Obesity and Cardiovascular Disease Risk Factors in Firefighters: A Prospective Cohort Study

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Abstract

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Objective: Obesity, despite being a significant determinant of fitness for duty, is reaching epidemic levels in the workplace. Firefighters' fitness is important to their health and to public safety.

Research Methods and Procedures: We examined the distribution of BMI and its association with major cardiovascular disease (CVD) risk factors in Massachusetts firefighters who underwent baseline (1996) and annual medical examinations through a statewide medical surveillance program over 5 years of follow-up. We also evaluated firefighters' weight change over time.

Results: The mean BMI among 332 firefighters increased from 29 at baseline to 30 at the follow-up examination (2001), and the prevalence of obesity increased from 35% to 40%, respectively ($p < 0.0001$). In addition, the proportion of firefighters with extreme obesity increased 4-fold at follow-up (from 0.6% to 2.4%, $p < 0.0001$). Obese firefighters were more likely to have hypertension ($p = 0.03$) and low high-density lipoprotein-cholesterol ($p = 0.01$) at follow-up. Firefighters with extreme obesity had an average of 2.1 CVD risk factors (excluding obesity) in contrast to 1.5 CVD risk factors for normal-weight firefighters ($p = 0.02$). Finally, on average, normal-weight firefighters gained 1.1 pounds, whereas firefighters with BMI ≥ 35 gained 1.9 pounds per year of active duty over 5 years of follow-up.

Discussion: Obesity is a major concern among firefighters and shows worsening trends over time. Periodic medical evaluations coupled with exercise and dietary guidelines are needed to address this problem, which threatens firefighters' health and may jeopardize public safety.

Key words: BMI, fitness, clustering, weight, cardiovascular disease

Introduction

Obesity has reached epidemic levels in our society and has been associated with numerous adverse health and employment outcomes in the general population, including lower productivity and job performance (1–6). Obesity can have a significant impact on work capacity and fitness for duty. When obesity affects first responders, it may jeopardize their own safety and well-being, as well as public safety (7). Hence, fitness for work is of paramount importance for the over 1 million U.S. professional and volunteer firefighters and the public they serve. Therefore, the National Fire Protection Association (NFPA)[1] has published recommendations for baseline and periodic fitness for duty evaluations to ensure that firefighters can safely perform essential job functions under emergency conditions (8).

The NFPA divides its recommendations into category A

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[1] Nonstandard abbreviations: NFPA, National Fire Protection Association; CVD, cardiovascular disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

and B medical conditions, including detailed evaluation criteria for heart disease, asthma, hypertension, diabetes, and other health problems. The presence of a category A condition excludes a firefighter from active duty. Category B conditions may be exclusionary depending on their severity. Although the NFPA specifies that body weight should be recorded annually and BMI evaluations should follow current NIH guidelines, even extreme obesity is not considered a category A or B condition (8). Additionally, there are no specific requirements for BMI in the current NFPA Standard on Health-Related Fitness Programs for Firefighters (9). Firefighters are expected to perform at near-maximal heart rates physically demanding job tasks such as rescue and fire suppression while wearing in excess of 50 pounds of personal protective equipment including self-contained breathing apparatus. Obese firefighters have lower exercise tolerance and are more likely to experience adverse consequences from heat stress, including heat disorders (10,11).

Despite the existing NFPA guidelines for periodic medical surveillance, many fire departments have no medical evaluation programs, other than baseline examinations for new recruits. In addition, most firefighters are not required to maintain minimum physical capacities or follow exercise training programs. In parallel with the general population, cardiovascular disease (CVD) is a frequent cause of morbidity and mortality among firefighters. Uniquely, it is also the most common cause of on-duty mortality in U.S. firefighters, accounting for ~45% of firefighter fatalities at work (12,13). These on-duty events are largely premature deaths due to coronary heart disease, many of which likely could be prevented through improved physical fitness, nutrition, and health surveillance.

Several researchers have evaluated the CVD risk factor profile of firefighters (14–16). We have reported previously on the impact of hypertension on the employment status of firefighters (17), the evolution of their lipid profiles over time (18), and the strong association between underlying risk factors and preexisting heart disease with on-duty coronary heart disease fatalities in firefighters (19).

Obesity is a significant risk factor for CVD and has also been associated with other adverse health outcomes. Although previous cross-sectional studies have examined BMI in firefighters (20–22), little is known about the evolution of obesity in firefighters over time (23).

The objectives of the present study were to describe the distribution of BMI in a cohort of firefighters over time, according to the current NIH guidelines (24). In addition, we examined the association of obesity with other CVD risk factors and evaluated weight changes in active duty firefighters over 5 years of prospective follow-up.

Research Methods and Procedures

Study Population

The study base consisted of 340 members of six regional hazardous materials teams in the Commonwealth of Massachusetts who underwent a baseline medical examination in 1996 or 1997 when a statewide medical surveillance program was initiated. The firefighters joined the hazardous materials teams on a contractual basis in addition to their primary occupational duties as municipal firefighters in local fire departments throughout the state of Massachusetts. Physical fitness criteria were not considered in the selection of hazardous materials team members.

Eight firefighters were excluded from the study sample, resulting in a baseline sample of 332 firefighters; one firefighter was excluded at baseline because BMI was missing, two firefighters because they had a medical examination but never joined a hazardous materials team, and a fourth firefighter because of "injured on duty" status at baseline. In addition, the only four female firefighters were also excluded from further analyses.

The study population consisted of an open cohort. Twenty-five additional firefighters were enrolled during the follow-up period, while other firefighters did not maintain active status, either temporarily or permanently. Overall, 62 firefighters were not included in the prospective analyses due to lack of follow-up information. Thus, a subsample of 270 firefighters, who had BMI measurements at both the baseline and the follow-up examination, was used in comparisons over time. Our study was approved by the Institutional Review Boards of the Harvard School of Public Health, by the Cambridge Health Alliance, and by the Northeast Specialty Hospital.

Baseline and Follow-up Medical Examinations

Medical surveillance examinations were performed at one of three contracted Massachusetts hospitals. The baseline examinations for most of the firefighters took place in 1996 (82%) and the remainder in 1997. The subsequent medical examinations for the total study sample took place during the fall of 1998, 1999, 2000, and 2001. The examinations were done for the dual purposes of medical surveillance and fitness for duty evaluation for the state hazardous materials teams. All examinations were conducted in a similar fashion and followed a written protocol. Examinations included a detailed medical and occupational/environmental history, a physical examination, and routine laboratory tests. BMI was not a fitness for duty criterion.

BMI Measurements

At the baseline and each follow-up examination, firefighters underwent weight and height measurements, which were documented on each firefighter's summary sheet and sent to a computerized medical record repository. Weight and height measurements were done without shoes and with light clothes using standard clinic scales and stadiometers. Weight was measured to the nearest pound and height to the nearest 0.5 inch. BMI was calculated using the formula: BMI = 703.1 × (weight in pounds)/(height in inches)^2, which is equivalent to weight in kilograms divided by height in meters squared. The firefighters were assigned to different BMI categories according to the current guidelines from the National Obesity Education Initiative of the National Heart Lung and Blood Institute (24). Obesity was defined as a BMI of 30 or greater and extreme obesity as a BMI of 40 or higher.

Additional CVD Risk Factors

Prospective information on several other factors was also routinely collected at every examination and entered into the computerized repository. Baseline and follow-up measurements included smoking status, blood pressure, blood glucose, lipids, and updated medical history. The blood glucose and lipid measurements were not fasting because the examinations had to be done at various times throughout the day while the firefighters were on duty, and it was not possible to keep them fasting over long periods of time while working.

Data Analyses

Summary results for each firefighter's examination were submitted to a computerized medical record repository. After electronic data management procedures, an investigator selected a random sample of records (>25% of the whole data set) and cross-examined the electronic files comparing them with the actual medical records. The results showed 1% miscoding between the two data sets, and all mismatched values were corrected.

Statistical analyses were performed using SAS software (version 6.12) (25). Student's t test and χ^2 tests were used to test for differences in standard CVD risk factors (age, smoking, hypertension, diabetes, cholesterol, etc.) among firefighters with normal or high BMI. Several different categorizations of BMI were used in our analyses including dichotomous (BMI <30 or ≥30) and categorical (three categories, tertiles, and quartiles of BMI according to the study distribution) measures. CVD risk factors such as hypertension, lipid profile parameters, and diabetes were dichotomized based on current NIH guidelines. Smoking was dichotomized as current vs. no current smoking (including ex-smokers). Additional comparisons for BMI were also made between baseline and follow-up examinations. Linear mixed-effects models were used to evaluate weight changes in firefighters over 5 years of follow-up. The level of significance was 0.05 and two-sided for all tests.

Results

A total of 332 firefighters were included in our baseline analyses. The mean age of the study participants at baseline was 39 years (range, 20 to 58 years). In Table 1, we present the distribution of BMI at baseline, in 1999, and in 2001. The mean BMIs at the baseline and 2001 follow-up exam-

Table 1. Distribution of BMI in firefighters at baseline and follow-up examinations*

		Follow-up	
	Baseline: 1996/1997	**1999**	**2001**
Total number	332	308	297
Mean BMI (±SD)	29.0 (4.1)	29.4 (4.3)	29.7 (4.3)
Median BMI (range)	28.5 (19.3–44.7)	28.8 (18.1–45.5)	29.2 (21.3–48.6)
	% (*n*)	% (*n*)	% (*n*)
Underweight (BMI < 18.5)		0.3 (1)	
Normal weight (18.5 ≤ BMI < 25)	12.0 (40)	13.3 (41)	10.4 (31)
Overweight (25 ≤ BMI < 30)	53.0 (176)	49.3 (152)	49.8 (148)
Obesity I (30 ≤ BMI < 35)	27.1 (90)	27.3 (84)	29.0 (86)
Obesity II (35 ≤ BMI < 40)	7.2 (24)	7.1 (22)	8.4 (25)
Extreme obesity III (BMI ≥ 40)	0.6 (2)	2.6 (8)	2.4 (7)
Obesity (total) (BMI ≥ 30)	34.9 (116)	37.0 (114)	39.7 (118)

* According to the National Heart Lung and Blood Institute guidelines on the identification, evaluation, and treatment of overweight and obesity in adults.

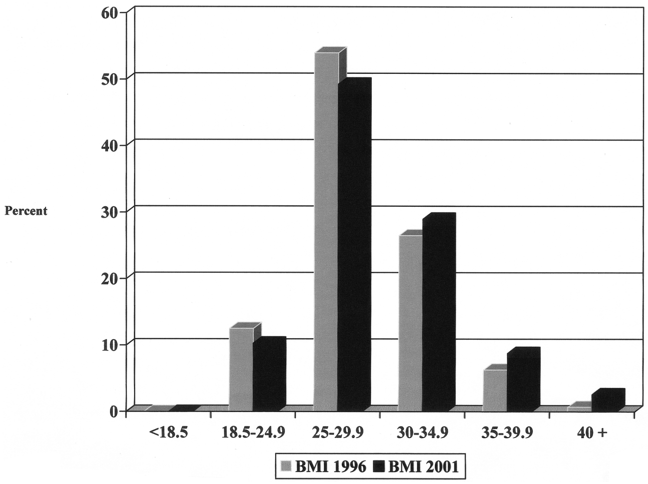

Figure 1: The distribution of BMI at baseline and follow-up examination for firefighters who maintained active status during the whole period of the study. Gray bars represent the BMI distribution at baseline, and dark bars represent the distribution in 2001 ($N = 270$).

inations were 29.0 and 29.7, respectively. Obesity prevalence increased significantly in 2001 (39.7%) compared with baseline (34.9%) ($p < 0.0001$). Extreme obesity (BMI $\geq$ 40) also increased significantly over time, from 0.6% to 2.4% ($p < 0.0001$). The overall incidence rate of obesity in our cohort was 45 per 1000 person-years. Given a constant incidence rate over time, we estimated a 5-year cumulative incidence of obesity to be 22%.

In Figure 1, we present the distribution of BMI at baseline and at 5 years of follow-up for firefighters who participated in both surveillance examinations ($N = 270$). We observed a shift to the right of the distribution of BMI, with increases in all obesity categories. The increases in obesity and extreme obesity also persisted when only those who maintained active duty throughout the whole study period were considered.

In Table 2, we compared the distribution of CVD risk factors in obese and non-obese firefighters over 5 years of follow-up. Firefighters with obesity were more likely to have hypertension at both examinations. On average, normal-weight firefighters were found to have 1.5 additional CVD risk factors (excluding obesity) compared with 1.8 additional CVD risk factors for obese firefighters ($p = 0.90$) and 2.1 additional CVD risk factors for firefighters with extreme obesity ($p = 0.02$).

The high-density lipoprotein (HDL)- and low-density lipoprotein (LDL)-cholesterol, for those who completed the follow-up examination, are also presented in Table 2. Tests for LDL- and HDL-cholesterol were not performed at baseline examination. Obese firefighters were significantly more likely to have low HDL-cholesterol compared with normal-weight firefighters.

Table 2. Association of obesity and CVD risk factors among firefighters who maintained active duty for the whole 5-year study period ($n = 270$)

	Baseline (1996/1997)			Follow up (2001)		
	BMI			BMI		
	<30 [% (*n*)]	≥30 [% (*n*)]	*p*	<30 [% (*n*)]	≥30 [% (*n*)]	*p*
Percentage (*n*)	66.3 (179)	33.7 (91)		59.6 (161)	40.4 (109)	
Age ≥ 45	21.8 (39)	26.4 (24)	0.40	46.0 (74)	50.9 (55)	0.42
Smoking	9.5 (17)	7.7 (7)	0.62	9.3 (15)	5.5 (6)	0.25
Hypertension*	14.0 (25)	25.3 (23)	0.02	16.3 (26)	27.1 (29)	0.03
High cholesterol†	69.9 (121)	70.3 (64)	0.95	58.4 (94)	60.2 (65)	0.77
Low HDL-cholesterol†				16.1 (27)	28.4 (31)	0.01
High LDL-cholesterol†				10.6 (17)	11.9 (13)	0.73
High glucose‡	2.6 (2)	2.4 (1)	0.95	6.2 (10)	9.2 (10)	0.37

* Hypertension was defined as a systolic blood pressure of 140 mm Hg or higher and/or a diastolic blood pressure of 90 mm Hg or higher.
† High cholesterol was defined as total cholesterol of 200 mg/dl or higher. Low HDL cholesterol was defined as HDL of 40 mg/dl or lower, and high LDL cholesterol was defined as LDL of 160 mg/dL or higher (non-fasting).
‡ High glucose was defined as blood glucose of 126 mg/dL or higher. Data were limited to 117 participants for the baseline examination (non-fasting).

Using linear mixed models, we examined temporal changes in body weight among firefighters on active duty. On average, firefighters gained 1.15 pounds per year of active duty over 5 years of follow-up ($p < 0.0001$). The weight gain per year of active duty for normal-weight, overweight, stage I obesity, and firefighters with obesity stage II or III was 1.1, 0.8, 1.1, and 1.9 pounds, respectively. Furthermore, weight gain in younger firefighters (age < 45) was twice that in older firefighters (Table 3). In addition, we found that the association of calendar year with weight changes was not linear, suggesting that firefighters gained weight at a higher rate during the later years of active duty compared with right after baseline. (A squared term for calendar year was statistically significant, $p < 0.0001$.)

Discussion

Our investigation demonstrated a high prevalence of obesity among a population of male firefighters that increased significantly over a 5-year period from ~35% to 40%. In addition, the whole distribution of BMI in the cohort of firefighters shifted toward obesity categories, with the proportion of firefighters with extreme obesity (BMI ≥ 40) increasing significantly at the follow-up examination. We also found that obesity was associated with the clustering of major CVD risk factors, except smoking. Furthermore, to our knowledge, this is the first study to examine annual weight gain in firefighters and show that, on average, firefighters gained weight during follow-up at an accelerating rate, while younger or obese firefighters gained significantly more weight compared with older or non-obese firefighters, respectively.

Previous studies have shown that obesity has become an epidemic in our society (26,27). Furthermore, obesity is associated with clustering of CVD risk factors (28,29) and many adverse health outcomes in the general population (30–32), while several studies have also examined the negative economic implications of obesity (33–36). The results of our investigation on the distribution of obesity and its association with major CVD risk factors in firefighters are in agreement with previous studies. Ide (14) found that the prevalence of obesity in firefighters from enlistment to retirement in a Scottish cohort increased significantly from 8% at baseline to 22% at the final examination. Glueck et al. (15) also reported a significant increase of BMI in a cohort of Cincinnati firefighters over an average of 6 years of follow-up. Similarly, Davis et al. (16) showed, in professional firefighters from California, that the percentage of body fat as well as obesity (BMI ≥ 30) increased significantly in firefighters between the 1st and 4th decades of their career span.

Table 3. Mixed linear regression coefficients for the relationship of weight in firefighters regressed on calendar year of active duty*

	Calendar year of active duty: multivariable-adjusted regression coefficient (S.E.)†	*p*
Firefighters' weight (overall)	1.15 (0.23)	<0.0001
Firefighters' weight		
Dichotomous		
Non-obese (BMI < 30)	0.72 (0.21)	0.0006
Obese (BMI ≥ 30)	1.36 (0.32)	<0.0001
Categorical		
Normal weight (BMI < 25)	1.08 (0.37)	0.005
Overweight (25 ≤ BMI < 30)	0.79 (0.21)	0.0002
Obesity I (30 ≤ BMI < 35)	1.06 (0.26)	<0.0001
Obesity II and obesity III (BMI ≥35)	1.92 (0.75)	0.01
Firefighters' age		
Dichotomous		
Younger (age < 45)	1.56 (0.55)	0.0052
Older (age ≥ 45)	0.75 (0.33)	0.02

* Firefighters' weight was regressed on calendar year, which was used as a dummy variable. Separate models were run for different strata to produce the above estimates.
† All models were adjusted for firefighters' age (continuous) and smoking status (dichotomous).

Another concerning finding of our study was that firefighters, on average, gained about 1 pound per year, whereas firefighters with BMI $\geq$ 35 gained almost 2 pounds per year of active duty. A number of previous studies have estimated the average cumulative weight gain in different populations by comparing two measurements over a time interval ranging from 7 to 10 years (37–40). The estimated annual weight gain in male firefighters in our study (adjusted for age and smoking status, and based on annual measurements) fell within the range of previous reports because the annualized estimate of weight gain in another study ranged from 1.5 to 2.7 pounds in men and women (38). Furthermore, our results are consistent with prior research showing that younger compared with older individuals are more likely to gain weight. Of more concern was our finding that the rate of weight gain increased over time and more so among younger firefighters. Both findings suggest an accelerating trend and may also indicate a cohort effect more prominent in the younger firefighters.

CVD is the most frequent cause of mortality among firefighters and is associated with underlying CVD risk factors (19). Because obesity is associated with the clustering of CVD risk factors, and BMI is increasing over time, findings from our current investigation and previous studies reinforce an urgent need for heightened attention to firefighters' CVD and overall risk profile. In particular, our results suggest that weight control and screening for CVD risk factors should be a major goal of every fire department and all physicians providing care for firefighters. Several layers of action including medical standards, increased physician awareness, in-house exercise programs, dietary modifications, and surveillance examinations are needed to address the obesity problem in firefighters.

Several limitations of our study should be acknowledged. Due to a small number of women, we limited analyses to men; therefore, our results may not be generalizable to female firefighters. Second, the annual examinations were conducted in three different hospitals. Height and weight measurements were standardized; we did not find significant differences in the prevalence of obesity among the three hospitals at baseline ($p = 0.36$). In addition, blood glucose and lipid profile were not based on fasting blood draws as explained in the methods section, thereby limiting our ability to perform further analyses on other conditions such as impaired fasting glucose. Third, the follow-up comparisons were performed on firefighters who had complete data on both examinations, limiting our sample size. Nevertheless, the above limitation most likely contributed to underestimation of the adverse consequences of obesity in our cohort because preliminary analyses showed that obese firefighters were less likely to maintain active duty due to adverse health and employment outcomes. Moreover, we compared the mean BMI of the 62 firefighters (29.5) not included in the prospective analyses with the mean BMI of the 270 firefighters (28.9) included in the prospective study and found no statistically significant difference between the two groups ($p = 0.30$). Fourth, rather than direct measurements of percentage body fat, we used BMI as a determinant of overweight and obesity with its documented limitations (41,42). Although BMI may overestimate overweight among muscular firefighters, it is the most recognized and studied measure of obesity, it provides a basis for comparison across studies, and it should have had limited impact on those classified as obese or extremely obese. Furthermore, this would not have affected our findings associating obesity with the clustering of CVD risk factors and annual weight gain in firefighters. Finally, we did not have information on physical activity and dietary intake of firefighters; therefore, we were unable to associate our findings on obesity with individual lifestyle factors. We do know, however, that the National Fire Protection Association recently documented that 89% of Massachusetts fire departments have no programs to maintain basic fitness and health (43).

In conclusion, we observed a high prevalence of obesity among firefighters that increased significantly over 5 years of follow-up. While on active duty, firefighters gained weight at an accelerating rate, and obese firefighters demonstrated a clustering of CVD risk factors. These results have negative implications for firefighters' health and potentially on public safety. Greater awareness of this problem in association with firefighters' risk for heart disease (13,19) should lead all physicians to manage firefighters' CVD risk factors more aggressively. In addition, we believe that obesity stage III (BMI $\geq$ 40) should be considered as an exclusion criterion for active duty firefighters and that the NFPA should develop specific guidelines regarding this issue. Finally, fire department initiatives addressing exercise, weight control, healthy diet, and periodic health surveillance (44) should be promoted across the country to positively impact on the current obesity epidemic.

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