Impact of a Design Modification in Modern Firefighting Uniforms on Burn Prevention Outcomes in New York City Firefighters

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Our aim was to determine the impact of three different firefighting uniforms (traditional, modern, and modified modern) on the incidence and severity of thermal burn injuries, the major occupational injury affecting firefighters. Injury data were collected prospectively for the entire New York City Fire Department (FDNY) firefighting force wearing FDNY's traditional uniform (protective over-coat) from May 1, 1993 to August 31, 1993; FDNY's modern uniform (protective over-coat and over-pant) from May 1, 1995 to August 31, 1995; and FDNY's modified modern uniform (short sleeved shirt and short pants, rather than long-sleeved shirt and long pants, worn under firefighter's protective over-clothes) from May 1, 1998 to August 31, 1998. Outcome measures were burn incidence and severity. Adverse outcomes were heat exhaustion and cardiac events. During this 12-month study, 29,094 structural fires occurred. The incidence rate for upper extremity burns was 2341 per 100,000 fires and for lower extremity burns, 2076 per 100,000 fires. With the change from the traditional to modern uniform, the distribution of burns per fire decreased significantly ($P = 0.001$) for upper extremity burns (86%) and lower extremity burns (93%). With the change from traditional to modern uniform, days lost to medical leave for upper or lower extremity burns decreased by 89%. The majority of burns occurred at the lower arm and mid-leg, and the change to the modern uniform decreased such burns by 87% and 92%. Burn incidence and severity were not significantly affected by the change to the modified modern uniform. The distribution of heat exhaustion or cardiac events per fire was not significantly affected by the change from the traditional to modern uniform, and heat exhaustion was decreased ($P < 0.001$) by the change to the modified modern uniform. In conclusion, the modern uniform dramatically reduced burn incidence and severity without adverse impact. The modified modern uniform significantly reduced heat exhaustion without significantly affecting thermal protection. (J Occup Environ Med. *2000;42: 827–834*)

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In 1992, the estimated economic impact of occupational injuries and illnesses in this country ($171 billion) equaled or exceeded that for circulatory disease ($164 billion) or cancer ($171 billion).[1] In the United States, firefighters are the second largest public safety workforce and include both paid and volunteer members. For nearly 20 years, annual occupational injury and fatality surveys by the US Department of Labor have consistently shown firefighter injury rates to be higher than those of any other workforce—and line-of-duty fatality rates to rank within the top five occupations in this country.[2–4] Over the same period, annual surveys by the International Association of Fire Fighters and the National Fire Protection Association have consistently ranked burns among the top five causes of injury in firefighters[5–8] and burns with or without asphyxia among the top two or three causes for line-of-duty fatalities.[5–10]

The New York City Fire Department (FDNY) is the largest career fire department in the United States (more than 11,000 firefighters) and the most active (averaging more than 2500 structural fires per month). In the 1990s, of the 22 FDNY firefighters who lost their lives in the line of duty, 15 (68%) died because of burn injuries with or without asphyxia. In 1994 (the last year for wearing a traditional firefighting uniform), over 600 FDNY firefighters suffered severe burns, 23 were admitted to a hospital burn center, and 4 suffered fatal burns. In an effort to reduce the

frequency and severity of firefighter burn injuries, FDNY re-outfitted to a modern fire protective uniform during the latter part of 1994. Modern uniforms include both a protective over-coat and over-pants, whereas the traditional uniform includes only an over-coat. In addition, modern uniforms are manufactured to meet or exceed National Fire Protection Association recommendations for structural firefighting[11] by consisting of improved thermal protective textiles that do not suffer damage until the temperature far exceeds that needed to decompose untreated cotton (250°C).[12,13] In both FDNY traditional and modern versions, the rest of the uniform remained essentially identical, with the same shirt and long pants (flame resistant 60% polyester/40% cotton blend) worn underneath.

FDNY firefighters have benefited from the greater thermal burn protection afforded by the modern uniform[14] but have been dissatisfied with its impact on comfort and work capacity.[15] Because of the modern uniform's increased thermal insulation, the shirt and long pants worn underneath the protective uniform rapidly became sweat-drenched, restrictive, and uncomfortable, especially during the summer. Simulated work capacity measurements confirm that work efficiency and comfort were significantly reduced when the modern uniform was compared with the traditional and could be significantly improved by wearing a modified modern uniform that substituted a short sleeved T-shirt (100% cotton) and short pants (flame resistant) for the original short sleeved shirt and long pants.[15] Laboratory mannequin studies found thermal protection was not significantly different between FDNY modern and modified modern uniforms under simulated flash fire conditions.[16] Because of these simulated laboratory studies, FDNY recently changed to the modified modern uniform for the summer months.

The primary purpose of this study was to compare thermal burn protection afforded by traditional, modern, and modified modern uniforms. Because the modified modern uniform was worn only during the summer months, our analysis focused on burn incidence rates and severity as a function of uniform type during three summers when there was 100% compliance with wearing the required uniform. Injury data while wearing the traditional (May 1, 1993 to August 31, 1993), modern (May 1, 1995 to August 31, 1995), and modified modern (May 1, 1998 to August 31, 1998) uniforms were collected prospectively as part of our occupational health and safety surveillance program. We also examined the association between uniform type and physiologic stress injuries (heat exhaustion and cardiac events) and fatalities to determine if there was any associated adverse impact of uniform type on health and safety. Finally, the economic cost of uniform re-outfitting was compared with medical leave costs during this same time period.

Methods

FDNY's traditional uniform used before 1995 consisted of a helmet, self-contained breathing apparatus mask and cylinder, protective over-coat, shirt, long pants, gloves, and boots. The over-coat (Model FDNY BC-1/TC-6, Total Fire Inc, Dayton, OH) consisted of an outer shell made of 7.5 oz Nomex III, a moisture barrier of Gore-Tex stitched on 100% Nomex III, and an inner thermal liner of Aralite 100% Aramid quilt stitched 7.5 oz per square yard. FDNY's modern uniform differed from the traditional uniform in its protective over-coat and over-pants (Model FDNY, Total Fire Inc). Both over-coat and over-pants consisted of an outer shell of 60% Kevalar Aramid/40% PBI, a moisture barrier of 1.2 oz Crosstech laminated to a 2.7-oz Nomex E-89 base, and an inner thermal liner of 3-layer E-89 fabric quilt stitched 8 oz per square yard. FDNY over-pants feature a 10 × 12 inch knee pad, usually composed of an outer layer of 60% Kevalar Aramid/40% PBI, a middle section with multiple layers of E-89 quilt and E-89 Crosstech, and an inner layer of 6.5 oz Ripstop Nomex (Level 2 Kneepad, Total Fire Inc). The rest of the uniform was identical, except that the modern uniform used a shorter boot. Under protective over-garments, firefighters wore short sleeved shirts (summer months) and long pants, both of flame resistant material. FDNY's modified modern uniform differed from the modern uniform by substituting a short sleeved T-shirt (100% cotton) and flame resistant short pants for flame resistant work shirt and long pants.

FDNY medical computerized database was searched for all service-connected burns during the study periods. Injury data while wearing the traditional (May 1, 1993 to August 31, 1993), modern (May 1, 1995 to August 31, 1995), and modified modern (May 1, 1998 to August 31, 1998) uniforms were collected prospectively as part of our occupational health and safety surveillance program. This database is complete because FDNY physicians evaluate all injured FDNY firefighters (in-hospital and outpatient) to improve medical care, morale, and duty status evaluation, and compliance is subject to command discipline. Physicians reviewed all medical charts and health insurance reimbursement records to determine and verify burn location and severity. Burn location was categorized into three areas (lower extremity, upper extremity, and trunk) and seven subareas: upper leg (above knee), mid-leg (knee to above ankle), lower leg (ankle and below), upper arm (above elbow), mid-arm (elbow to above wrist), lower arm (wrist and below), and trunk. Head burns were excluded because all uniforms provided identical coverage to this area. For non-fatal burns, in the rare instances when burns involved more than one

location (<5%), burns were classified according to the location requiring greatest duration of medical leave. Thus, for analysis purposes, no firefighter could receive more than one burn per fire. Severity indicators included: total days lost to medical leave (includes in-hospital days), numbers of hospitalizations, and skin grafts. Hospitalization was defined as admission rather than observation in an Emergency Department. Burn severity (first-, second-, or third-degree) was considered unreliable for analysis because of its subjectivity in a health care setting with numerous evaluators.

To assess adverse impact, the FDNY medical database was searched for service-connected physiologic stress injuries (heat exhaustion and cardiac events). Heat exhaustion was defined as severe dehydration, exhaustion, heat stress, or heat stroke requiring medical leave. Cardiac events were defined as myocardial infarction, coronary ischemia, arrhythmia, and/or cardiac syncope suffered during firefighting. Fire fatalities included only firefighter deaths occurring during firefighting or during hospitalization for an acute life-threatening injury occurring during firefighting.

Comorbid factors that may influence the morbidity or mortality of burn injuries, heat exhaustion, and/or cardiac events were not a factor in this study. FDNY prohibits firefighters from performing full-duty activities if they develop diabetes requiring medication, heart disease, obstructive airway disease, and/or other illnesses that may interfere with performance while firefighting. Disease status is monitored through entrance and annual medical evaluations.

FDNY computerized fire activity records were reviewed for structural and serious fires. FDNY defines serious fires as "all hands" fire (≥11 units with ≥55 firefighters responding) or a second-alarm or greater fire (≥20 units with ≥99 firefighters responding). FDNY medical and fire activity databases were linked by date, location, and fire codes to determine distribution of burns per structural or serious fire.

Statistical Analysis

Incidence of structural fires, serious fires, and burns by anatomic location are presented by month. A Kruskal-Wallis test was used to assess the significance of differences in structural or serious fire distributions among the three study periods. Distribution of 0, 1, 2, or ≥3 burns per structural or serious fire are presented for traditional, modern, and modified modern uniforms. Burn injury per fire (exposure) was analyzed because the distribution of exposures may have varied among the three study periods. Burn injury per firefighter (population at risk) could not be analyzed because the number and location of FDNY firefighters at a fire was never recorded. However, the number, average age, and average tenure of FDNY firefighters remained relatively constant throughout the study years: 1993 (n = 11,342; average age = 40.3 years; average tenure = 13.6 years); 1995 (n = 11,174; average age = 40.1 years; average tenure = 13.1 years); and 1998 (n = 11,239; average age = 40.4 years; average tenure = 13.3 years). A Mantel-Haenszel chi-squared test using a Bonferroni adjustment for multiple comparisons was used to test a priori contrasts between traditional and modern uniforms and between modern and modified modern uniforms (adjusted alpha level = 0.025). Statistics were analyzed by using Statgraphics (Version 6.1, 1993, STSC Inc, Rockville, MD) or SAS (Version 6.11, Cary, NC). All P values are unadjusted; thus, a P value of ≤0.025 was considered significant.

Results

FDNY structural and serious fire activity is shown in Table 1. During this study 29,094 structural fires and 3483 serious fires occurred. There were significant differences in the distributions of serious fires (P = 0.024) but not structural fires (P = 0.03) across the three time periods. When the traditional uniform was compared with the modern, the decrease in structural (P = 0.112) and serious (P = 0.99) fires was not significant. When the modern was compared with the modified modern uniform, the decrease in structural fires was not significant (P = 0.194), but there was a significant decrease (21%; P = 0.024) in serious fires.

TABLE 1
FDNY Fire Activity[a]

Month	TU	MU	MMU
Structural fires			
May	2,571	2,535	2,376
Jun	2,477	2,341	2,264
Jul	2,856	2,409	2,302
Aug	2,442	2,291	2,230
Total	10,346	9,576	9,172
Serious fires			
May	319	323	236
Jun	304	304	258
Jul	362	274	253
Aug	278	336	236
Total	1,263	1,237	983**

[a] TU, traditional uniform (May 1–Aug 31, 1993); MU, modern uniform (May 1–Aug 31, 1995); MMU, modified modern uniform (May 1–Aug 31, 1998). Serious fires = "all hands" and second-alarm or greater.
** $P \leq 0.025$ (MMU vs MU).

The distribution of upper extremity burns per fire is shown in Tables 2 and 3. The incidence of upper extremity burns is shown in Fig. 1. The incidence rate was 2341 upper extremity burns per 100,000 fires. With the change from the traditional to modern uniform, there was a significant decrease in the distribution of upper extremity burns per structural fire (P = 0.001) and per serious fire (P = 0.001). Upper extremity burns decreased by 86%. When the modern uniform was compared with the modified modern uniform, there was no significant difference in the distribution of upper extremity burns per structural fire (P = 0.903) or per serious fire (P = 0.620). Throughout all periods, the majority of upper extremity burns occurred to the lower arm (94%). With the change

TABLE 2
FDNY: Distribution of Burns in Structural Fires[a]

No. of Burns	TU	MU	MMU
All burns*†			
0	10,071*	9,525	9,130**
1	215	47	33
2	39	4	6
≥3	21	0	3
Upper extremity*†			
0	10,185*	9,550	9,152**
1	141	26	16
2	17	0	3
≥3	3	0	1
Lower extremity*†			
0	10,210*	9,563	9,153**
1	112	13	17
2	15	0	1
≥3	9	0	1
Upper arm			
0	10,343	9,576	9,172
1	3	0	0
2	0	0	0
≥3	0	0	0
Mid-arm			
0	10,339	9,573	9,171
1	7	3	1
2	0	0	0
≥3	0	0	0
Lower arm*†			
0	10,192*	9,553	9,153**
1	137	23	15
2	14	0	3
≥3	3	0	1
Upper leg			
0	10,324	9,576	9,169
1	22	0	3
2	0	0	0
≥3	0	0	0
Mid-leg*†			
0	10,231*	9,564	9,156**
1	94	12	15
2	12	0	0
≥3	9	0	1
Lower leg			
0	10,340	9,575	9,171
1	6	1	1
2	0	0	0
≥3	0	0	0

[a] TU, traditional uniform (May 1–Aug 31, 1993); MU, modern uniform (May 1–Aug 31, 1995); MMU, modified modern uniform (May 1–Aug 31, 1998). All burns = trunk + upper + lower extremities; upper leg = above the knee; mid-leg = knee to above ankle; lower leg = ankle and below; upper arm = above the elbow; mid-arm = elbow to above wrist; lower arm = wrist, hand, and fingers.

*$P \leq 0.025$ (MU vs TU); †$P \leq 0.025$ (MMU vs MU).

TABLE 3
FDNY: Distribution of Burns in Serious Fires[a]

No. of Burns	TU	MU	MMU
All burns*†			
0	988	1,186	941
1	215	47	33
2	39	4	6
≥3	21	0	3
Upper extremity*†			
0	1,102	1,211	963
1	141	26	16
2	17	0	3
≥3	3	0	1
Lower extremity*†			
0	1,127	1,224	964
1	112	13	17
2	15	0	1
≥3	9	0	1
Upper arm			
0	1,260	1,237	983
1	3	0	0
2	0	0	0
≥3	0	0	0
Mid-arm			
0	1,256	1,234	982
1	7	3	1
2	0	0	0
≥3	0	0	0
Lower arm*†			
0	1,109	1,214	964
1	137	23	15
2	14	0	3
≥3	3	0	1
Upper leg			
0	1,241	1,237	980
1	22	0	3
2	0	0	0
≥3	0	0	0
Mid-leg*†			
0	1,148	1,225	967
1	94	12	15
2	12	0	0
≥3	9	0	1
Lower leg			
0	1,257	1,236	982
1	6	1	1
2	0	0	0
≥3	0	0	0

[a] For definition of abbreviations, see Table 2.

*$P \leq 0.025$ (MU vs TU); †$P \leq 0.025$ (MMU vs MU).

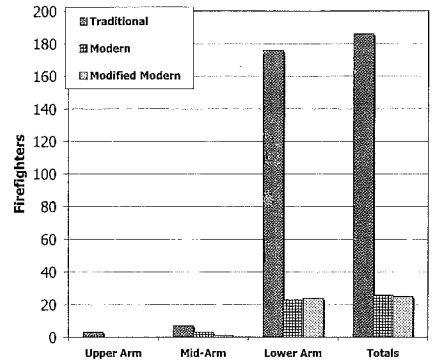

Fig. 1. Total numbers of FDNY firefighters receiving upper extremity burns while wearing FDNY's traditional uniform, modern uniform, or modified modern uniform. Upper arm = above the elbow; mid-arm = elbow to above wrist; lower arm = wrist and below. With the change from the traditional to modern uniform, lower arm burns decreased by 87% and total burns decreased by 86%. No significant differences were found with the change from the modern to modified modern uniform.

from the traditional to modern uniform, there was a significant decrease in the distribution of lower arm burns per structural fire ($P = 0.001$) and per serious fire ($P = 0.001$). Lower arm burns decreased by 87%. With the change from the modern to modified modern uniform, there was no significant difference in the distribution of lower arm burns per structural fire ($P = 0.893$) or per serious fire ($P = 0.467$). The incidences of upper and mid-arm burns were too few for sufficient power.

The distribution of lower extremity burns per fire is shown in Tables 2 and 3. The incidence of lower extremity burns is shown in Fig. 2. The incidence rate was 2076 lower extremity burns per 100,000 fires (Fig. 3). With the change from traditional to modern uniform, there was a significant decrease in distribution of lower extremity burns per structural fire ($P = 0.001$) and per serious fire ($P = 0.001$). Lower extremity burns decreased by 93%. When the modern uniform was compared with the modified modern uniform, there was no significant difference in the distribution of lower extremity burns per structural fire ($P = 0.156$) or per serious fire ($P = 0.051$). During this study, the majority of lower extremity burns occurred to the mid-leg (84%), and almost all occurred anteriorly. With the change from the traditional to the modern uniform, there was a significant decrease in the distribution of mid-leg burns per structural fire ($P = 0.001$) and per serious fire ($P = 0.001$). Mid-leg burns decreased by 92%. With the

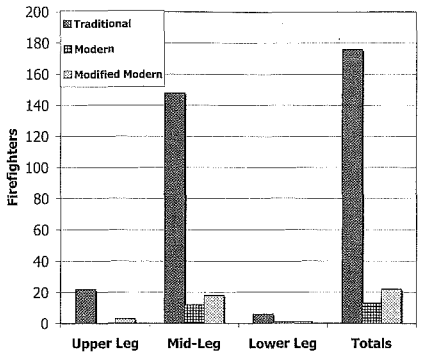

Fig. 2. Total numbers of FDNY firefighters receiving lower extremity burns while wearing FDNY's traditional uniform, modern uniform, or modified modern uniform. Upper leg = above the knee; mid-leg = knee to above ankle; lower leg = ankle and below. With the change from the traditional to modern uniform, mid-leg burns decreased by 92% and total burns decreased by 93%. No significant differences were found with the change from the modern to modified modern uniform.

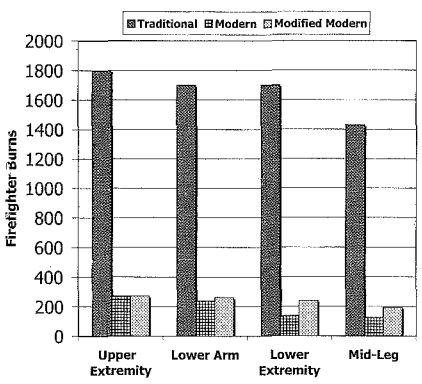

Fig. 3. Incidence rates expressed per 100,000 fires for upper extremity, lower arm, lower extremity, and mid-leg burns while wearing FDNY's traditional uniform, modern uniform, or modified modern uniform. With the change from traditional to modern uniform, upper extremity burns decreased from 1797 per 100,000 to 271 per 100,000, lower arm burns decreased from 1700 per 100,000 to 240 per 100,000, lower extremity burns decreased from 1700 per 100,000 to 136 per 100,000, and mid-leg burns decreased from 1430 per 100,000 to 125 per 100,000. No significant differences were found with the change from the modern to modified modern uniform.

change from the modern to the modified modern uniform, there was no significant difference in the distribution of mid-leg burns per structural fire ($P = 0.381$) or per serious fire ($P = 0.168$). The incidence of upper leg and lower leg burns were too few for sufficient power. It is notable that after changing from the traditional to the modern or modified modern uniforms, upper and lower leg burns became a rarity.

TABLE 4
FDNY: Severity of Upper and Lower Extremity Burns[a]

Severity Level	TU	MU	MMU
Upper arm			
Admissions	0	0	0
Grafts*	0	0	0
Days lost†	85	0	0
Days lost/burn‡	28	0	0
Mid-arm			
Admissions	0	0	0
Grafts	0	0	0
Days lost	208	65	20
Days lost/burn	30	22	20
Lower arm			
Admissions	1	0	3
Grafts	0	0	1
Days lost	5,085	548	994
Days lost/burn	29	24	41
Upper leg			
Admissions	1	0	0
Grafts	1	0	0
Days lost	678	0	41
Days lost/burn	31	0	14
Mid-leg			
Admissions	3	1	2
Grafts	3	0	2
Days lost	3,777	471	512
Days lost/burn	26	39	28
Lower leg			
Admissions	0	0	1
Grafts	0	0	1
Days lost	126	27	360
Days lost/burn	21	27	360

[a] For definition of abbreviations, see Table 2.

* Grafts = no. of firefighters receiving grafts.

† Days lost = no. of days on medical leave.

‡ Days lost/burn = no. of days on medical leave per no. of firefighters burned.

During this study there were 12 hospital admissions and eight firefighters requiring skin grafts (Table 4). All four upper extremity burns requiring hospitalization were to areas covered by gloves rather than by uniform sleeve or sleeve-glove interface. Six of eight lower extremity burns were to the anterior mid-leg. Skin grafting was required for one firefighter with a lower arm burn and for five firefighters with mid-leg burns. These numbers were too few for sufficient power, but for upper arm, mid-arm, and upper leg burns, the numbers of days lost to medical leave relative to the numbers of burns seemed to decrease with the change from the traditional to the modern uniform (Table 4).

The association between trunk burns and uniform type was not significant, regardless of whether analyzed by structural fire ($P = 0.059$) or serious fire ($P = 0.108$). Trunk burns (20 in traditional, 16 in modern, and 8 in modified modern uniforms) did not result in hospitalization, skin grafting, or substantial days lost.

With the change from the traditional to modern uniform, there was no significant difference in the distribution of heat exhaustion events per structural ($P = 0.244$) or per serious ($P = 0.374$) fires or of cardiac events per structural ($P = 0.859$) or per serious ($P = 0.719$) fires. In fact, when the modern uniform was compared with the modified modern uniform, there was a decrease in distribution of heat exhaustion events per structural fire ($P < 0.001$) or per serious fire ($P < 0.001$), but there was no significant effect on cardiac events per structural ($P = 0.065$) or per serious ($P = 0.163$) fires. Heat exhaustion did not result in hospitalization or substantial days lost. All cardiac events resulted in hospitalization, but the number of days lost was not analyzed inasmuch as these events resulted in early retirement or office duty re-assignments. Thus, there was no evidence for an increase in adverse outcomes (heat exhaustion or cardiac events) with the change from the traditional to the modern uniform (Fig. 4).

No FDNY firefighter suffered a fire fatality during this study while wearing the traditional or modern uniforms. While wearing modified modern uniforms, two firefighters died during a building collapse, one from crush trauma without burns and the other from burns involving over

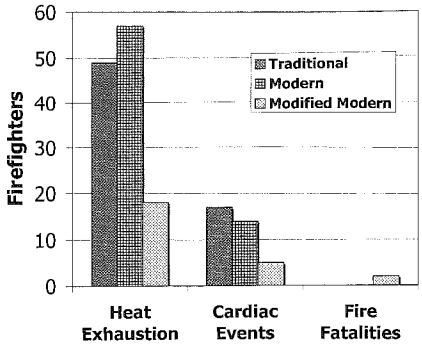

Fig. 4. FDNY firefighter physiologic stress injuries (heat exhaustion and cardiac events) and fatalities. Heat exhaustion is defined as severe dehydration, exhaustion, heat stress, or heat stroke requiring medical leave. Cardiac events are defined as myocardial infarction, coronary ischemia, arrhythmia, and/or cardiac syncope suffered during firefighting. Fire fatalities included only firefighter deaths occurring during firefighting or during hospitalization for an acute life-threatening injury occurring during firefighting. Heat exhaustion and cardiac events were not significantly affected by the change from the traditional to modern uniform, whereas heat exhaustion was significantly decreased by the change from the modern to modified modern uniform.

90% body surface area (Fig. 4). The FDNY Fatal Fire Safety Investigation concluded that uniform type was not a factor.

Discussion

Annual occupational injury and fatality surveys consistently show firefighter injury rates to be higher than those of any other workforce, and line-of-duty fatality rates to rank within those of the top five occupations in this country.[2–4] For firefighters, burns are consistently among the top five causes of injury,[5–8] and burns with or without asphyxia are among the top two or three causes of line-of-duty fatalities.[5–10] In the 1990s, of the 22 FDNY firefighters who lost their lives in the line of duty, 15 (68%) died because of burn injuries with or without asphyxia. In 1994 (the last year of wearing the traditional firefighting uniform), over 600 FDNY firefighters suffered severe burns, 23 were admitted to a hospital burn center, and 4 suffered fatal burns. In an effort to reduce the frequency and severity of firefighter burn injuries, FDNY re-outfitted to a modern fire protective uniform. This study demonstrates: (1) the high level of thermal protection afforded by FDNY's modern uniform during structural firefighting; (2) that wearing FDNY's modified modern uniform did not reduce thermal protection; and (3) that substantial improvement in burn protection occurred without adverse impact on firefighter health and safety.

During the 12 months studied, 29,094 structural fires, 3483 serious fires, and 469 burns (extremities and trunk) occurred. Incidence rates were 2341 upper extremity burns (94% lower arm) and 2076 lower extremity burns (84% mid-leg) per 100,000 fires (Fig. 3). With the change from the traditional to modern uniform, upper extremity burns decreased by 86% and lower extremity burns decreased by 93%. The majority of burns occurred at the lower arm and mid-leg, and the change to modern uniform decreased such burns by 87% and 92%, respectively. With the change from the modern to modified modern uniforms, we found no evidence to support an increase in burns at any anatomic location.

Previously we showed that upper extremity burns decreased by 65% and lower extremity burns by 85% in FDNY firefighters when the modern uniform was compared with the traditional uniform over similar 2-year periods.[14] However, our prior study did not analyze: (1) frequency of burns relative to fire activity, (2) burns to specific areas of upper and lower extremities, or (3) burns while wearing FDNY's modified modern uniform. Our current study shows that reductions in upper and lower extremity burns when wearing FDNY modern and modified modern uniforms were not the result of decreased fire activity, because our statistical analysis was based not on absolute numbers but rather on the distribution of burns per fire.

Because traditional uniforms never had protective over-pants, the reduction in lower extremity burns when wearing the modern uniform was expected, but the magnitude of this reduction far exceeded expectations (Tables 2 and 3 and Fig. 2). Upper extremity burns were also dramatically reduced with the change from the traditional to modern uniform (Tables 2 and 3 and Fig. 1). Because traditional uniforms already had protective over-coats, a reduction in upper extremity burns of this magnitude was unexpected. We speculate that upper extremity burns decreased because modern over-coats were constructed of superior thermal protective materials and may also have provided superior interfacing between the over-coat sleeve and glove.

By subclassifying upper and lower extremity burns according to more localized anatomic areas, we hoped to provide information relevant to future considerations of risk and prevention. The majority of burns were to the lower arm (wrist and hand) and anterior mid-leg (knee and shin). This occurred because common to all uniforms was: (1) a potential opening at the over-coat sleeve to glove interface, and (2) considerable thermal stress to anterior knees/shins when kneeling on hot surfaces or in hot water during hose line operations. Despite dramatic reductions, lower arm and mid-leg burns still represent 92% of upper extremity burns and 80% of lower extremity burns while wearing modern and modified modern uniforms (Tables 2 and 3 and Figs. 1 and 2). To reduce these burns further will require advances in glove, glove-coat interface, and knee-shin pad designs and materials.

To improve firefighter comfort and work capacity in modern uniforms,[15] FDNY's modified modern uniform substitutes a short sleeved T-shirt (100% cotton) and flame resistant short pants for a flame resistant work shirt and long pants. One concern was the modified modern uniform's potential for reducing thermal protection and increasing mid-arm, lower arm, mid-leg, and

lower leg burns. FDNY felt confident that this would not occur because of: (1) the design specifications of the protective outer-coat/outer-pants, and (2) the laboratory manikin burn experiments performed on the modern and modified modern uniforms.[16] This study supports that decision with actual field data collected over 8 months, during which there were 18,748 structural fires, 2220 serious fires, and 92 burns (extremities and trunk). With the change from the modern to modified modern uniform, no significant differences were observed in the distribution of burns per fire, regardless of anatomic location (Tables 2 and 4 and Figs. 1 and 2).

Another concern was that the modern and modified modern uniforms would lead to an increase in frequency and/or severity of physiologic stress injuries, such as heat exhaustion and cardiac events. This could have occurred if a false sense of security allowed firefighters to penetrate too deeply into the fire and/or from the physiologic stress of firefighting[15,17–19] being increased further by the modern uniform's added mechanical resistance and thermal encapsulation.[12,15] Our findings indicated no adverse impact (heat exhaustion, cardiac events, or fire fatalities) (Fig. 4).

The strengths of this study design were that by studying each uniform during separate time periods: (1) the entire workforce was outfitted rather than artificially created subgroups, and (2) compliance with personnel wearing the uniform was 100%. Yet potential limitations may have been introduced because comparisons were not run concurrently. Examples include decreases in structural and serious fires (adjusted for by studying the distribution of burns per fire), differences in ambient temperature (monthly comparison across time periods show no significant differences in average temperature, according to Central Park, New York City recordings in the National Weather Service on-line database), and changes in FDNY operational procedures (encouraging increased rotation of firefighters at fires and increased firefighter hydration before and after firefighting). It is reasonable to assume that operational changes may have limited adverse outcomes by decreasing the physiologic stress responsible for heat exhaustion and cardiac events, but it is extremely unlikely that the changes had any effect on burn incidence rates.

Severity of upper and lower extremity burns (ie, days lost) seems to have decreased with the change from the traditional to modern uniform and remains unaffected with the change from the modern to modified modern uniform. The economic impact of the change from traditional to modern uniforms was clear and substantial. FDNY "minimum manning" needs require that every firefighter on medical leave be replaced with another full-duty firefighter. During the three study periods, expenditures of $1665,846, $220,266, and $417,786 were incurred to cover medical leaves resulting from non-head burns. Between 1990 and 1993, the last years in which FDNY wore traditional uniforms, annual personnel costs to cover medical leaves from non-head burns increased by nearly 4-fold, from 1.36 million in 1990 to $4.29 million in 1993. Between 1995 and 1998, the first years of wearing modern and/or modified modern uniforms, annual personnel costs to cover medical leaves from non-head burns remained stable, averaging $0.9 million per year and reaching a peak of $1.05 million in 1998. The investment by FDNY to re-outfit from the traditional to modern uniforms was $12.8 million. This investment was fully recovered in 4 years on the basis of the following assumption: the difference between 4 years × 4.29 million and 4 years × 1.05 million, for a total of $13.6 million in medical leave cost savings. In fact, this simplified analysis presents figures that underestimate the true cost savings because it does not account for rank differentials, night-tour differentials, litigation costs, disability benefits, and health care utilization costs. The latter were not analyzed because reductions in health insurance reimbursement rates that occurred contemporaneously with this study falsely magnified cost savings from burn reductions.

In conclusion, the change from the traditional to modern firefighting uniforms has significantly reduced the frequency and incidence of lower and upper extremity burns and, hence, the total number of days lost and associated medical leave costs. With the change from the modern to modified modern uniform, thermal protection remained unaffected while heat exhaustion events were significantly decreased. Reductions in burn frequency and severity, the major occupational injury affecting this workforce, were so dramatic and so without adverse impact that the introduction of FDNY modern and modified modern firefighting uniforms must be considered a sentinel event in the history of occupational preventive medicine and in firefighter health and safety.

Acknowledgments

Supported by National Institute for Occupational Safety and Health, National Institutes of Health NORA R01-OHO3082–01.

Today, FDNY firefighters wear modern and modified modern firefighting uniforms because the Commissioner of the New York City Fire Department (Mr Thomas Von Essen), the former Commissioner of the New York City Fire Department (Mr Howard Safir), the Uniformed Firefighters Association, the Uniformed Fire Officers Association, and a core group of FDNY firefighters and officers worked long and hard to convince people of the advantages of these uniforms. Without the efforts (including those of Mayor Rudolph W. Giuliani) of those who value the safety of firefighters and the sacrifices they make, this change would not have been possible. With deep appreciation, we dedicate this study to those individuals and to every firefighter who has been burned in the line of duty.

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Losing the Scent

Firefighters run a high risk of damaging or losing their sense of smell, perhaps because toxic fumes get past protective masks, according to a new study. There could be a hidden problem "of massive proportions" among firefighters in the United States, one that puts them at risk for identifying dangerous smells such as that of the ingredient added to otherwise odorless natural gas, says the report by the Smell and Taste Treatment Research Foundation.

—Schogol M. Personal Briefing. *Philadelphia Inquirer,* November 11, 1999, p F6.