive to participants' potential questions when filling the form.

Brachial systolic and diastolic office blood pressures were measured by one of the authors as a trained and experienced physician, using each of auscultatory (mercury sphygmomanometer) (Riester diplomat-premaster, Jungingen, Germany) and oscillometric (Omron M3 intellisense, Omron Healthcare, Kyoto, Japan) validated devices according to the recommendations of American Heart Association Council on High Blood Pressure Research for blood pressure measurement in humans.[24] In brief, the blood pressures were measured twice using each device with a 2- to 3-min interval, after the initial 5 min rest, in sitting position. Brachial systolic and diastolic pressures were defined as the average of the two measurements done through each of the auscultatory and oscillometric methods. Brachial mean arterial and pulse pressures were calculated accordingly. Central systolic and diastolic pressures were estimated based on the brachial measures and the difference between auscultatory and oscillometric measurements for individual patients.[25] The estimation was evaluated by several multivariate techniques, including artificial neural network and Bayesian methods, of which linear regression analysis had been the most accurate result ($R^2 = 91.1\%$) using the following formula:

$$1\_Central\ Systolic\ Pressure = (0.8461 * Oscillatory\ Systolic\ Pressure) - (0.2054 * Age) + 0.8461$$

$$2\_Central\ Diastolic\ Pressure = (0.9889 * Oscillatory\ Diastolic\ Pressure) - (0.0074 * Age) + 2.4586$$

Values for lipid profile were obtained according to the previously available lab results if done within the three months before the visit, or newly requested lab tests at the time of visit for this study.

Ethics

The project was approved by the local institutional review board considering The Code of Ethics of the World Medical Association (Declaration of Helsinki,

Edinburgh 2000 revision). Written informed consent was obtained from all the participants.

Statistical analysis

PASW 18.0 software (IBM SPSS Statistics, IBM Co., New York, United States) was used for all statistical analysis. Mann–Whitney U test and either of Chi-square test or Fisher's exact test were used to compare distribution of respective continuous or categorical data between PTSD and control groups. In regression analysis, measures of blood pressure were dependent variables, and PTSD status and BDI score were considered as predictors beside other HTN risk factors. Because the number of measured HTN risk factors was high relative to our sample size and could cause over-fitting effect, first we assessed correlation of measures of blood pressure with each hypertension risk factor using Spearman correlation, and then selected the risk factors with statistical significance for multivariate linear regression analysis. In all analysis, coefficients of variations as well as count (%) or median (range) of the variables were reported where appropriate. Two-tailed p-values were reported.

Results

Baseline characteristics of participants

Concerning demographic characteristics of study population based on PTSD status (Table 1), median age was 49.00 and 52.00 for PTSD and control groups, respectively, with no significant difference. Frequencies of smoking and exposure to chemical warfare were significantly higher in the PTSD group.

Concerning frequencies of chronic diseases (Table 1), diabetes mellitus, and hypertension were significantly higher in the PTSD group. The difference for CHD and cerebral vascular disease was not significant.

Concerning brachial and estimated central blood pressures (Table 1), the brachial systolic, diastolic, mean arterial and pulse pressures, as well as central systolic and diastolic pressures were significantly higher in the PTSD group.

Concerning lipid profile (Table 1), no significant difference was found for any of the markers including total cholesterol, LDL cholesterol, HDL cholesterol, and triglyceride in the PTSD group compared to the control group.

BDI scores were significantly higher in the PTSD group compared with the control group (Table 1).

Regression models for prediction of blood pressures

Table 2 represents the results of linear regression analysis for measures of blood pressure as dependent variables, including brachial systolic, diastolic, and pulse

Table 1. Characteristics of veterans according to PTSD status.

	PTSD (n = 50)	Control (n = 50)	p-value
Age (years)	49.00 (41.00–73.00)	52.00 (40.00–70.00)	0.201
BMI (kg/m^2)	27.17 (22.84–35.42)	26.39 (17.30–33.62)	0.078
Smoking	26 (52.0%)	16 (32.0%)	0.043
Exposure to chemical warfare	23 (46.0%)	7 (14.0%)	<0.001
History of Chronic Diseases			
Hypertension	11 (22.0%)	3 (6.0%)	0.041
Coronary Heart Disease	7 (14.0%)	3 (6.0%)	0.318
Cerebral Vascular Disease	1 (2.0%)	2 (4.0%)	1.000
Diabetes	15 (30.0%)	3 (6.0%)	0.003
Office Blood Pressures and Estimated Measures (mmHg)			
Aus. Systolic OBP	120.00 (97.50–188.50)	105.00 (87.50–140.00)	<0.001
Aus. Diastolic OBP	80.00 (65.00–132.50)	71.75 (55.00–100.00)	<0.001
Osc. Systolic OBP	125.00 (104.00–178.50)	113.25 (83.00–152.00)	<0.001
Osc. Diastolic OBP	88.50 (59.00–116.00)	76.25 (51.50–102.00)	<0.001
Aus. Mean Arterial Pressure	93.67 (78.33–151.17)	83.08 (66.67–110.83)	<0.001
Osc. Mean Arterial Pressure	100.92 (76.00–135.50)	86.58 (66.67–117.17)	<0.001
Aus. Pulse Pressure	40.00 (27.50–65.00)	35.00 (20.00–47.50)	<0.001
Osc. Pulse Pressure	44.00 (27.50–70.00)	37.25 (22.00–66.50)	<0.001
Central Systolic Pressure	117.11 (98.49–162.35)	107.26 (83.19–142.18)	<0.001
Central Diastolic Pressure	89.61 (60.34–116.85)	77.48 (52.95–102.93)	<0.001
Lipid Profile (mg/dL)			
Total cholesterol	240.00 (108.00–492.00)	239.50 (135.00–390.00)	0.926
LDL cholesterol	178.00 (80.00–360.00)	160.00 (68.00–358.00)	0.496
HDL cholesterol	135.00 (35.00–383.00)	103.50 (40.00–290.00)	0.826
Triglyceride	133.00 (49.00–341.00)	120.00 (45.00–455.00)	0.242
Depressive Symptoms			
BDI-II score	27.00 (4.00–59.00)	5.00 (0.00–34.00)	<0.001

PTSD: post traumatic stress disorder; BDI: Beck Depression Inventory; OBP: Office Blood Pressure; Aus.: Auscultatory; Osc.: Oscillatory. Data represented as count (percent) or median (range). Chi-square test, Fisher's exact test, or Mann–Whitney U test were used where appropriate.

Table 2. Multivariate linear regression models for blood pressure measures.

	Adjusted R square	PTSD status	BDI score	Hypertension	CHD	Diabetes	BMI	Age	Triglyceride
Aus. Systolic OBP	0.554	11.116 (0.002)	−0.203 (0.096)	23.573 (<0.001)	14.384 (0.003)	2.994 (0.460)	0.757 (0.143)	−0.115 (0.533)	0.021 (0.238)
Osc. Systolic OBP	0.530	13.522 (0.001)	−0.108 (0.430)	23.790 (<0.001)	16.319 (0.003)	6.085 (0.184)	0.130 (0.823)	−0.189 (0.363)	−0.003 (0.874)
Aus. Diastolic OBP	0.473	9.261 (0.001)	−0.252 (0.013)	18.186 (<0.001)	9.052 (0.023)	−2.636 (0.428)	1.064 (0.013)	−0.299 (0.050)	0.015 (0.301)
Osc. Diastolic OBP	0.386	12.798 (<0.001)	−0.241 (0.040)	14.223 (0.001)	6.341 (0.166)	−0.061 (0.987)	0.529 (0.282)	−0.255 (0.149)	0.029 (0.090)
Aus. Pulse Pressure	0.131	3.070 (0.114)	−0.098 (0.150)	−0.676 (0.782)	−2.205 (0.411)	0.421 (0.853)	0.108 (0.709)	−0.121 (0.242)	0.037 (<0.001)
Osc. Pulse Pressure	0.653	1.939 (0.001)	−0.014 (0.485)	3.503 (<0.001)	2.441 (0.002)	0.937 (0.162)	0.014 (0.868)	−0.239 (<0.001)	−0.001 (0.782)
Central Systolic Pressure	0.529	11.441 (0.001)	−0.091 (0.430)	20.129 (<0.001)	13.807 (0.003)	5.148 (0.184)	0.110 (0.823)	0.045 (0.796)	−0.003 (0.874)
Central Diastolic Pressure	0.387	12.656 (<0.001)	−0.238 (0.040)	14.065 (0.001)	6.270 (0.166)	−0.061 (0.987)	0.524 (0.282)	−0.260 (0.137)	0.029 (0.090)

PTSD: post traumatic stress disorder; BDI: Beck Depression Inventory; CHD: coronary heart disease; Aus.: Auscultatory; Osc.: Oscillatory. B coefficient (p-value) is reported for independent variables.

pressures as well as central systolic and diastolic pressures. PTSD status was an independent significant predictor for all the measures except brachial pulse pressures. BDI score did not reach significance as a covariate in any of the models.

Discussion

Our main finding was that brachial systolic, diastolic, mean arterial, and pulse pressures measured through both auscultatory and oscillometric methods were higher in the PTSD group compared to the control group. We also found higher central systolic and diastolic pressures in the PTSD group compared to the control group.

Our findings are in line with some of the previous research on heart disease risk factors in patients with PTSD.[13,15,26] A meta-analysis of 34 studies showed higher blood pressures in patients with PTSD in comparison with control individuals.[26] In a review, Coughlin[13] concluded that the evidence favored increased blood pressures in patients with PTSD compared with the non-PTSD individuals. A recent study on refugees with PTSD reported significantly higher systolic, diastolic, and pulse pressures as well as higher arterial stiffness in these individuals compared to the non-refugee controls;[15] however, in this study, the controls were selected from non-refugees which could predispose the results to bias as

refugees had been subjected to different health conditions from the general population. The fact that we selected all the participants from veterans is a strength in our study. Inconsistent with our findings, two observational studies showed no significant difference for blood pressures between the PTSD and control participants.[14,27]

It is suggested that measures of central hemodynamics, including central systolic and pulse pressures are more accurate predictors of heart diseases compared to brachial measures.[28,29] In specific, central systolic pressure has been emphasized as a predictor of cardiovascular diseases.[30] In comparison to previous studies, one of the strengths of our study is that we have estimated the central blood pressures in addition to brachial blood pressures in veterans.

The average 5- to 15-mmHg-difference we observed in blood pressures between the two groups is clinically relevant considering that a meta-analysis of 61 studies with a total sample of 1 million participants emphasized that the rate of mortality from IHD and cerebrovascular accidents doubles for each 20 mmHg increase in brachial systolic blood pressure or each 10 mmHg increase in brachial diastolic blood pressure in middle age or older adults.[31] Also, it is estimated that after adjustments for age and other risk factors, relative risk of cardiovascular events increases for about 10% with each 10 mmHg increase in central systolic pressure, and increases for about 15% with each 10 mmHg increase in central pulse pressure.[32]

Concerning the methodology of this study, we used BDI to account for the role of depression in predicting blood pressures. Beside the well-established relationship between clinical depression and cardiovascular diseases, several studies have indicated the importance of depressive symptoms.[33–36] As an example, in patients with myocardial infarction, both depressive symptoms and clinical depression were associated with increased morbidity and mortality.[36] Interestingly in that study, while the association between clinical depression and cardiac morbidity/mortality could be statistically explained by increased depressive symptoms, the association between depressive symptoms and cardiac morbidity/mortality could not be explained by clinical depression.[36]

As another finding of our study, PTSD status was an independent predictor of all blood pressure measures except the auscultatory pulse pressure. It is noteworthy that according to a longitudinal study of 25-year follow-up for cardiovascular and all-cause mortalities on several thousand participants, systolic and diastolic blood pressure measurements have been associated more strongly with mortality outcomes compared with pulse pressures.[37] We did not found BDI score as an independent predictor in any of the models; however, we do not know whether there was an interaction between PTSD and depression in predicting blood pressures. It remains to be scrutinized in future studies through comprehensive hierarchical interaction analyses.

This study was subject to some limitations. First, it was designed as case control not longitudinal cohort. Therefore, potentially there might be veterans

with more severe cardiovascular diseases who were not alive at the time of study and consequently could not participate. Second, this study had a relatively small sample size. Third, we did not account for the antidepressant or anti-hypertensive medications in participants which could relatively mask the measurements. Fourth, we used linear regression models for estimation of central blood pressures; however, the estimation method we applied was the most accurate model with more than 90% accuracy. Fifth, we did not account for the potential interaction between PTSD and depression in predicting measures of blood pressure. Further comprehensive studies are warranted to statistically scrutinize any potential interaction between PTSD and depression through hierarchical models.

In conclusion, veterans with PTSD are potentially predisposed to increased blood pressures independent of accompanied depression and other cardiovascular risk factors. Further comprehensive research is needed to confirm our findings.

Author Contributions

EM contributed to the design, collected the data, carried out statistical analyses, drafted the manuscript, and revised the manuscript for important intellectual content. AK designed the study, contributed to statistical analyses, and revised the manuscript for important intellectual content. FA contributed to the design, contributed to data collection, and revised the manuscript for important intellectual content. AR contributed to the design, contributed to data collection, and revised the manuscript for important intellectual content.

Declaration of Conflicting Interests

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