Effect of Obesity on Acute Hemostatic Responses to Live-Fire Training Drills

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The objective of this study was to evaluate the impact of obesity and firefighting activities on coagulation and fibrinolytic activity in relatively young, apparently healthy firefighters. Firefighters performed simulated firefighting activities for 18 minutes in a live-fire training structure. Blood samples were obtained at baseline, before firefighting, and within a few minutes of completing the activity. Nearly all markers of coagulation and fibrinolytic activity increased immediately after firefighting with an overall shift toward a procoagulatory profile. Obese firefighters exhibited lower levels of tissue plasminogen activator activity (0.98 vs 0.63 IU/ml) and higher levels of plasminogen activator inhibitor-1 activity (2.2 vs 4.5 ng/ml) at baseline compared with normal-weight firefighters, suggesting that fibrinolytic activity was lower in obese firefighters. There were few interactions between body mass index and firefighting activity, thus our findings suggest that obese firefighters did not exhibit a greater procoagulatory response to live firefighting compared with normal-weight firefighters. Acute live firefighting produced increases in both fibrinolytic and coagulatory responses; although obesity was associated with a reduced fibrinolytic profile at baseline, the changes produced by acute firefighting were similar in obese and nonobese firefighters. **(Am J Cardiol 2014;114:1768−1771)**

Obesity is an established cardiovascular risk factor that is associated with increased cardiovascular disease mortality and morbidity. Obese firefighters are at increased risk for on-duty coronary heart disease events and cardiovascular disease retirements.[1,2] Obesity is also associated with an increased procoagulatory profile, evidenced by increased levels of fibrinogen, factor VII and factor VIII, and von Willebrand factor.[3] Furthermore, obesity is associated with reduced fibrinolysis, evidenced by reduced levels of tissue plasminogen activator (tPA) and increased levels of plasminogen activator inhibitor-1 (PAI-1).[4,5] In fact, the normal exercise-induced increase in fibrinolysis is blunted in obese subjects.[6,7] This is of potential concern because obesity is prevalent in firefighters, with several studies reporting that approximately 70% of firefighters are overweight or obese.[8−10] Thus, it is possible that the combination of obesity with high thermal and psychological stress coupled with strenuous physical activity may produce a procoagulatory hemostatic milieu during live firefighting. However, this has not been investigated to date. Therefore, the purpose of this study was to investigate changes in markers of coagulation and fibrinolysis in response to live-fire training and to evaluate the effect of obesity on the hemostatic response.

Methods

Participants were 36 male firefighters, (19 normal weight, defined as a body mass index [BMI] <25 and 17 obese, defined as those with a BMI >30), from fire departments across the state of Illinois. Table 1 displays the descriptive data for the study participants.

This study was approved by the University of Illinois Institutional Review Board, and all participants signed an informed consent document before participation in the study. Based on health history, exclusion criteria included atherosclerotic cardiovascular disease, medications for high blood pressure or cholesterol, or medications that affect blood hemostasis.

Venous blood samples were obtained in the sitting position with little or no stasis. Baseline physiological data (heart rate and core temperature) were then recorded. Core temperature was measured throughout the firefighting activities using a MiniMitter CorTemp (Philips Respironics, Inc, Bend, OR) capsule. Heart rate was measured using a heart rate monitor (Polar Electro Oy, Warminster, PA). Simulated firefighting activities were performed in a 6-story training tower. After the simulated firefighting activities, participants immediately returned to the testing area where the same measurements and a second blood sample were collected.

The simulated firefighting activities took place on the second floor of the training building, where temperatures at waist level (1.2 m) averaged between 71 to 82°C and the floor temperatures were maintained at 35 to 41°C. Throughout the study, participants wore National Fire

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See page 1771 for disclosure information.

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Table 1
Descriptive statistics for normal weight (body mass index [BMI] < 25) and obese and obese (BMI > 30) firefighters (mean ± standard deviation). Unless otherwise noted there were 19 subjects in the normal weight and 17 subjects in the obese group

Variable	Normal weight (BMI < 25)	Obese (BMI > 30)	p
Age (yr)	25.7±7.0	34.3±7.4	**0.001**
Height (m)	1.77±0.07	1.76±0.05	0.698
Weight (kg)	71.8±7.3	103.6±9.6	**<0.001**
Body Mass Index ($kg \cdot m^{-2}$)	22.8±1.8	33.5±2.9	**<0.001**
Waist circumference (cm)*	78.9±4.8	99.0±8.1	**<0.001**
Resting Heart Rate ($b \cdot min^{-1}$)†	55.4±10.0	62.0±10.8	0.070
Systolic blood pressure (mm Hg)†	121.8±8.7	127.9±9.6	0.063
Diastolic blood pressure (mm Hg)†	66.2±6.6	74.7±10.1	**0.008**

* Data from 18 subjects in normal weight and 15 subjects in obese group were analyzed for this variable.

† Data from 18 subjects in normal weight and 16 subjects in obese group were analyzed for these variables.

Protection Association 1971 compliant bunker style personal protective equipment (Total Fire Group, Dayton, OH) that was purchased for the study and fitted to each participant. Participants wore a Scott 50i (Monroe, NC) self-contained breathing apparatus with a 30-minute carbon fiber air cylinder. The average weight of a full set of personal protective equipment with Scott 50i self-contained breathing apparatus was ∼20 kg. The firefighters completed a total of 18 minutes of simulated firefighting activity divided into 9 two-minute periods of alternating rest or work cycles. Thus, the drills involved 8 minutes of activity and 10 minutes of relative inactivity, during which the participants received instructions, in a building that contained live fires. The alternating periods of work and relative inactivity simulated realistic fire scenarios during which firefighters often perform brief bouts of strenuous work followed by periods during which they wait for coordinated activities to be accomplished and further instruction from officers. The work cycles included stair climbing, simulated forcible entry, a simulated secondary search, and simulated hose advance. The prescribed firefighting activities (other than stair climbing) required participants to work almost exclusively in the vertical location from 0.5 to 1 m from the floor.

Blood samples were obtained using tubes containing 3.2% sodium citrate for measurements of all coagulation and fibrinolytic factors, except for the assessment of tPA activity, in which those samples were collected into Stabilyte tubes (Biopool, Wicklow, Ireland). All the samples were centrifuged at 2,300 rpm for 25 minutes at 4°C with the plasma removed and placed into 12 aliquots and stored at −70°C for later analysis. PAI-1 antigen, tPA antigen, fibrinogen, and tissue factor were analyzed in duplicate using an enzyme-linked immunosorbent assay kit (ELISA; American Diagnostica, Stamford, Connecticut). Prothrombin fragment 1 and 2 (PF1+2) was analyzed by the way of Enzygnost F 1 + 2 ELISA kits (Siemens Healthcare Diagnostics, Inc, Deerfield, IL). Antithrombin III was analyzed in duplicate using an ACTICHROME chromogenic activity kit (American Diagnostica, Stamford, Connecticut). tPA and PAI-1 activities were analyzed in duplicate using commercially available chromogenic substrate kits (Diapharma Group, Inc., West Chester, Ohio). Factor VIII activity was analyzed in duplicate using a chromogenic assay kit (Chromogenix/Diapharma Group Inc., West Chester, Ohio). Activated partial thromboplastin time was analyzed using STA-PTT Automate 5 (Diagnostica Stago, Inc., Parsippany, New Jersey). Platelet count was assessed from venous whole blood as part of a complete blood count analysis (COULTER LH 700 Series; Beckman Coulter, Inc., Fullerton, California). Platelet function was assessed by epinephrine-induced and adenosine 5′-diphosphate−induced platelet aggregability using a platelet function analyzer (PFA-100; Dade Behring, Deerfield, Illinois). Plasma volume was determined according to the methods of Dill and Costill.[11]

Descriptive statistics were calculated for each variable before and after firefighting and are reported as mean ± SD. Variables were checked for normal distribution, and those variables not normally distributed were log transformed (natural logarithm) before statistical analyses. Differences in participants' descriptive variables between the BMI groups were evaluated with a 1-way analysis of variance test. To evaluate the effect of live firefighting and potential group differences in the response to live firefighting, a 2 × 2 (group [normal vs obese] by time [before vs after firefighting]) analysis of variance with repeated measures was conducted. The *t* test was used for post hoc evaluations when analysis of variance findings were significant. Significance was set at $p < 0.05$.

Results

The obese group exhibited significantly higher BMI than the normal-weight group and they were also significantly older and had higher diastolic blood pressures ($p < 0.05$) (Table 1). There were no significant differences between the groups in the heart rate response to firefighting, but core temperature increased significantly more in the normal-weight group (Table 2). There was no significant difference between the groups in the plasma volume shift after firefighting. Thus, all coagulatory and fibrinolytic variables are presented without corrections for changes in plasma volume. As shown in Table 3, there was a significant effect of acute firefighting on platelet count, epinephrine-induced closure time, and all coagulatory (other than fibrinogen and PF1+2) and fibrinolytic variables (before vs after firefighting, $p < 0.05$). In addition, there was a group effect for tPA activity, PAI-1 activity, and PF1+2, with the obese group exhibiting lower tPA activity and higher levels of PAI-1 activity and PF1+2 ($p < 0.05$). However, a significant group by time interaction was only observed for tPA antigen and tissue factor ($p < 0.05$), with the normal-weight group exhibiting a greater response to firefighting (Table 3).

Discussion

The main finding of this study was that a short bout of live-fire training caused a significant increase in levels of coagulatory and fibrinolytic markers in apparently healthy young firefighters; however, there was an overall shift toward a procoagulatory state as evidenced by a decrease in activated partial thromboplastin time and an increase in platelet activity. Our results add to previous findings