AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 59:486–500 (2016)

24-Hour Work Shifts, Sedentary Work, and Obesity in Male Firefighters

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Background *Little is known about the occupational risk factors for obesity in US firefighters.*

Methods *308 male California firefighters, who participated in a work and obesity project, were chosen. Working conditions were measured with a firefighter-specific occupational health questionnaire. Adiposity was clinically assessed using body mass index (BMI), waist circumference (WC), and body fat percent.*

Results *In a multivariate analysis, the prevalence of obesity by all measures was significantly higher (PRs = 3.69–6.03, $P < 0.05$) in the firefighters who reported seventeen to twenty-one shifts than those who reported eight to eleven shifts in the past month. Prolonged sedentary work was also a risk factor for obesity by BMI (PR = 4.18, $P < 0.05$). Furthermore, there was a linear dose-response relationship of obesity by BMI and WC with the number of 24-hr shifts and sedentary work.*

Conclusions *Many additional 24-hr shifts and prolonged sedentary work substantially increased the risk for obesity in male firefighters.* Am. J. Ind. Med. 59:486–500, 2016.

KEY WORDS: California; working conditions; body mass index; waist circumference; body fat percent

INTRODUCTION

Obesity is a well-known risk factor for many chronic diseases as well as increased mortality [National Institute of Health, 1998; World Health Organization, 2000; McGee, 2005; Flegal et al., 2013]. The prevalence of obesity in the working population of the United States (US) has increased, particularly over the last three decades [Caban et al., 2005; Gu et al., 2014]. About 1.2 million firefighters are among the occupational groups with high obesity prevalence in the US [Caban et al., 2005; Choi et al., 2011; Haddock et al., 2011; Gu et al., 2014] and are at high risk of on-duty cardiovascular disease (CVD) mortality [Kales et al., 2007; Geibe et al., 2008]. At the same time, they are also at higher risk for work-related injuries [Poplin et al., 2012; Jahnke et al., 2013] also associated with obesity or aerobic fitness level [Kuehl et al., 2012; Jahnke et al., 2013; Poplin et al., 2014].

However, little is known about the occupational risk factors for obesity in US professional firefighters. To the best of our knowledge, no epidemiological studies have been conducted to examine the associations between adverse psychosocial working conditions and obesity in US professional firefighters who contractually work a 24-hr shift work schedule [Choi et al., 2011, 2014a]. This lack of information is a significant barrier to establishing an effective and comprehensive worksite strategy for prevention of obesity in professional firefighters by integrating

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Accepted 13 January 2016
DOI 10.1002/ajim.22572. Published online 22 February 2016 in Wiley Online Library (wileyonlinelibrary.com).

health protection (occupational safety and health) with health promotion approaches [Hymel et al., 2011]. The etiology of obesity is multifactorial involving significant environmental factors, including physical and psychosocial working conditions, culture, and socioeconomic status [Davidson and Knafl, 2006; Choi et al., 2011; Agne et al., 2012; Pandalai et al., 2013]. Several epidemiological studies have reported associations of adverse working conditions with obesity in general working populations and other occupational groups, albeit not supported in some studies [Ghiasvand et al., 2006; Lallukka et al., 2008; Pulsford et al., 2013]: low work-related physical activity (e.g., sedentary work) [Mummery et al., 2005; Choi et al., 2010]; shift work [van Amelsvoort et al., 1999; Kubo et al., 2011; Macagnan et al., 2012]; long working hours [Di and Mummery et al., 2009; Solovieva et al., 2013; Jang et al., 2014; Luckhaupt et al., 2014; Lemke et al., 2015]; and low organizational support for employee heath [Tabak et al., 2015].

In this study with a survey data base from the Firefighter Obesity Research: Workplace Assessment to Reduce Disease (FORWARD) study [Choi et al., 2011], we examine whether adverse psychosocial working conditions (number of 24-hr shifts, number of daily calls, sedentary work, poor worksite health climate, and low perceived organizational support) are associated with obesity in a group of professional firefighters, as hypothesized from a theoretical framework on working conditions, health behaviors, and obesity in firefighters [Choi et al., 2011] and the findings from focus groups with firefighters [Dobson et al., 2013], prior to the survey.

MATERIALS AND METHODS

Background—FORWARD Study

The main purpose of the FORWARD study (2010–2013) was to explore occupational and behavioral risk factors for obesity in firefighters who work for a fire department in Southern California [Choi et al., 2011, 2014b, 2015b; Dobson et al., 2013]. The FORWARD study had strong support from both the fire department and a local union of the International Association of Fire Fighters (IAFF). It has been conducted as a joint project between university researchers and firefighters based on the principles of participatory action research [Greenwood et al., 1993; Dollard et al., 2008]. The protocol of the FORWARD study was reviewed and approved by the Institutional Review Board (IRB) of the University of California, Irvine. All firefighters in this study were fully informed of the study and signed written informed consent forms. Phase I of the study involved developing a firefighter-specific work and health questionnaire (called hereafter the FORWARD study questionnaire) through four focus groups with 20 firefighters of different ranks from January to April 2011 [Dobson et al., 2013]. Phase II of the study was a cross-sectional study using the FORWARD study questionnaire and various weight related health outcomes. A random sample of 365 firefighters (356 males and 9 females) from the total population of about 800 firefighters in the fire department participated in the survey (participation rate, 84% of 436 invited firefighters) when they visited a university clinic for their biennial wellness and fitness (WEFIT) medical examinations between May 2011 and December 2012. In Phase III of the study, among the survey participants, a random selection of 83 firefighters were additionally recruited for a sub-study (participation rate, 50%) beginning in September 2011 and ending in July 2012 in which firefighters were asked to wear a physical activity monitor (ActiGraph GT3X^{+}) and record their food intake in a diary for 1 on-duty day (24 hr) and 1 off-duty day (24 hr). A computerized call record was obtained from the fire department for each firefighter's on-duty day. Furthermore, for short-term test–rest reliability of the FORWARD study questionnaire, the sub-study participants were asked to fill out a short version of the FORWARD study questionnaire 1–8 weeks after they completed the full version [Choi et al., 2014b]. There were no substantial differences in age, gender, race/ethnicity, education, rank, and three adiposity measures (see below) between the 83 firefighters who participated in the sub-study and the 365 firefighters who participated in the survey.

Firefighters for the Current Study (308 Male Firefighters)

Given the purpose of the current study, among the 365 firefighters who participated in the FORWARD study survey, we excluded the firefighters who did not work a 24-hr shift schedule (e.g., worked at the headquarters of the fire department) (N = 19) or who, even if they worked at a fire station, reported <8 24-hr shifts in the past month (because they likely just returned to work after an occupational injury or a long break; according to the standard work schedule of the fire department, they are supposed to do 10–11 shifts per month) (N = 15), who were rookies (having <1 year of employment at the fire department) or who had special job titles (e.g., medical director, training officer, investigator, etc.) (N = 16), or who did not have valid information on any one of the three adiposity measures (N = 10). Given the small number of female firefighters and the fact that their obesity prevalence was reported in another paper [Choi et al., 2015a], we excluded female firefighters from this study. Thus, 308 male firefighters were included in the current study. There were no substantial differences in age, race/ethnicity, education, and three adiposity measures (see below) between the 308 male

firefighters of this study and 356 male firefighters who originally participated in the FORWARD study.

Main Exposures—Psychosocial Working Conditions

On a typical 24-hr shift (e.g., from 0800 to 0800), firefighters can sleep at night at the fire station, but they can be frequently woken for emergency calls. The standard shift schedule is 10 to 11 24-hr shifts per month; however, many firefighters work voluntarily and involuntarily additional 24-hr shifts beyond their standard work schedule [Choi et al., 2011, 2014a]. Number of 24-hr shifts in the past month, number of calls on a typical 24-hr shift, sedentary work, worksite health climate, and perceived organizational support were measured with the FORWARD study questionnaire. Number of 24-hr shifts in the past month (including overtime, backfill and/or shift trade) and number of calls on a typical 24-hr shift were measured with one item each. Prolonged sedentary work was measured with the single item ("My job often requires sitting for long periods of time.") with the four-point Liket response set (strongly disagree to strongly agree) drawn from the MIDUS II study [Ryff et al., 2007; Choi et al., 2010]. The number of calls was divided into three groups (low, medium, and high) based on its tertiles for analyses (see Table I). Three aspects of worksite health climate were measured: co-worker support for exercise (two items with the four-point Likert response set, "My coworkers encourage me to exercise." And "My coworkers exercise with me."); fire station dietary climate (one item with six response options: 0%, 20%, 40%, 60%, 80%, and 100%; "Estimate the % of firefighters in my station eating more than 5 servings of fruits and vegetables each day.") from the PHLAME study [Elliot et al., 2007]; and supervisor support for exercise with one item with four response options ["My supervisor. . .", 1) encourages me to exercise, 2) discourages, 3) neither encourages nor discourages, and 4) not applicable] that was created by the research team of the FORWARD study. Low co-worker support for exercise was defined as those who strongly disagreed or disagreed to one of the two items. The responses to the item for fire station dietary climate were further collapsed into three [poor (0–20%), fair (40–60%), and good (80–100%)] for analyses. The responses to the item for supervisor support for exercise were further dichotomized for analyses as follows (encouraging vs. the other three response options) because of only one response to each of the two options (discourage and not applicable). Perceived organizational (management) support was measured with two items with the four-point Likert response set ("Management cares about my opinions." and "Management considers my goals and values."). The low organizational support group was defined as those who strongly disagree or disagreed with one of the two items. Regarding the description about the validity and reliability tests of the questionnaire items of the above psychosocial working conditions, see the statistical analyses section below.

Health-Related Behaviors at Work and During Leisure Time

Frequency of exercise (i.e., moderate or vigorous level of physical activity and more than 30 min) at fire station and during leisure-time was each assessed with one questionnaire item with four options (0, 1, 2, and $\geq$3 days per week). The low exercise group was defined as firefighters who reported exercising 0–1 day per week. Frequency of consumption of high-fiber fruits and vegetables was measured with one questionnaire item ("How many servings of food do you eat per day that are high in fiber, such as whole grain bread, high-fiber cereal, fresh fruits or vegetables?) with the following response options: (i) 5–6 servings; (ii) 3–4 servings; (iii) 1–2 servings; and (iv) never/rarely. The responses were dichotomized into two groups (5–6 servings/day vs. the others) for analyses, according to the current recommendation for US adults [Dietary Guidelines Advisory Committee, 2015]. Several other eating behaviors were measured: frequency of consumption of canned drinks at the fire station was measured with one item ("I drink canned soft drinks, energy drinks, sports drinks or nutritional drinks.") with three response options (never/rarely, sometimes, and frequently) from a Japanese study [Nishitani and Sakakibara, 2006]. Frequent consumers of canned drinks were compared with the other two response groups. Stress-induced overeating at fire station was measured with two items (e.g., "I eat more than I usually do under stressful events.") from the MIDUS II Study [Ryff et al., 2007; Choi et al., 2010]. Stress-induced overeaters were defined as those who endorsed one of the two items. Overeaters since childhood were defined as those who agreed to the following item ("Since childhood, have you always eaten a lot?") from the Japanese study. Smoking status (current smoker, ex-smoker, and current non-smoker) and alcohol consumption (non-drinker, moderate, and heavy drinker) were self-reported with the survey questions. Since the proportion of heavy alcohol drinkers (>2 drinks per day) was very low (<3%), they were grouped together with the moderate alcohol drinkers for the multivariate analyses (see below).

Sleep and Mental Health

Number of sleep hours of firefighters at the fire station and at home were each self-reported in the FORWARD questionnaire. Sleep hours was divided into three groups for analyses (see Table I). Mental health was measured with the standard 12-item General Health Questionnaire (GHQ)

TABLE I. Distributions of Study Variables and Obesity Prevalence by Body Mass Index (BMI), Waist Circumference (WC), and Skinfold-Based Body Fat Percent (BFP) in 308 Male Firefighters

				Obesity prevalence		
Study variables	**Category**	**Subcategory**	**Distribution of study variables (%) among 308 firefighters**	**BMI-based**	**WC-based**	**BFP-based**
Sociodemographic	Age	25–34	25.0	6.5***	7.8***	7.8***
		35–44	30.5	26.6***	25.5***	14.9***
		45–54	37.7	31.1***	33.6***	32.8***
		55–64	6.8	23.8***	38.1***	19.0***
	Race/ethnicity	Non-Hispanic White	80.2	24.3	27.1*	21.1
		Hispanic/Asia/others	19.8	18.0	16.4*	16.4
	Marital status	Married or living with partner	79.1	24.8*	28.5***	16.9
		Others	20.9	15.6*	12.5***	15.6
	Education	Some college or high school	53.7	24.8	26.1	23.6*
		College or graduate school	46.1	20.6	24.1	16.3*
	Job title	Firefighters/engineers	70.1	19.4**	18.1***	16.7**
		Captains/chiefs	29.9	31.5**	41.3***	28.3**
Psychosocial working conditions	Number of 24-hr shifts in the past month	8–11	9.4	10.3*	13.8**	10.3**
		12	21.8	19.4*	17.9**	20.9**
		13	13.3	19.5*	24.4**	14.6**
		14	25.0	20.8*	20.8**	20.8**
		15	12.0	29.7*	32.4**	16.2**
		16	11.7	30.6*	36.1**	19.4**
		17–21	6.8	42.9*	47.6**	47.6**
	Number of calls on a typical 24-hr shift	1–4	28.9	33.7**	33.7*	25.8
		5–7	38.3	20.3**	22.0*	19.5
		8–14	32.8	16.8**	20.8*	15.8
	Sedentary work	Strongly disagree	7.2	13.6***	18.2***	18.2**
		Disagree	54.8	17.4***	16.8***	13.8**
		Agree	28.2	30.2***	36.0***	25.6**
		Strongly agree	9.8	40.0***	43.3***	36.7**
	Co-worker support for exercise	High	86.4	22.9	24.1	19.5
		Low	13.6	23.8	31.0	23.8
	Supervisor support for exercise	High	62.0	21.7	22.2	15.9**
		Low	38.0	23.3	28.4	26.7**
	Station dietary climate	Good (80–100%)	14.9	15.6	17.8	15.6*
		Fair (40–60%)	16.5	22.0	22.0	12.0*
		Poor (0–20%)	68.6	24.5	27.4	23.1*
	Perceived organizational support	High	38.6	22.7	20.2*	18.5
		Low	61.4	23.3	28.0*	21.2
Health-related behaviors	Exercise at work	≥2 days/week	87.6	20.4***	21.9***	18.2**

(*Continued*)

TABLE I. (*Continued*)

Study variables	Category	Subcategory	Distribution of study variables (%) among 308 firefighters	Obesity prevalence		
				BMI-based	WC-based	BFP-based
		≤1 day/week	12.4	42.1***	47.4***	34.2**
	Exercise during leisure time	≥2 days/week	72.5	18.9***	20.7***	14.4***
		≤1 day/week	27.5	34.5***	35.7***	35.7***
	High-fiber fruits/vegetable consumption	High	12.7	12.8*	12.8*	10.3*
		Low	87.3	24.3*	26.9*	21.6*
	Stress-induced overeating	Yes	11.4	45.7***	48.6***	37.1***
		No	88.6	20.1***	22.0***	17.9***
	Overeating since childhood	Yes	52.3	30.0***	30.6**	22.5
		No	47.7	15.1***	19.2**	17.8
	Frequently drink canned drinks at fire station	Yes	19.8	31.1*	32.8*	24.6
		No	80.2	21.1*	23.1*	19.0
	Smoking	Current smokers	10.1	22.6	32.3	12.9
		Ex-smokers	26.0	18.8	20.0	17.5
		Never-smokers	63.9	24.9	25.9	22.3
	Alcohol consumption	No	14.3	34.1*	36.4*	38.6***
		Moderate/heavy[a]	82.8[a]	21.2*	23.1*	17.0***
Sleep and Mental health	Sleep hours at fire station	2.5 to <5 hr	15.3	17.0**	17.0**	14.9**
		5 or 6 hr	61.0	19.7**	22.9**	17.6**
		>6 to 8.5 hr[b]	23.7	35.6**	35.6**	30.1**
	Sleep hours at home	4 to <7 hr	17.8	37.7***	41.5**	34.0***
		7 or 8 hr	71.8	23.4***	22.4**	19.2***
		>8 to 10 hr	10.4	3.2***	19.4**	6.5***
	GHQ	≤1	79.5	22.4	23.3*	18.8
		≥2	20.5	25.4	31.7*	25.4
Obesity		BMI-based	23.1			
		WC-based	25.0			
		BPF-based	20.1			

*$P < 0.20$, **$P < 0.05$, and ***$P < 0.01$ at Chi-square test.
[a]The percent of heavy drinkers were 2.9%.
[b]One firefighter reported 10 hr of sleep.

[Goldberg, 1972]. The GHQ items were scored according to the 0-0-1-1 scoring formula. The high-psychological distress group was defined as firefighters having GHQ scores of ≥2 [Goldberg et al., 1998].

Three Measures of Adiposity

The adiposity of the firefighters was assessed by an experienced exercise physiologist during their WEFIT medical examinations using standard assessment protocols of body mass index (BMI), waist circumference (WC), and skinfold thickness-based body fat percent (BFP) (for details, see Choi et al. [2015a]). The three adiposity measures were highly correlated (Spearman correlations, 0.70–0.83) [Choi et al., 2015a]. Obese firefighters were defined with each of the three adiposity measures based on the respective standard cut-points that have been recommended by the World Health Organization [2000]: BMIs ≥30 kg/m^2 and WCs of >102 cm (40 in) for men. Although the American Council on Exercise [2009] suggested 25% as the cut-point for BFP-based obesity in males, we used 24% in this study with consideration of a possible underestimation of skinfold-based BFP by 1%, on average, when compared to the underwater weighing method [Fogelholm and van Marken Lichtenbelt, 1997]. In our previous study [Choi et al., 2015a], all three obesity measures

were good for identifying obese firefighters and for predicting the associations with CVD risk factors, although BMI overestimated the prevalence of overweight firefighters compared to WC and BFP.

Other Variables

Age, race/ethnicity (Whites and Non-Whites), job title, and education were measured with questions in the FORWARD survey questionnaire. For the multivariate analyses, job title was simplified into two groups (firefighters/firefighter apparatus engineers and captains/chiefs).

Statistical Analyses

Validity and reliability of the questionnaire items about psychosocial working conditions were first examined. A Spearman correlation coefficient was calculated between the numbers of calls on a typical 24-hr shift on the questionnaire and the 24-hr call records of the fire department administration among the 83 firefighters who participated in the survey and the sub-study (Phase II and Phase III). Among the 83 firefighters, the responses of the firefighters to the sedentary work item in the survey were compared to the sitting times from the physical activity monitors (inclinometers) using an analysis of variance test. The questionnaire items about sedentary work, worksite health climate, and perceived organizational support were administered twice with a time interval of 1–8 weeks in the 83 firefighters. The short-term (1–8 weeks) test and re-test reliability of the questionnaire items (see above) was calculated with Kappa statistics. To evaluate the kappa statistics, we followed the conventional guide suggested by Landis and Koch [1977]: ≤ 0 = poor, 0.01–0.20 = slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–1.00 = almost perfect.

For an overview, the correlations between the exposures and covariates were examined. The bivariate association between each of the psychosocial working conditions and obesity was examined using Pearson's chi-square test. We then examined the prevalence ratio (PR) and its 95% confidence interval (CI) of each of the psychosocial working conditions for obesity using multivariate Cox's proportional hazards models [Breslow, 1974; Lee and Chia, 1993]. Only the variables that were at least marginally ($P < 0.20$) significant risk factors for at least one obesity measure in the bivariate analyses were entered in the multivariate Cox models: after adjustment of other psychosocial working conditions (Model 1); additionally after adjustment for sociodemographic variables (Model 2); and additionally after adjustment for health-related behaviors, sleep, and mental health variables (Model 3).

Sensitivity Analyses

Lastly, for a sensitivity test, we replicated the above analyses with the cut-point of 25% for BFP-based obesity. Also, we replicated the above analyses using multivariate linear regression models with the three adiposity measures (BMI, WC, and BPF) as continuous variables. We replicated the above analyses with some standard items of the Job Content Questionnaire (JCQ) [Karasek et al., 1985] and the Effort-Reward Imbalance Questionnaire (ERIQ) [Siegrist et al., 2004] given some evidence from the working populations, including multiple occupational groups [Brunner et al., 2007; Inoue et al., 2010; Choi et al., 2014c; Fujishiro et al., 2015]: job control, job demands, and job strain (the combination of low job control and high job demands using the median cut-points), extrinsic effort, reward, and effort-reward imbalance (the combination of high effort and low rewards using the median cut-points) at the scale level as well as four (three JCQ and one ERIQ) items at the item level that showed some response variation (see below).

Initially, 19 JCQ (for job control, psychological job demands, social support at work, and job insecurity) and 6 ERIQ items (for extrinsic effort and reward) were included in the FORWARD study questionnaire [Choi et al., 2014b], although the domains were not hypothesized as key risk factors for obesity in firefighters [Choi et al., 2011] due to the possibility of little variation in this single occupation-based study. Indeed, there was generally little variation in the responses of the firefighters to the standard questionnaire items [Choi et al., 2014b], except the four items showing some response variation (i.e., >20% of agree/strongly agree or disagree/strongly disagree) from the JCQ and the ERIQ: one JCQ decision authority ("lot of say") and two psychological job demands items ("not asked to do an excessive amount of work" and "conflicting demands") and one ERIQ extrinsic effort item ("more and more demanding"). Generally, the firefighters reported high job control, high psychological job demands, high physical job demands, high supervisor and co-worker support, high job security, high extrinsic effort, and high job reward.

RESULTS

Validity and Reliability of the Questionnaire Items About Psychosocial Working Conditions

Among the 83 firefighters who participated in the survey and sub-study, the number of calls on a typical 24-hr shift on the survey questionnaire was significantly correlated (rho $= 0.74$, $P < 0.01$) with the call records of the fire department. Also, there was a substantial ($P = 0.07$) difference in the

sitting times recorded by the physical activity monitors in the firefighter (N = 7) who strongly agreed to the sedentary work item compared to the firefighters (N = 7) who strongly disagree to the sedentary work item on the survey questionnaire: 494 min (standard error, 41 min) and 361 min (standard error, 40 min), respectively. The short-term (1–8 weeks) test–retest reliability of the questionnaire items about psychosocial working conditions was generally moderate: sedentary work ($\kappa = 0.33$), co-worker support for exercise ($\kappa = 0.58$ for the item, "encouraging me to exercise" and $\kappa = 0.50$ for the item, "exercise with me"), fire station-level dietary climate ($\kappa = 0.37$), and supervisor support for exercise ($\kappa = .66$). All Kappa values were statistically significant ($P < 0.01$).

Distributions of the Study Variables in the Male Firefighters

The detailed distribution of each of the study variables among the 308 male firefighters is presented in Table I. The mean age of the male firefighters was 42.1 (standard deviation, 8.8). Most of them were White, and had some college or were high school graduates. The means (standard deviations) of BMIs, WCs, and skinfold-based BFP were 27.66 kg/m^2 (3.16 kg/m^2), 95.50 cm (9.53 cm), and 18.70% (6.09%), respectively. Obesity prevalence was 23.1% (by BMI), 25.0% (by WC), and 20.1% (by BFP). There are significant variations in all of the psychosocial working conditions among firefighters, except for co-worker support for exercise (Table I). For example, firefighters reported that they worked, on average, 13.7 shifts (standard deviation, 2.08 shifts) in the past month. More than 90% of firefighters reported at least one more additional shift than their standard shift work schedule and 19% of the firefighters reported 16 or more shifts in the past month. The number of calls on a typical 24-hr shift ranged 1–14 (on average, 6.3 calls). 38% of firefighters reported prolonged sedentary work. In general, the firefighters were active in terms of exercise both at the fire station and during leisure time, while only 13% of firefighters consumed 5–6 servings per day of high-fiber fruits and vegetables and 15% of the firefighters reported good dietary climate at the fire station (Table I). About 15–20% of the firefighters reported <5 hr of sleep at the fire station or <7 hr of sleep at home. 21% of the firefighters reported psychological distress.

The Correlations of Psychosocial Working Conditions With Other Non-Obesity Study Variables

The correlations between the psychosocial working conditions and other non-obesity study variables were examined at the significance level of 0.05. Here only statistically significant correlations are reported. The high ranks (captains and chiefs) were positively correlated with age ($r = 0.43$, $P < 0.001$), sedentary work ($r = 0.42$, $P < 0.001$), and psychological distress ($r = 0.14$, $P = 0.01$), while they were negatively correlated with the number of cal1s ($r = -0.11$, $P = 0.05$) and supervisor support for exercise ($r = -0.30$, $P < 0.001$). The number of calls on a typical 24-hr shift was positively correlated with supervisor ($r = 0.16$, $P < 0.01$) and co-worker support ($r = 0.17$, $P < 0.01$) for exercise and exercise at the fire station ($r = 0.17$, $P < 0.01$), while it was negatively correlated with age ($r = -0.30$, $P < 0.001$), sedentary work ($r = -0.14$, $P = 0.01$), and sleep hours at fire station ($r = -0.49$, $P < 0.001$).

The number of 24-hr shifts in the past month was correlated with stress-induced overeating ($r = 0.12$, $P = 0.03$). Sedentary work was also positively correlated with stress-induced overeating ($r = 0.12$, $P = 0.04$) and psychological distress ($r = 0.18$, $P < 0.01$), while it was inversely correlated with co-worker support for exercise ($r = -0.13$, $P = 0.03$). Supervisor support for exercise was positively correlated with co-worker support for exercise ($r = 0.25$, $P < 0.001$) and good station-level dietary climate ($r = 0.14$, $P = 0.02$). Good dietary climate at station was positively correlated with frequent consumption of high-fiber fruits and vegetables ($r = 0.22$, $P < 0.001$) and sleep hours at fire station ($r = 0.12$, $P = 0.03$). Low organizational support was positively correlated with low frequency of exercise at fire station ($r = 0.18$, $P < 0.01$) and high-psychological distress ($r = 0.17$, $P < 0.01$).

The Univariate Associations With Obesity

As expected, obesity prevalence was significantly higher in the older firefighters than the younger firefighters (Table I). It varied only marginally ($P < 0.20$) by race/ethnicity, marital status, and education, although WC-based obesity prevalence significantly varied by marital status. Obesity prevalence varied significantly by job title, number of 24-hr shifts in the past month, and sedentary work across all three obesity measures (Table I). In particular, there was a clear linear trend between the number of 24-hr shifts in the past month and BMI-and WC-based obesity prevalence (Fig. 1). Also there was a clear linear trend between sedentary work and BMI-based obesity prevalence ($P < 0.05$). Low daily calls (1–4 calls/day) and low supervisor support for exercise were significantly associated with one of the three obesity measures. Fire station dietary climate and perceived organizational support were marginally associated with some obesity measures, while co-worker support for exercise was not statistically associated with any of the obesity measures.

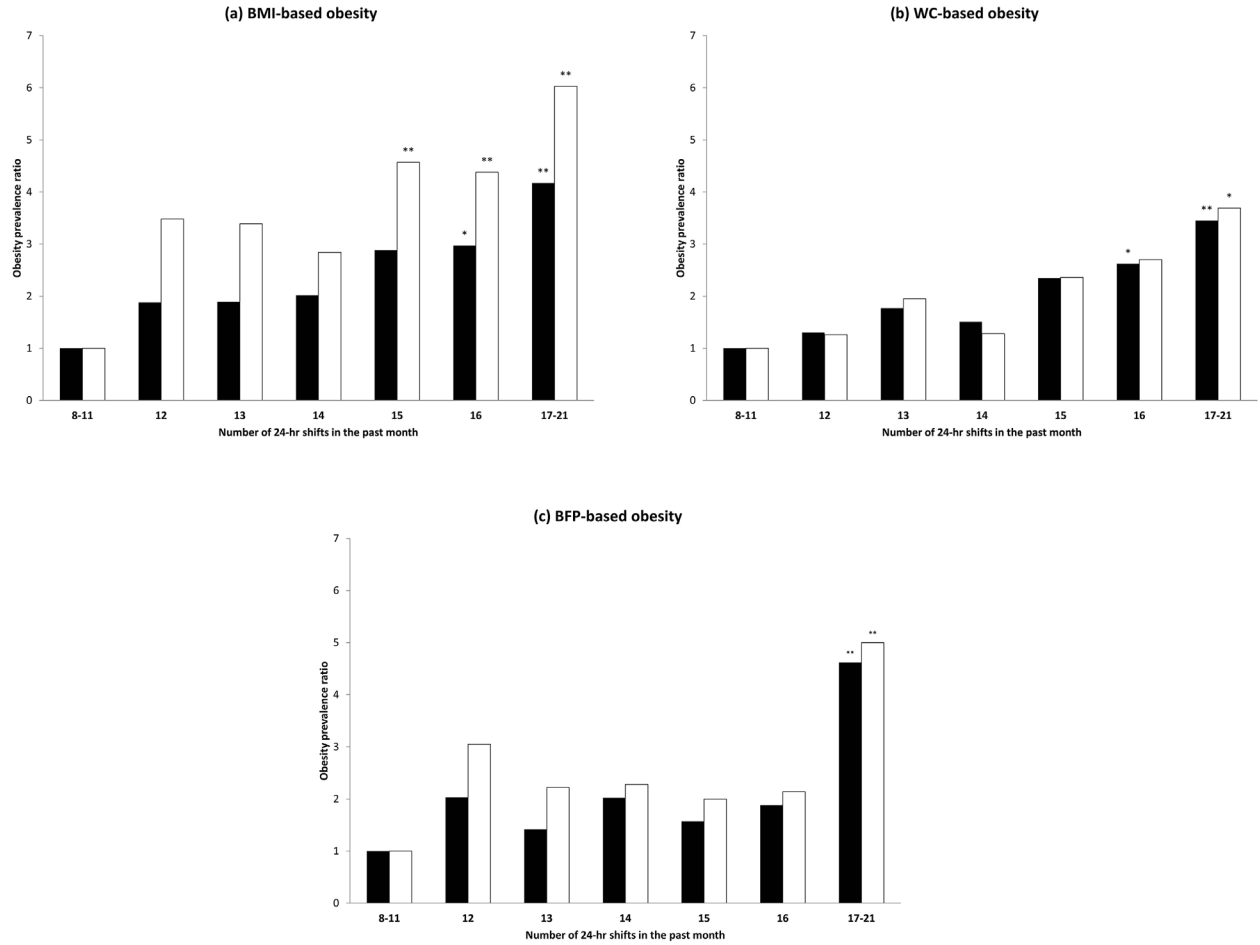

FIGURE 1. The obesity prevalence ratios (PRs) of the number of 24-hr shifts in the past month in 308 male firefighters (the reference group: 8–11 shifts). The black bars indicate the PRs from the bivariate analysis and the white bars indicate the PRs from the multivariate analysis after controlling for the other psychosocial, sociodemographic, health-related behavioral, sleep hours, and mental health. $^{*}P < 0.10$ and $^{**}P < 0.05$. Tests of linear trend of the PRs were significant ($P < 0.05$) in (**a**) body mass index (BMI)-based obesity and (**b**) waist circumference (WC)-based obesity, but not in (**c**) body fat percent (BFP)-based obesity.

Among the health-related behaviors, exercise at the fire station and during leisure-time, stress-induced overeating, and overeating since childhood were significantly associated with obesity in all three or at least two obesity measures. Sleep hours at the fire station was positively associated with obesity, while sleep hours at home were negatively associated with obesity. Psychological distress was marginally ($P < 0.20$) associated with obesity only by WC.

Multivariate Associations Between the Adverse Working Conditions and Obesity

There was a significant ($P < 0.05$) linear dose-response relationship between the number of 24-hr shifts in the past month and BMI-based obesity prevalence in the multivariate Cox models (Table II). A similar dose-response relationship was also observed with WC-based obesity (Table III), but not with BFP-based obesity (Table IV). In the final multivariate model, after controlling for the other psychosocial working conditions, sociodemographic (age, race/ethnicity, job title, and marital status) and health-related behavioral variables (exercise at station and at home, overeating since childhood, stress-induced overeating, low consumption of high-fiber fruits and vegetables, frequent consumption of soft/energy drinks at station, alcohol consumption), sleep hours, and psychological distress (Model 3 in Tables II–IV), the obesity prevalence was 3.7–6.0 times higher in the firefighters who reported 17–21 shifts than those who reported 8–11 shifts in the past month. In addition, the risk for BMI-based obesity was also significantly higher in the firefighters who reported both 15 and 16 shifts in the past month (Table II), compared to the standard work schedule group.

TABLE II. Prevalence Ratios (95% Confidence Intervals) of Psychosocial Working Conditions for Obesity (BMIs $> 30\ kg/m^2$) in 308 Male Firefighters

Psychosocial working conditions	Category	Model 1	Model 2[a]	Model 3[b]
Number of 24-hr shifts in the past month[c]	8–11	1.00	1.00	1.00
	12	1.69 (0.47–6.10)	1.56 (0.42–5.77)	3.48 (0.77–15.75)
	13	1.77 (0.46–6.78)	1.72 (0.44–6.76)	3.39 (0.75–15.45)
	14	1.88 (0.54–6.56)	1.70 (0.48–6.01)	2.84 (0.70–11.51)
	15	2.69 (0.73–9.87)	2.57 (0.69–9.56)	4.57 (1.06–19.68)
	16	2.46 (0.67–9.02)	2.26 (0.61–8.40)	4.38 (1.01–18.90)
	17–21	4.10 (1.09–15.35)	3.63 (0.95–13.88)	6.03 (1.31–27.78)
Number of calls on a typical 24-hr shift	1–4	1.49 (0.85–2.63)	1.44 (0.82–2.55)	1.40 (0.77–2.53)
	5–7	1.00	1.00	1.00
	8–14	0.87 (0.45–1.67)	1.04 (0.53–2.04)	1.10 (0.50–2.46)
Sedentary work[c]	Strongly disagree	1.00	1.00	1.00
	Disagree	1.42 (0.42–4.72)	1.43 (0.42–4.81)	2.06 (0.57–7.45)
	Agree	2.42 (0.72–8.13)	2.22 (0.63–7.89)	2.42 (0.65–9.03)
	Strongly agree	3.09 (0.85–11.23)	2.92 (0.79–10.85)	4.18 (1.03–16.99)
Supervisor support for exercise	High	1.00	1.00	1.00
	Low	0.88 (0.53–1.48)	0.80 (0.47–1.37)	0.72 (0.41–1.27)
Station dietary climate	Good	1.00	1.00	1.00
	Fair	1.33 (0.49–3.56)	1.51 (0.55–4.11)	1.69 (0.58–4.87)
	Poor	1.59 (0.71–3.59)	1.71 (0.75–3.90)	1.60 (0.66–3.90)
Perceived organizational support	High	1.00	1.00	1.00
	Low	0.96 (0.58–1.58)	0.93 (0.56–1.56)	0.69 (0.39–1.22)

[a]Controlling for the psychosocial working condition variables in Model 1 plus sociodemographic variables (age, race/ethnicity, marital status, and job title).
[b]Controlling for the psychosocial working condition, sociodemographic, and health-related behavioral variables (exercise at station and at home, overeating since childhood, stress-induced overeating, low consumption of high-fiber fruits and vegetables, frequent consumption of soft/energy drinks at station, alcohol consumption), sleep hours at station and at home, and mental health.
[c]Test for linear trend, $P < 0.05$ in Models 1– 3.

There was also a significant ($P < 0.05$) linear dose-response relationship between sedentary work and BMI-based and WC-based obesity prevalence in the multivariate Cox models (Tables II and III), but it was not the case with BFP-based obesity (Table IV). In the final model, the BMI-based obesity prevalence was 4.2 times higher in the firefighters who strongly agreed to the sedentary work item than in the firefighters who strongly disagreed to the sedentary work item. However, the prevalence ratios (PRs) of sedentary work for WC-based and BFP-based obesity were smaller (2.44–2.79) and not statistically significant (Tables III and IV).

Number of calls on a typical 24-hr shift, supervisor support for exercise, station-level dietary climate, and perceived organizational support were not significant risk factors for obesity across any of the three obesity measures. In the final model, the following variables were significant ($P < 0.05$) risk factors for obesity: age [PR (95%CI) = 1.04 (1.00–1.09), $P = 0.04$], overeating since childhood [2.91 (1.57–5.37), $P < 0.01$], and non-alcohol drinkers [2.16 (1.12–4.17), $P = 0.02$] for BMI-based obesity; overeating since childhood [2.05 (1.17–3.59), $P = 0.01$] for WC-based obesity; and age [1.07 (1.02–1.12), $P < 0.01$], low exercise during leisure time [2.26 (1.26–4.03), $P < 0.01$], and non-alcohol drinkers [2.30 (1.17–4.52), $P = 0.02$] for BFP-based obesity. On the other hand, firefighters who reported shorter sleep hours at the fire station (5 or 6 hr at fire station, compared to >6 to 8.5 hr) appeared to be less obese by BMI (but not by WC or PBF) [PR(95%CI) = 0.49 (0.26–0.91), $P = 0.02$], although there was no significant association between the shortest sleep hours (2.5 to <5 hr, compared to >6 to 8.5 hr) at the fire station and BMI-based obesity. By contrast, shorter sleep at home (<7 hr and 7–8 hr, compared to >8 hr) appeared to be a significant risk factor for BMI-based obesity: PRs (95%CI) = 6.90 (0.87–54.66) ($P = 0.068$) and 5.78 (0.77–43.05), $P = 0.087$), respectively.

Sensitivity Tests

The multivariate Cox models for BFP-based obesity with the cut-point of 25% did not make a difference. When it comes to psychosocial working conditions, the results of the multivariate linear regressions with three adiposity measure

TABLE III. Prevalence Ratios (95% Confidence Intervals) of Psychosocial Working Conditions for Obesity (WCs > 102 cm) in 308 Male Firefighters

Psychosocial working conditions	Category	Model 1	Model 2[a]	Model 3[b]
Number of 24-hr shifts in the past month[c]	8–11	1.00	1.00	1.00
	12	1.14 (0.36–3.59)	0.85 (0.26–2.78)	1.26 (0.34–4.75)
	13	1.61 (0.50–5.22)	1.30 (0.39–4.34)	1.95 (0.53–7.20)
	14	1.23 (0.40–3.77)	0.92 (0.30–2.90)	1.28 (0.37–4.40)
	15	1.97 (0.61–6.34)	1.64 (0.50–5.39)	2.36 (0.65–8.53)
	16	2.08 (0.66–6.51)	1.61 (0.51–5.13)	2.70 (0.77–9.46)
	17–21	3.44 (1.06–11.09)	2.59 (0.78–8.60)	3.69 (0.98–13.89)[e]
Number of calls on a typical 24-hr shift	1–4	1.44 (0.82–2.50)	1.34 (0.76–2.34)	1.20 (0.66–2.16)
	5–7	1.00	1.00	1.00
	8–14	1.06 (0.57–1.97)	1.26 (0.67–2.39)	1.34 (0.64–2.80)
Sedentary work[d]	Strongly disagree	1.00	1.00	1.00
	Disagree	1.01 (0.36–3.06)	1.02 (0.35–3.00)	1.24 (0.40–3.87)
	Agree	2.31 (0.80–6.66)	1.65 (0.54–5.04)	1.70 (0.53–5.45)
	Strongly agree	2.63 (0.84–8.29)	2.05 (0.63–6.64)	2.44 (0.71–8.42)
Supervisor support for exercise	High	1.00	1.00	1.00
	Low	1.09 (0.67–1.78)	0.92 (0.55–1.53)	0.81 (0.47–1.40)
Station dietary climate	Good	1.00	1.00	1.00
	Fair	1.03 (0.39–2.74)	1.12 (0.41–3.04)	1.21 (0.42–3.46)
	Poor	1.48 (0.69–3.18)	1.55 (0.71–3.36)	1.34 (0.58–3.10)
Perceived organizational support	High	1.00	1.00	1.00
	Low	1.24 (0.76–2.05)	1.30 (0.77–2.18)	0.99 (0.56–1.74)

[a]Controlling for the psychosocial working condition variables in Model 1 plus sociodemographic variables (age, race/ethnicity, marital status, and job title).
[b]Controlling for the psychosocial working condition, sociodemographic, and health-related behavioral variables (exercise at station and at home, overeating since childhood, stress-induced overeating, low consumption of high-fiber fruits and vegetables, frequent consumption of soft/energy drinks at station, alcohol consumption), sleep hours at station and at home, and mental health.
[c]Test for linear trend, $P < 0.05$ in Models 1–3.
[d]Test for linear trend, $P < 0.05$ in Models 2 and 3.
[e]*P*-value was 0.054.

as continuous variables were very similar to those of the multivariate Cox models. For example, in the final model (Model 3) of the multivariate linear regression, the level of all three adiposity measures was significantly ($P < 0.05$) higher in the firefighters who reported 17–21 shifts than in the firefighters who reported the standard work schedule in the past month. In addition, the level of BMI was also significantly higher in the firefighters who reported 16 shifts in the past month. The level of BMI and WC was significantly higher in the firefighters who strongly agreed to the sedentary work item than in the firefighter who strongly disagreed to the sedentary work item. The level of all three adiposity measures was significantly ($P < 0.05$) higher in the following groups compared to their counterparts: age, low exercise during leisure time, and overeaters since childhood. In addition, stress-induced overeating was associated with higher BMIs and WCs. Frequent consumption of canned drinks (for higher BMI), no alcohol consumption and low consumption of high-fiber fruits and vegetables (for higher WC and BFP), and low exercise at fire station (for higher WC). However, neither sleep hours at fire station nor sleep hours at home appeared to be associated with any adiposity measure, although the shortest sleep hours at home (4 to <7 hr vs. >8 to 10 hr) had higher BMI and WC levels ($P = 0.22$ and $P = 0.24$, respectively). Neither job strain (and its components) or effort-reward imbalance (and its components) nor the three JCQ and one ERIQ items tested made a difference in the results. None of them were associated with obesity in the multivariate analyses.

DISCUSSIONS

To the best of our knowledge, this is the first study demonstrating that many additional 24-hr shifts (≥17 24-hr shifts in the past month, compared to the standard work schedule) and prolonged sedentary work are significant risk factors for obesity in professional male firefighters, independent of other working conditions, sociodemographic variables, health-related behaviors, and psychological distress. Also, the risk for obesity by BMI and WC increased monotonically as the number of 24-hr shifts in the past month

TABLE IV. Prevalence Ratios (95% Confidence Intervals) of Psychosocial Working Conditions for Obesity (BPF > 24%) in 308 Male Firefighters

Psychosocial working conditions	Category	Model 1	Model 2[a]	Model 3[b]
Number of 24-hr shifts in the past month[c]	8–11	1.00	1.00	1.00
	12	1.72 (0.49–6.08)	1.73 (0.48–6.24)	3.05 (0.73–12.68)
	13	1.27 (0.31–5.14)	1.37 (0.33–5.69)	2.22 (0.49–10.14)
	14	1.74 (0.50–6.05)	1.73 (0.49–6.13)	2.28 (0.59–8.83)
	15	1.38 (0.33–5.82)	1.35 (0.32–5.74)	2.00 (0.43–9.17)
	16	1.34 (0.33–5.42)	1.31 (0.32–5.38)	2.14 (0.47–9.77)
	17–21	4.37 (1.19–16.05)	4.17 (1.12–15.56)	5.00 (1.14–21.83)
Number of calls on a typical 24-hr shift	1–4	1.22 (0.67–2.25)	1.12 (0.61–2.06)	1.15 (0.60–2.20)
	5–7	1.00	1.00	1.00
	8–14	0.89 (0.45–1.75)	1.17 (0.58–2.37)	1.25 (0.53–2.97)
Sedentary work[d]	Strongly disagree	1.00	1.00	1.00
	Disagree	0.95 (0.33–2.78)	1.06 (0.35–3.17)	0.98 (0.31–3.09)
	Agree	1.60 (0.54–4.75)	1.71 (0.53–5.46)	1.69 (0.50–5.66)
	Strongly agree	2.13 (0.66–6.95)	2.14 (0.64–7.17)	2.79 (0.78–10.02)
Supervisor support for exercise	High	1.00	1.00	1.00
	Low	1.37 (0.80–2.36)	1.27 (0.72–2.25)	1.20 (0.66–2.17)
Station dietary climate	Good	1.00	1.00	1.00
	Fair	0.59 (0.18–1.88)	0.69 (0.21–2.25)	0.72 (0.21–2.44)
	Poor	1.18 (0.52–2.67)	1.27 (0.55–2.93)	1.25 (0.51–3.08)
Perceived organizational support	High	1.00	1.00	1.00
	Low	1.08 (0.63–1.86)	0.99 (0.56–1.75)	0.71 (0.39–1.30)

[a]Controlling for the psychosocial working condition variables in Model 1 plus sociodemographic variables (age, race/ethnicity, marital status, and job title).
[b]Controlling for the psychosocial working condition, sociodemographic, and health-related behavioral variables (exercise at station and at home, overeating since childhood, stress-induced overeating, low consumption of high-fiber fruits and vegetables, frequent consumption of soft/energy drinks at station, alcohol consumption), sleep hours at station and at home, and mental health.
[c]Test for linear trend, $P < 0.20$ in Models 1–3.
[d]Test for linear trend, $P < 0.10$ in Models 1 and 3, $P < 0.05$ in Model 2.

and the degree of sedentary work increased. However, other psychosocial working conditions in this study were not associated with obesity in the multivariate analyses. This study suggests new intervention points for the prevention of obesity in professional male firefighters in addition to the typical firefighter WEFIT program: the number of 24-hr shifts per month (or per year) and the on-duty sedentary ("sitting") time of firefighters.

Comparisons With the Previous Studies

This study is consistent with several previous studies that have supported the association between long work hours/overtime and obesity [Di and Mummery, 2009; Jang et al., 2014; Solovieva et al., 2013; Luckhaupt et al., 2014; Lemke et al., 2015] or between shift work and obesity [van Amelsvoort et al., 1999; Kubo et al., 2011; Macagnan et al., 2012] in male or gender-mixed working populations, although some studies have not supported the association [Ghiasvand et al., 2006; Lallukka et al., 2008; Choi et al., 2010]. The current study is the first showing the association among professional male firefighters who work on a 24-hr shift work schedule and who also had a large variation in additional (overtime) 24-hr shifts. Compared to the aforementioned studies, the current study has some methodological merits: use of multiple clinical obesity measures and analytical adjustment for a broad range of possible confounders (e.g., other working conditions, health behaviors at work and during leisure time, sleep hours, and psychological distress).

The current study is also consistent with some previous studies in terms of the association between sedentary work and obesity [Mummery et al., 2005; Choi et al., 2010] in male or gender-mixed working populations, although the association was weaker with obesity by BFP. However, it is not consistent with one longitudinal study [Pulsford et al., 2013]. The current study is relatively unique in terms of the following: use of reliable and valid (against inclinometers) questionnaire information; use of multiple clinical obesity measures; and adjustment for many possible confounders (including job title).

On the other hand, other psychosocial working conditions were not significant risk factors for obesity in

this study. Results need to be carefully interpreted due to the following reasons. Since, the firefighters in the current study can change their fire station or working unit (team) on a regular basis (e.g., about every 4 months), the information about the number of calls on a typical 24-hr shift and fire station dietary climate at their current fire station is limited in reflecting their changing exposures. In addition, in the middle of the FORWARD study, the fire department implemented a new standard operating procedure (SOP) that would prohibit firefighters from doing competitive team sports (e.g., football, soccer, baseball, basketball, etc.) at fire stations partly due to their concern about increasing injury-related workers compensation costs. We were informed in our focus groups with the firefighters after the FORWARD study survey that the new SOP was a significant detriment to the morale of the firefighters, which may have had a negative effect on firefighters' perceived organizational support or supervisor support for exercise. Thus, this cross-sectional study was somewhat limited in being able to capture the impact of the changing exposures on obesity in these firefighters. Not surprisingly, given this is a single occupation study with limited variation in job control, psychological job demands, extrinsic efforts, and reward among the firefighters, job strain and effort-reward imbalance were not significant risk factors for obesity in this study.

As expected, shorter sleep hours at home (particularly, 4 to <7 hr) showed an expected, albeit not statistically significant, association with obesity. However, unexpectedly, firefighters who reported 5 or 6 hr at the fire station appeared to be less obese by BMI than firefighters who reported >6 to 8.5 hr. However, a higher number of calls was also correlated with less sleep hours, lower rank and age, high exercise at fire station, and high social support for exercise suggesting that this finding might be related to younger less obese firefighters in busier fire stations getting less sleep because of call volume, and perhaps a better exercise culture. However, it was not the case with WC-based and BFP-based obesity, neither with all three adiposity measures, including BMI as continuous variables in the multivariate linear regression analysis.

Implications for Prevention of Obesity Among Professional Firefighters

The current study indicates many additional 24-hr shifts and prolonged sedentary work are important risk factors for obesity among professional male firefighters, independent of health-related behaviors (e.g., exercise and healthy eating behaviors) at the worksite or during leisure-time. Chronic strain from doing many additional 24-hr shifts beyond the standard work schedule may induce dysfunction of the hypothalamus [Rosmond and Björntorp, 1999; Björntorp, 2001; Bose et al., 2009; Shively et al., 2009]. It could shift energy balance toward the positive via alterations of the autonomic nervous system, endocrine systems, and circadian rhythms in relation to lipid metabolism [Plotsky et al., 1989; Björntorp, 1996; Dodt et al., 2003; Scheer et al., 2009; Bose et al., 2009; Huang et al., 2011]. In our recent small field study [Choi et al., 2014a, 2015b], the level of morning salivary cortisol of seven firefighters who did three consecutive 24-hr shifts (a 72-hr shift) was significantly higher in the 3rd shift than in the 1st shift.

These findings, along with several US firefighter fatality reports involving multiple consecutive 24-hr shifts [National Institute for Occupational Safety and Health, 2008, 2011], suggests that introducing a cap on the number of 24-hr shifts that firefighters can work in a month, may be a good, proactive approach for the prevention of obesity and CVD among firefighters. After the end of the FORWARD study, the fire department in the current study implemented such a policy, restricting firefighters' annual voluntary 24-hr shifts (to 15 shifts per month, on average) in order to share the burden of additional 24-hr shifts more equally among the firefighters. However, many fire departments in the US do not yet have such a proactive policy [Choi et al., 2014a].

This study also indicates that many additional 24-hr shifts, as a work stressor, may increase the risk for obesity in male firefighters indirectly through stress-induced over-eating behaviors (a significant correlation, $r = 0.12$, $P < 0.02$), but not through the other eating behaviors measured, nor exercise, sleep hours, or psychological distress. This indirect effect points to some potential beneficial effects of incorporating stress management training particularly regarding eating behaviors (e.g., mindful eating) [O'Reilly et al., 2014] into firefighter WEFIT programs.

On the other hand, this study reminds us of the importance of reducing sedentary work time in addition to doing regular exercise at work and during leisure-time, which is in line with the recommendation of the US College of Sports Medicine [Garber et al., 2011]. In this context, many fire departments need to take into consideration the possible long-term negative impacts of prohibiting team sports at fire stations on the overall physical activity, fitness, and cardiovascular health of firefighters. It may inadvertently result in increased on-duty sedentary time and incremental weight gain in firefighters. A recent longitudinal study [Jahnke et al., 2013] reported that obese firefighters are 5.2 times more likely to experience musculoskeletal injuries than non-obese firefighters. According to another study [Kuehl et al., 2012], obese firefighters are 2.9 times more likely to file workers' compensation claims than non-obese firefighters. Team sports at fire stations have great potential to be leveraged for the prevention of CVD and even injuries in firefighters who are also an inherently competitive group/occupational culture. In addition to team sports, other actions can be explored with firefighters to reduce their on-duty

sedentary time: using active work stations (e.g., a sit-and-stand work station) [Chau et al., 2014; Swartz et al., 2014] and having regular short-term breaks during desk work (e.g., 5–10 min every 1 hr computer work) [Occupational Safety and Health Administration, 1997; Dunstan et al., 2012] coupled with walking around in the fire station or in the nearby community.

Limitations

This study has several limitations. First, this study is a cross-sectional study, so we cannot be completely sure of the temporal relationships between obesity and the number of 24-hr shifts in the past month and prolonged sedentary work. However, it is unlikely that obesity is a cause of additional 24-hr shifts because voluntary additional 24-hr shifts are motivated mainly by the financial needs of firefighters, the need of the fire department to ensure full coverage of all fire-stations, and are determined through an internal competitive process, regardless of obesity status. In addition, reverse causation does not explain the dose-response relationship between the number of 24-hr shifts and obesity in the current study. Furthermore, our qualitative research with the firefighters confirmed that 24-hr shift work is a risk factor for obesity because of its relationship from the perspective of firefighters in the focus groups, to fatigue and eating choices [Dobson et al., 2013]. However, two longitudinal studies [Ekelund et al., 2008; Pulsford et al., 2013] reported that baseline obesity or BMI status was associated with time spent watching TV or overall sitting time (but not work sitting time). Thus, future longitudinal studies are needed to clarify the temporal relationship between on-duty sedentary time during a 24-hr work shift and obesity among firefighters. Second, the information on numbers of 24-hr shifts in the past month was self-reported and the time reference was limited to the past month. However, the average of the 24-hr shifts in the past month in the current study coincided with that of the administrative records of the fire department (2–3 more additional 24-hr shifts). Although the number of 24-hr shifts that firefighters work can change month to month, we do not think it changed substantially because the fire department relies on firefighters doing additional 24-hr shifts and it is related to the household income of firefighters. In our recent another study [Choi, 2015] with 11 male firefighters from the same fire department as in the current study and filled out the FORWARD questionnaire twice with a time interval of a month, we had a chance to examine the distributions and 1 month test–retest reliability of the number of 24-hr shift in the past month. The mean was 13.3 shifts (standard deviation, 2.00 shifts) at the first administration and 13.5 shifts (standard deviation, 3.2 shifts) at the second administration. This is very similar to the average and standard deviation of the number of 24-hr shifts in the current study. The information on the number of 24-hr shift in the past month between the first and second administrations was reliable: Spearman correlation, 0.81 ($P < 0.01$) and intra-class coefficient, 0.68 ($P < 0.01$). However, using long-term administrative records of fire departments will improve the quality of exposure assessment in future research.

AUTHORS' CONTRIBUTION

All authors meet the authorship described as recommended by the ICJME: all authors made substantial contributions to the design of this study and acquisition, analysis, or interpretation of data for the work. BC devised and drafted this manuscript and MD, PS, and JG revised it critically. All authors read and approved this manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ACKNOWLEDGMENTS

We express our sincere thanks to a fire department and a local union of the International Association of Fire Fighters (IAFF) in Southern California for their support and input for this study. The fire department and union had no decision-making role in the decision to publish study results or the content of the publication. This study was supported by the Centers for Disease Control and Prevention (CDC)/National Institute for Occupational Safety and Health (NIOSH) (Grant #, 5R21OH009911-02). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the CDC/NIOSH.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven Markowitz declares that he has no competing or conflicts of interest in the review and publication decision regarding this article.

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