

Association Between Posttraumatic Stress Disorder and Lack of Exercise, Poor Diet, Obesity, and Co-Occurring Smoking: A Systematic Review and Meta-Analysis

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Objectives: Research has shown that posttraumatic stress disorder (PTSD) increases the risk of development of cardiometabolic disease (CMD) including cardiovascular disease and diabetes. Whether PTSD is also associated with behavioral risk factors (e.g., diet, exercise, smoking and obesity) for CMD, is less clear. **Methods:** PubMed, Web of Science, and Scopus databases were searched to obtain papers published between 1980–2016. Studies were reviewed for quality using the Quality of Cohort screen. Significance values, odds ratios (OR), 95% confidence intervals (CI), and tests of homogeneity of variance were calculated. **Principal Findings:** A total of 1,349 studies were identified from our search and 29 studies met all eligibility criteria. Individuals with PTSD were 5% less likely to have healthy diets (pooled adjusted OR = 0.95; 95% CI: 0.92, 0.98), 9% less likely to engage in physical activity (pooled adjusted OR = 0.91; 95% CI: 0.88, 0.93), 31% more likely to be obese (pooled adjusted OR = 1.31; 95% CI: 1.25, 1.38), and about 22% more likely to be current smokers (pooled adjusted OR = 1.22; 95% CI: 1.19, 1.26), than individuals without PTSD. **Conclusions:** Evidence shows PTSD is associated with reduced healthy eating and physical activity, and increased obesity and smoking. The well-established association between PTSD and metabolic and cardiovascular disease may be partly due to poor diet, sedentary lifestyle, high prevalence of obesity, and co-occurring smoking in this population. The well-established association of PTSD with CMD is likely due in part to poor health behaviors in this patient population.

Keywords: PTSD, diet, exercise, smoking, cardiometabolic disease

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Patients with posttraumatic stress disorder (PTSD) are known to have a greater risk of cardiovascular and metabolic disease, compared to persons without PTSD (Coughlin, 2013). The mecha-

nisms responsible for the increased risk of cardiometabolic disease (CMD) in PTSD are complex and multifactorial and include hypothalamic-pituitary-adrenal (HPA) axis dysregulation, increased inflammation, autonomic nervous system dysfunction (Cohen, Marmar, Ren, Bertenthal, & Seal, 2009; Scherrer et al., 2007; Schnurr, in press), comorbid psychiatric disorders such as depression and alcohol abuse/dependence (Pietrzak, Goldstein, Southwick, & Grant, 2011; Whooley et al., 2008), and poor health behaviors such as increased caloric intake, sedentary lifestyle, and smoking (Pietrzak et al., 2011; Zen, Whooley, Zhao, & Cohen, 2012). Relative to the large literature on HPA axis dysregulation and psychiatric comorbidity, there is less research on PTSD and poor health behaviors. A better understanding of the strength of the prevalence of these poor health behaviors in PTSD and their contribution to the risk of CMD development is important as these behaviors are modifiable and improvement may prevent development or slow progression of CMD in persons with PTSD.

Several systematic reviews and meta-analysis of PTSD and comorbid psychiatric and substance use disorders exist (Atwoli, Stein, Koenen, & McLaughlin, 2015), as well as similar studies of PTSD and cardiovascular and metabolic disease. However, we are not aware of systematic reviews and meta-analysis of the associ-

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ation between PTSD and poor health behaviors that are typically associated with diabetes and cardiovascular disease (CVD). To fill this gap in the literature, we conducted a systematic review and meta-analysis of the literature on the association between PTSD and diet, exercise, obesity, and co-occurring smoking.

Methods

We conducted a systematic literature review to identify publications reporting on the association between PTSD and health behaviors. Health behaviors included diet, exercise, obesity, and smoking.

We first searched for existing reviews of PTSD and metabolic or CVD. We then searched for literature published between 1980 and 2016 in four databases (PubMed, Web of Science, PsycInfo, and Scopus). We used the following search terms: “posttraumatic stress disorder,” “acute reaction to stress,” “combat,” and “domestic violence.” We also filtered for “health behavior,” “self-care,” “physical fitness,” “exercise,” “nutrition,” “fitness,” “diet,” “obesity,” “body mass index (BMI),” “social determinants of health,” “abnormal EKG,” “cardiovascular,” and “chronic disease.” For inclusion, studies needed to be from peer-reviewed publications, include adult populations (18 or older), published between 1980 and 2016, involve human subjects (no animals), and be published in an English-language journal. Citations of review articles uncovered through the database search were also included in this review.

Five of the authors reviewed titles and abstracts to confirm eligibility criteria. Articles were excluded if they were guidelines, theoretical or review papers or did not include measures of PTSD and one of the health behaviors (i.e., diet, exercise, obesity and smoking). Articles that met eligibility criteria were then subjected to a full-text screening by four of the investigators (Carissa van den Berk-Clark, Jesse Walls, Scott Secrest, and Jeffrey F. Scherrer). At the full-text screening, four investigators independently reviewed the full text of each article for inclusion and a subset of full text reviews were examined again by another reader to ensure consistency in rating content and quality. At this stage, we excluded papers that focused exclusively on PTSD and smoking due to several existing systematic reviews of this topic. Smoking was included in this analysis if it was included as a covariate in papers that reported on diet, exercise, and obesity. We used the Quality of Cohort studies (Q-Col) screen of methodology quality to identify studies that could bias the meta-analysis (Jarde, Losilla, Vives, & Rodrigo, 2013). The Q-Col screen was specifically developed for observation studies and, unlike many other instruments, uses more rigorous procedures to assess methodological quality, including use of standard psychometric techniques. The Q-Col has also shown to have moderate to good agreement among multiple raters. Q-Col scores range from 0 to 33. Examining the distribution of Q-Col scores and the quality of papers with low scores indicated a logical threshold for inclusion was a Q-Col >20.

Odds ratios (ORs) and 95% confidence intervals (CI) were computed to estimate the association between PTSD and each health behavior. We constructed a forest plot to show the range of different ORs for each of the health behaviors in order by size of sample. We used recommendations of Chang and Hoaglin (2017) to determine heterogeneity using log ratios through Stata user-written code “METAN,” which determined pooled ORs and heterogeneity (i^2) using ORs combined with upper and lower 95% CI

(Harris et al., 2010) from calculations provided in the Cochrane Collaboration handbook. Publication sampling bias was measured using Rosenthal's (1979) “File Drawer” method, which calculates what number of hypothetical studies are needed to null results of published studies. The formula is as follows:

$$N_{fs} = (N_0/Z^2)(N_0\bar{Z}^2 - Z^2),$$

where N_0 is the number of studies, Z_c is the critical value of z , and $\bar{Z}$ is the mean Z obtained for N_0 studies.

Results

We identified 1,349 citations from all sources. As shown in Figure 1, after removing duplicates and articles that were clearly irrelevant ($n = 1,145$), we reviewed the full text of 204 articles. Of these, 175 were excluded at the full text screening stage, leaving a total of 29 articles. The majority of studies tested the relationship between PTSD and BMI or weight gain (22 studies; Boscarino, 2008; Boscarino & Chang, 1999; Chwastiak, Rosenheck, & Kazis, 2011; Cohen et al., 2009; Coughlin, 2011; Dedert et al., 2010; Farr et al., 2015; Godfrey, Lindamer, Mostoufi, & Afari, 2013; Goldberg et al., 2014; Hirth et al., 2011; Jin et al., 2009; Kozaric-Kovacic et al., 2009; Kubzansky et al., 2014; Leardmann et al., 2015; Littman et al., 2013; Maia et al., 2008; Mitchell et al., 2013; Pagoto et al., 2012; Smith, Tyzik, Neylan, & Cohen, 2015; Spitzer et al., 2009; Sumner et al., 2015; Talbot, Neylan, Metzler, & Cohen, 2014). The associations between PTSD and smoking were available in 13 studies (Boscarino, 2008; Boscarino & Chang, 1999; Chwastiak et al., 2011; Cohen et al., 2009; Farr et al., 2015; Goldberg et al., 2014; Kozaric-Kovacic et al., 2009; Kubzansky et al., 2014; Leardmann et al., 2015; Roberts et al., 2015; Spitzer et al., 2009; Sumner et al., 2015; Talbot et al., 2014; Zen et al., 2012), and associations with physical exercise in 13 studies (Chwastiak et al., 2011; de Assis et al., 2008; Farr et al., 2015; Godfrey et al., 2013; Goldberg et al., 2014; Kozaric-Kovacic et al., 2009; Leardmann et al., 2015; Maguen et al., 2016; Roberts et al., 2015; Sumner et al., 2015; Talbot et al., 2014; Van Zelst, De Beurs, Beekman, Van Dyck, & Deeg, 2006; Zen et al., 2012) and diet in four studies (Godfrey et al., 2013; Hirth et al., 2011; Roberts et al., 2015; Sumner et al., 2015; see Table 1). As shown in Table 1, 10 studies used a longitudinal design and 18 studies had a sample size of 1,000 or more. Fifteen studies had a quality score over 27 (meaning we determined that the study satisfied most of the Q-Col screening measures), which had a mean sample size of 64,058 (see Supplemental Table S2 in the online supplementary material for more information about study quality).

A total of 18 studies used survey data, 12 studies used either medical record or administrative data, and two studies used secondary data from a clinical trial. The earliest studies used data from the late 1980s and the most recent used data from 2013. A total of 1,666,555 participants were included in these studies. Participants were mostly from community samples (nine studies) and veteran samples (10 studies). There were also four studies (Dedert et al., 2010; Hirth et al., 2011; Spitzer et al., 2009; Zen et al., 2012) that used a primary care/health center sample, two studies (de Assis, et al., 2008; Jin et al., 2009) that used clinical (inpatient psychiatric) samples, and five studies (Boscarino, 2008; Boscarino & Chang, 1999; Leardmann et al., 2015; Littman et al., 2013; Maia et al., 2008) that used military service members or

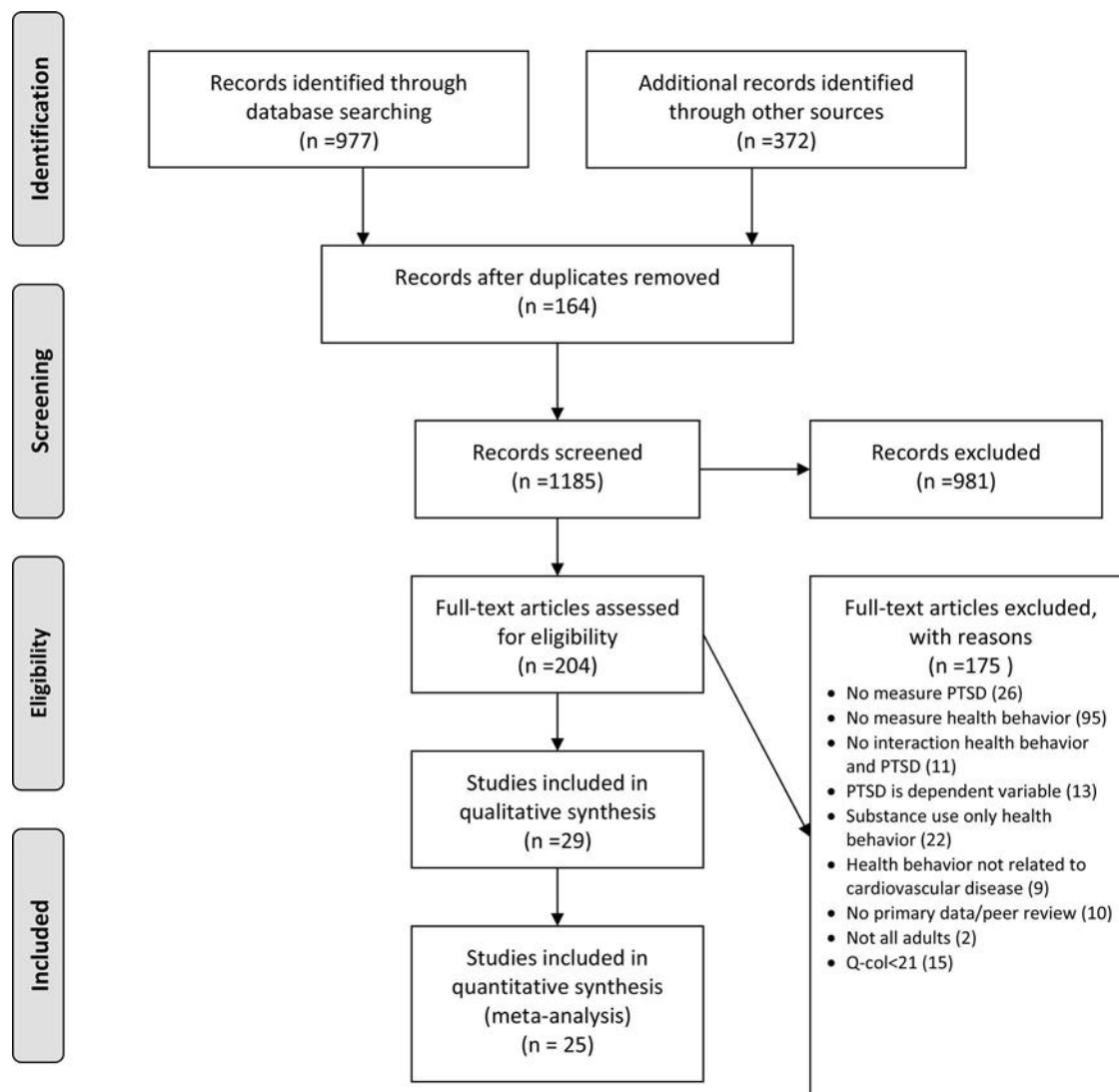


Figure 1. PRISMA Flow Diagram.

police officers. Mean age of participants in all studies was 44.43 (range 21 to 72) and about 82% of pooled participants were male. Of the 28 studies with racial information, 84% of the pooled sample was White. Twelve percent of participants were diagnosed with PTSD in the 23 pooled studies reporting the prevalence of PTSD diagnosis and 29% were obese in eight pooled studies reporting overall rates of obesity.

Heterogeneity across studies was high, with i^2 of 91.3% BMI, 97.1% physical activity, 96.0% for diet, and 99.5% for smoking. However, it was lower within specific populations (see Supplemental Table S3 in the online supplemental material). For example, when it came to physical activity, heterogeneity was lower when comparing studies of general population/community samples ($i^2 = 12.8\%$) and individuals at certain age groups (60s and over $i^2 = 65.0\%$). Studies measuring likelihood of obesity showed lower homogeneity among military populations and police ($i^2 = 0.0\%$), individuals at certain age groups (40s/50s $i^2 = 42.5\%$, 60s and over $i^2 = 0.0\%$) and samples that were mostly female ($i^2 = 0.0\%$). There was lower heterogeneity

in studies of smokers in the general population/community ($i^2 = 75.9\%$), primary care/hospital ($i^2 = 1.8\%$), individuals over the age of 60 ($i^2 = 60.0\%$) and samples that were mostly female ($i^2 = 68.8\%$). Higher effect sizes were observed in studies with small sample sizes (see Tables 2–5), which may show an effect of missing studies. Nevertheless, fail safe N s were 4.1, 39.0, 155.7, and 172.1 for unadjusted diet, physical activity, obesity, and smoking, respectively. For adjusted, fail safe N s were substantially low as adjusted exercise had only four studies (fail safe, $N = 5.2$) and adjusted obesity had only five studies (fail safe, $N = 33.6$).

Diet and Exercise

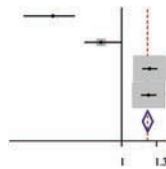
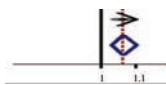
A total of 14 studies assessed the association between PTSD and diet or exercise (see Table 2). Diet was measured according to self-reports using the alternative healthy eating index in two studies, by the total self-reported consumption of fruits, vegetables, soda, caffeinated beverages per day in the third study, and by

Table 1
Study Characteristics

Study	Sample Size	Sample	Dates	Average age	% Male	Outcomes
Boscarino & Chang, 1999	4,462	Vietnam era service members	1985–2000	37.9	100	BMI, cigarette pack years, drinks per month
Boscarino, 2008	18,581	Vietnam era service members	1985–2000	37.9	100	BMI, cigarette pack years
Chwastiak et al., 2010	559,985	VA enrollees	1999, 2008	64.1	95.9	all-cause mortality
Chwastiak et al., 2011	501,161	VA enrollees	1999	64.1	95.9	Physical activity, BMI, smoking, alone and in combination
Cohen et al., 2009	267,731	OEF/OIF VA enrollees	2008	31.0	88.0	BMI, smoking
Coughlin, 2011	9,970	Gulf VA enrollees	2003–2005	47.6	78.0	BMI
De Assis et al., 2008	50	Psychiatric Patients with PTSD	2008	40.1	32.0	Physical activity
Dedert et al., 2010	148	Community hospitals via flyer	2001–2005	39.9	.0	BMI
Farr et al., 2015	158	Greater Boston area via flyer	2013	45.7	47.5	Physical activity, BMI, smoking, alcohol use
Godfrey et al., 2013	80	San Diego area via flyer	2012	40.0	55.0	Physical activity, unhealthy eating, BMI
Goldberg et al., 2014	5,574	Vietnam era VA enrollees	2010–2012	61.0	100.0	Physical activity, BMI, smoking
Hirth et al., 2011	3,181	Safety net health center	2010	20.8	.0	BMI, diet
Jin et al., 2009	203	Psychiatric patients	2008	65.9	67.0	BMI
Kozaric-Kovacic et al., 2009	2,031	Croatian war veterans with psychiatric diagnosis	2005–2008	41.4	100.0	Physical activity, BMI
Kubzansky et al., 2009	50,504	U.S. nurses	1989–2005	34.0	.0	BMI, smoking status
Leardmann et al., 2015	38,883	OIF/OEF service members	2001–2006	40.0	77.0	BMI, physical activity, smoking status
Littman et al., 2013	38,686	OIF/OEF service members	2001–2006	37.9	75.0	Weight gain
Maguen et al., 2016	24,899	VA enrollees	2008–2013	38.0	79.0	Involvement in exercise program
Maia et al., 2008	118	Police officers	2004	33.0	100.0	BMI, smoking
Mitchell et al., 2013	463	African Americans in Detroit	2008	56.7	37.0	BMI
Pagoto et al., 2012	20,013	U.S. General population	2001–2003	44.9	47.0	BMI
Roberts et al., 2015	49,739	U.S. nurses	1989–2005	34.0	.0	Physical activity, healthy eating, smoking
Scott et al., 2008	12,992	New Zealand general population	2003–2004	44.0	48.0	BMI
Smith et al., 2015	735	VA enrollees	2008–2010	24.0	42.0	BMI
Spitzer et al., 2009	3,171	German medical centers (2)	1997–2001	47.0	49.0	BMI, smoking, heart failure
Sumner et al., 2015	49,978	U.S. nurses	1989–2005	34.0	.0	Physical activity, healthy eating, BMI, smoking, CVD risk
Talbot et al., 2014	736	VA enrollees	2008–2010	58.0	94.0	Physical activity, BMI, smoking
Van Zelst et al., 2006	1,721	Community based elderly	1998–1999	72.4	43.1	Physical activity
Zen et al., 2012	1,022	Patients with CVD	2000–2002	63.0	82.0	Physical activity, smoking

Note. VA = Veterans Affairs; BMI = body mass index; OEF/OIF = Operation Enduring Freedom/Operation Iraqi Freedom; CVD = cardiovascular disease.

Table 2
The Effect of PTSD on Diet

Study	Sample size	ES (95% CI)	Odds ratio (95% CI)	% Weight
Unadjusted studies				
Godfrey et al., 2013	80		.33 (.05, .54)	.08
Hirth et al., 2011	3,181		.80 (.64, .99)	3.09
Roberts et al., 2015	49,739		1.27 (1.20, 1.34)	48.30
Sumner et al., 2015	49,978		1.26 (1.19, 1.33)	48.53
Pooled	102,978		1.25 (1.20, 1.30)	100.00
Adjusted studies				
Hirth et al., 2011	3,181		.95 (.92, .98)	100.00
Pooled	3,181		.95 (.92, .98)	100.00

Note. ES = effect size; CI = confidence interval.

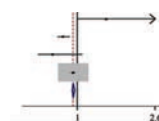
self-reported consumption of fast food in the fourth study (see Supplemental Table S4 in the online supplemental material). Physical exercise was self-reported except for one study by Maguen et al. (2016) which used Veterans Affairs (VA) medical records. Physical activity either was tracked by the amount of physical activity in a week (nine studies) or month (one study), or by presence of physical activity more generally (two studies).

The association between PTSD and healthy diet was examined in four studies (Godfrey et al., 2013; Hirth et al., 2011; Roberts et al., 2015; Sumner et al., 2015). All four studies showed significant differences between PTSD and non-PTSD groups in unadjusted models (pooled unadjusted OR = 1.25; 95% CI: 1.20, 1.30; see

Table 2). A study by Hirth et al. (2011), which adjusted for demographics and BMI, however, showed that individuals with PTSD were less likely to avoid consumption of fast food (past week; OR = 0.95; 95% CI: 0.92, 0.98).

Of these 12 studies examining physical activity, six reported no significant association between PTSD and physical activity (See Table 3). Among studies reporting a significant association, one longitudinal study by Talbot et al. (2014) revealed a significant reduction in physical activity 1 year after a PTSD diagnosis ($\beta = -.113$, $p < .05$), compared to patients with no PTSD diagnosis. Three of the 12 studies adjusted for confounders such as age, gender, chronic disease, mental health factors, and marital

Table 3
The Effect of PTSD on Physical Activity

Study	Sample size	ES (95% CI)	Odds ratio (95% CI)	% Weight
Unadjusted studies				
de Asis et al., 2008	50		.26 (.11, .62)	.01
Godfrey et al., 2013	80		1.56 (.09, 25.92)	.01
Farr et al., 2015	153		.97 (.43, 2.24)	.02
Talbot et al., 2014	736		.50 (.48, .52)	.11
Zen et al., 2012	1,022		1.50 (.98, 2.29)	.16
Van Zelst et al., 2006	1,721		.30 (.10, 1.40)	.26
Kozaric-Kovacic et al., 2009	2,031		.41 (.28, .59)	.31
Goldberg et al., 2014	5,574		.55 (.42, .72)	.86
Leardmann et al., 2015	38,883		.97 (.89, 1.05)	5.97
Roberts et al., 2015	49,739		1.01 (.93, 1.10)	7.64
Sumner et al., 2015	49,978		1.01 (.93, 1.10)	7.68
Chwastiak et al., 2011	501,161		.61 (.59, .62)	76.97
Pooled	651,078		.69 (.68, .71)	100.00
Adjusted studies				
Zen et al., 2012	1,022		1.60 (1.00, 2.60)	.19
Van Zelst et al., 2006	1,721		.50 (.20, 1.10)	.32
Leardmann et al., 2015	38,883		.71 (.60, .84)	7.16
Chwastiak et al., 2011	501,161		.92 (.89, .94)	92.33
Pooled	542,787			.91 (.88, .93)

Note. ES = effect size; CI = confidence interval. Dependent variable of all adjusted studies is physical activity. Odds ratio is related to positive outcomes, which include higher physical activity and a healthy diet.

status. Chwastiak et al. (2011) reported PTSD was associated with lower odds of physical activity in unadjusted models (OR = 0.62; 95% CI: 0.59, 0.61). This association remained significant (OR = 0.94; 95% CI: 0.89, 0.92) after adjusting for age, gender, education, race, service connection, medical comorbidity, alcohol and drug abuse or dependence, schizophrenia, bipolar, and manic depression. Leardmann et al. (2015) showed similar results with a sample of veterans' (adjusted OR = 0.71; 95% CI: 0.60, 0.84). Maguen et al. (2016; not in Table 3) measured use of the Veterans Health Administration weight loss program called "Move!" among patients with PTSD and found lower odds of Move! use by veterans (average age 38) with PTSD versus those without in unadjusted (predicted probability = 4.20; 95% CI: 3.8, 4.5) and adjusted models (predicted probability = 3.5; 95% CI: 3.2, 3.9).

When diet and physical activity were examined within different populations (see Supplemental Table S5 in the online supplemental material), we found that populations who were in their 40s and 50s were least likely to engage in healthy eating (OR = 0.33; 95% CI: 0.09–0.58; Godfrey et al., 2013), whereas female populations in their 20s and 30s were more likely to engage in healthy eating (pooled OR = 1.25; 95% CI: 1.20, 1.30; Hirth et al., 2011; Roberts et al., 2015; Sumner et al., 2015), and clinical populations (inpatient psychiatric populations) with PTSD were least likely to engage in physical activity (OR = 0.26; 95% CI: 0.01–0.52; de Assis et al., 2008).

BMI and Obesity

A total of 21 studies assessed whether PTSD was associated with obesity (Table 4) and five additional studies assessed differences in BMI (these were not included in the table; Farr et al., 2015; Kubzansky et al., 2014; Maia et al., 2008; Spitzer et al., 2009; Sumner et al., 2015). ORs ranged from 0.83 to 3.70 in unadjusted studies (pooled OR = 1.58; 95% CI: 1.49, 1.67). When PTSD was adjusted for demographics (i.e., age, gender, education, race, income), military status (rank, branch, number of deployments, etc.), mental health (diagnosis and use of psychotropic medication and antipsychotics), substance use/dependence and physical activity, ORs ranged from 1.10 to 1.72 with a pooled OR of 1.31 (95% CI: 1.25, 1.38). Studies that compared differences in BMI, rather than likelihood of obesity, however, showed that BMI rates were slightly higher among those with PTSD, but were not significantly different between PTSD and non-PTSD subjects, except for Dedert et al. (2010) ($\beta = 0.98$, $SD = 0.49$, $p < .01$).

PTSD was most strongly associated with obesity in persons 20–30 years old (pooled OR = 2.04; 95% CI: 1.88, 2.21; see Supplemental Table S5 in the online supplemental material). However, over 60-year-old individuals were more likely to be obese (OR = 2.90; 95% CI: 1.28–2.22) if they had current PTSD and OR = 2.46 (95% CI: 1.21–4.99) if they had a history of PTSD, than their non-PTSD peers in the same age group (See Smith et al.,

Table 4
The Effect of Posttraumatic Stress Disorder on Obesity

Study	Sample size	ES (95% CI)	Odds ratio (95% CI)	% Weight
Unadjusted studies				
Godfrey et al., 2013	80		3.70 (1.53, 8.92)	.01
Dedert et al., 2010	148		1.89 (.23, 15.46)	.02
Farr et al., 2015	158		1.57 (1.02, 2.41)	.02
Mitchell et al., 2013 ^b	171		1.00 (.20, 3.80)	.02
Jin et al., 2009	203		1.74 (.90, 3.37)	.02
Mitchell et al., 2013 ^a	292		4.40 (1.30, 14.40)	.03
Kozaric-Kovacic et al., 2009	478		1.06 (.75, 1.48)	.05
Talbot et al., 2014	736		1.69 (1.28, 2.22)	.08
Hirth et al., 2011	3,181		1.05 (.86, 1.29)	.33
Boscorino, 2008	4,462		.83 (.57, 1.21)	.46
Goldberg et al., 2014	5,574		1.45 (1.06, 1.98)	.57
Coughlin, 2011	9,970		1.34 (1.15, 1.55)	1.02
Scott et al., 2008	12,992		2.64 (1.97, 3.53)	1.34
Boscarino & Chang, 1999	18,000		1.10 (.48, 2.52)	1.85
Pagoto et al., 2012	20,013		1.51 (1.18, 1.95)	2.06
Littman et al., 2013	38,686		1.20 (.89, 1.61)	3.98
Leardmann et al., 2015	38,883		1.60 (1.43, 4.79)	4.00
Kubzansky et al., 2009	50,504		1.13 (1.09, 1.17)	5.19
Cohen et al., 2009	267,311		2.14 (1.98, 2.31)	27.47
Chwastiak et al., 2011	501,161		1.36 (1.33, 1.39)	51.51
Pooled	973,003		1.58 (1.49, 1.67)	100.00
Adjusted studies				
Smith et al., 2015	735		1.72 (1.01, 2.90)	.09
Pagoto et al., 2012	9,406		1.46 (1.12, 1.90)	1.18
Pagoto et al., 2012 ^c	10,606		1.49 (1.16, 1.91)	1.33
Cohen et al., 2009	267,311		1.69 (1.52, 1.89)	34.62
Chwastiak et al., 2011	501,161		1.10 (1.08, 1.13)	62.78
Pooled	789,219		1.31 (1.25, 1.38)	100.00

Note. ES = effect size; CI = confidence interval.

^a Just females. ^b Just males. ^c Just elderly population (over 60).

2015). In addition, a study by Littman et al. (2013) showed that individuals with PTSD (who on average were 40 years old), gained more weight than individuals who did not have PTSD (OR = 1.20; 95% CI: 0.89–1.61). Obesity also seemed to be a more significant issue among male samples (pooled OR = 1.59; 95% CI: 1.50, 1.68), than female samples (pooled OR = 1.15; 95% CI: 1.09, 1.20). Nevertheless, several adjusted studies revealed that gender did moderate the association between obesity and PTSD. Cohen et al., (2009), which studied Operation Enduring Freedom/Operation Iraqi Freedom VA enrollees, found, after controlling for demographics, military status, and health utilization, that men and women with PTSD had a similar likelihood of obesity (OR men = 2.71, 95% CI: 2.52–5.61 and OR women = 2.54, 95% CI: 2.06, 2.29). Even so, Pagoto et al. (2012) found women with PTSD were more likely to be obese than women without PTSD (OR = 1.40; 95% CI: 1.11, 1.76), after adjusting for demographics, alcohol/drug use, smoking, psychotropic medication use, depression and binge eating. Furthermore, Mitchell et al. (2013), a study of an African American intercity population that also controlled for lifetime trauma, showed that the odds of being obese for women with PTSD was four times that of women without PTSD (OR = 4.4; 95% CI: 1.30, 14.30). In both studies, there were no significant differences in likelihood of obesity among men with PTSD and men without PTSD.

Smoking

Twelve studies examined differences in smoking among participants with and without PTSD (See Table 5). About 22% of study participants were current smokers and participants with PTSD were much more likely to smoke than participants without PTSD (36.1% vs. 19.9%; OR range = 0.71 to 10.62). Only two of the 12 studies found no significant association between PTSD and current smoking (Talbot et al., 2014 and Maia et al., 2008). Results from

studies of PTSD and pack years were mixed. Boscarino et al. (Boscarino, 2008; Boscarino & Chang, 1999) found no differences between military personnel with and without PTSD and pack years, whereas Zen et al. (2012) found PTSD was associated with significantly higher levels of cigarette pack years ($\beta = 6.4$ pack years; 95% CI: 1.80, 10.90). Likelihood of current smoking among male subjects with PTSD was highest among individuals in their twenties and thirties (pooled OR = 2.36; 95% CI: 2.31, 2.40) and lowest among females (pooled OR = 1.35; 95% CI: 1.29, 1.41).

Results of Subsample of High Quality (Q-Col >27) and Large Sample Studies

We scored 11 studies as “high quality” because they had a Q-Col over 27 and a sample size $\geq 1,000$. In this group of studies, PTSD increases the likelihood of a healthier diet (pooled OR = 1.27; 95% CI: 1.22, 1.31; $i^2 = 0\%$; Roberts et al., 2015; Sumner et al., 2015) and decreases the likelihood of physical activity (pooled unadjusted OR = 0.68; 95% CI: 0.66, 0.69, $i^2 = 98.5\%$; adjusted OR = 0.92; 95% CI: 0.89, 0.95, $i^2 = 67.3\%$; Chwastiak et al., 2010; Kozaric-Kovacic et al., 2009; Roberts et al., 2015; Sumner et al., 2015). Individuals with PTSD were also less likely to be involved in exercise programs (adjusted predicted probability = 3.5; 95% CI: 3.2, 3.9; Maguen et al., 2016). In addition, PTSD increased the likelihood of obesity (pooled unadjusted OR = 1.36, 95% CI: 1.32, 1.41, $i^2 = 96.1\%$; adjusted OR = 1.11, 95% CI: 1.08, 1.14, $i^2 = 67.0\%$; Boscarino & Chang, 1999; Boscarino, 2008; Chwastiak et al., 2010; Kozaric-Kovacic et al., 2009; Kubzansky et al., 2014; Pagoto et al., 2012; Scott et al., 2008; Smith et al., 2015) and individuals had an increased likelihood of gaining more weight (adjusted OR = 1.20; 95% CI: 0.89–1.61) than those without PTSD (Littman et al., 2013). Finally, PTSD was associated with increased likelihood of smoking (pooled unadjusted OR = 1.50, 95% CI: 1.42, 1.58, $i^2 = 99.3\%$;

Table 5
The Effect of PTSD on Smoking

Study	Sample size	ES (95% CI)	Odds ratio (95% CI)	% Weight
Unadjusted studies				
Maia et al., 2008	119		.71 (.22, 2.30)	.01
Farr et al., 2015	158		10.62 (5.05, 22.35)	.02
Talbot et al., 2014	736		1.03 (.72, 1.46)	.08
Zen et al., 2012	1,022		2.49 (1.60, 3.89)	.11
Spitzer et al., 2009	3,171		1.76 (1.03, 3.00)	.33
Goldberg et al., 2014	5,574		2.47 (2.01, 3.03)	.58
Leardmann et al., 2015	38,883		2.21 (2.01, 2.42)	4.02
Roberts et al., 2015	49,739		1.45 (1.32, 1.58)	5.14
Sumner et al., 2015	49,978		1.29 (1.19, 1.41)	5.16
Kubzansky et al., 2009	50,504		1.31 (1.26, 1.35)	5.22
Cohen et al., 2009	267,311		2.92 (2.87, 2.98)	27.60
Chwastiak et al., 2011	501,161		1.94 (1.90, 1.99)	51.75
Pooled	968,356		2.13 (2.10, 2.16)	100.00
Adjusted studies				
Chwastiak et al., 2011	501,161		1.22 (1.18, 1.25)	100.00
Pooled	501,161		1.22 (1.19, 1.26)	100.00

Note. ES = effect size; CI = confidence interval.

adjusted OR = 1.22, 95% CI: 1.19, 1.25, $i^2 = 0\%$; Chwastiak et al., 2010; Kubzansky et al., 2014; Roberts et al., 2015; Sumner et al., 2015). However, two studies by Boscarino and colleagues (1999, 2008) showed no differences in cigarette pack years among individuals with PTSD compared to individuals without.

Discussion

The association between PTSD and diabetes and CVD is well established (Coughlin, 2013). This association may be partly explained by poor health behaviors. To our knowledge, there have been no systematic reviews that evaluated the association between PTSD and multiple health behaviors that can increase risk for diabetes and CVD. In the present review of the association between PTSD and diet, physical activity, obesity and smoking, we found that existing evidence supports the conclusion that patients with PTSD are more likely to exercise less, be obese and be current smokers. However, less consistent results were found when it came to determining the likelihood of eating a healthy diet.

The association between PTSD and obesity may be due to less physical activity. This is supported by the evidence that PTSD is linked to less physical activity (Chwastiak et al., 2011) in one half of the studies we examined, and reduced engagement in the VA's MOVE! weight loss program among veterans with PTSD (Maguen et al., 2016). However, diet may not play a significant role in the development of CVD or diabetes among individuals with PTSD. Our review of the literature only retrieved four studies of PTSD and diet. Two of the three studies indicated that PTSD was associated with a healthier diet in female health professionals (Roberts et al., 2015; Sumner et al., 2015), and one small study using a community and veteran sample and a larger study of females in a safety net clinic found a negative relationship (Godfrey et al., 2013). The larger study had a very small effect size.

It is also clear that individuals with PTSD were more likely to have all three of the most consistent conditions (i.e., lack of physical activity, obesity, and smoking; Chwastiak et al., 2011). In this way, it appears that many poor health behaviors could be grouped together as potentially impulsive decisions that occur as a result of PTSD, which serve to reduce symptomology or to temporarily feel better. According to Shipherd, Clum, Suvak, and Resick (2014), as PTSD symptoms start to diminish, individuals will engage in fewer negative health behaviors, (like smoking, eating candy or sweets, driving over the speed limit, etc.) and fewer positive health behaviors (like going for walks, eating breakfast, exercise, etc.). As this study illustrates, which includes only treatment-seeking women with PTSD, it remains uncertain whether health behaviors improve with reduction in PTSD symptoms because individuals likely vary in the ways in which they cope with PTSD symptoms. In other words, some healthy behaviors may be used to cope with increasing hyperarousal occurring as a result of PTSD, like taking walks or eating regular meals (see Harte, Vujanovic, & Potter, 2015), and these may occur at the same time as negative behaviors, like increased smoking (Vujanovic et al., 2013). Patients with PTSD may also adopt sedentary lifestyles partly from fear of exposures to environmental cues that elicit PTSD symptoms.

Even though the study of decision making about health behaviors as a result of PTSD is still in its infancy, the relation between PTSD and physical health is fairly well understood. Shipherd et al.

(2014) found that change in PTSD accounted for 34% of variance in changes in physical health complaints over time. These physical health complaints likely have a greater effect on an individual's ability to engage in physical activity, which is associated with obesity. Comorbid physical complaints and chronic pain is common among individuals with PTSD, and may lead to reduced physical activity, but may have less of an effect on diet. Comorbid pain and pain-related impairment and physical conditions has also been suggested as reasons for low participation in weight loss programs among veterans with PTSD (Maguen et al., 2016; Vujanovic, Farris, Harte, Smits, & Zvolensky, 2013).

In addition, individuals with PTSD might be at increased risk for weight gain because of co-occurring psychiatric disorders and stress. Atypical antipsychotics are often prescribed to patients with PTSD which can lead to rapid weight gain (Roerig, Steffen, & Mitchell, 2011). Likewise, HPA disruption occurs in PTSD and has been shown to contribute to weight gain (Kubzansky et al., 2014; Littman et al., 2013; Miller, Chen, & Zhou, 2007), as well as diabetes and cardiovascular disease (Coughlin, 2011). Future studies are warranted to determine the relative contributions of physiological changes following PTSD, diet and comorbid psychiatric conditions to metabolic and cardiovascular disease in this patient population.

Individuals with PTSD smoke more than individuals without PTSD (Feldner, Babson, & Zvolensky, 2007). They also have a lower threshold of toleration for distress related to withdrawal (Beckham et al., 1996), and are more sensitive to trauma cues during withdrawal. Our metanalysis shows that individuals with PTSD are not only more likely to smoke but also tended to smoke more cigarettes for longer periods of time. For example, in the Zen et al. (2012) study of San Francisco hospital and outpatient clinic patients with CVD, patients with PTSD had a mean cigarette pack/year rate of 27.3 ± 22.0 and patients without PTSD had a mean cigarette pack/year rate of 19.9 ± 21.0 . These findings coincide with the numerous systematic reviews on PTSD and smoking.

There are several limitations of available literature in our systematic review. The majority of studies focused on White populations and 11 of the 27 studies used military samples. Other problems included inconsistent measures of diet and physical activity and use of self-report measures. Many of these self-report measures have a reasonable level of validity and reliability (Ainsworth, Jacobs, & Leon, 1993), but with the advent of technologies to track real-time movement, food intake, and smoking, more rigorous and consistent measures of health behavior will soon be available. Furthermore, outcomes were not adjusted for confounders because measures of diet, obesity and smoking were often modeled as covariates. As a result, there was significant heterogeneity across different studies. Finally, even though more than one million individuals were participants in these studies, the vast majority of these individuals lived in the United States, were male and were White.

Conclusions

PTSD is associated with many poor health behaviors that contribute to metabolic and cardiovascular disease. Although substantial evidence supports an association between PTSD, sedentary

lifestyle, smoking, and obesity, additional research is needed to determine if PTSD is associated with adopting a poor diet.

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