Correlates of Body Mass Index in Hazardous Materials Firefighters

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We analyzed results from the medical examinations of 340 hazardous materials (HAZMAT) firefighters and observed the relationships between selected parameters and body mass index (BMI). Heights and weights were available for 98% of the subjects (333 of 340). The mean BMI was 28.9 ± 4.1 kg/m^2. Eighty-seven percent (290 of 333) of subjects were overweight (BMI ≥ 25) and 34% (113 of 333) were obese (BMI ≥ 30). Two percent (7 of 333) were morbidly obese (BMI ≥ 39). For comparison purposes, we divided subjects into low (BMI < 27), medium (BMI 27 to <30), and high (BMI ≥ 30) BMI groups. The results demonstrated adverse associations between increasing BMI and resting blood pressures, forced vital capacity, alanine aminotransferase, aspartate aminotransferase, serum cholesterol, and overall morbidity scores. The high prevalence of overweight and obesity and the associated adverse health effects support the development and implementation of fitness-promotion programs for firefighters.

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Excess body weight is an increasing health problem in the United States. Based on the previous National Center for Health Statistics' definition of overweight as a body mass index (BMI) of 27.3 for women and BMI of 27.8 for men, approximately 70 million adult Americans were considered to be overweight.[1] Using the new National Institutes of Health standard for healthy weights (BMI < 25), it is estimated that 97 million, or 55%, of adult Americans will be considered overweight.[2] Likewise, obesity, or a BMI ≥ 30, is also epidemic, with a prevalence of 22.5% in the United States, according to the third National Health and Nutrition Examination Survey conducted from 1988–1994.[3]

Overweight individuals are at increased risk for the development of diabetes, high blood pressure, and coronary heart disease. Obesity is associated with an increased risk for many comorbidities, including insulin resistance and type II diabetes mellitus,[4,5] dyslipedemias,[4,5] elevated liver function tests and fatty liver,[4–7] hypertension,[4,5] coronary heart disease,[4,5] cholelithiasis,[4,5] pulmonary disorders (decreased lung capacity, obstructive sleep apnea, and Pickwickian syndrome),[4,5,8,9] excess daytime sleepiness,[8] certain cancers,[4,5] and degenerative joint disease.[4,5] In addition, good evidence exists that obesity increases mortality as well.[10] When smoking and weight loss from coexisting diseases are adjusted for, the risk of death appears to increase linearly with increasing BMI.[11]

Obesity is associated with additional serious concerns for occupational medicine, including decreased physical fitness (work capacity),[12] increased risk of heat-related illness,[13] the confounding effects of obesity on medical surveillance for potential hepatotoxins (eg, obesity-related increases in liver function tests[6–7]) and safety hazards due to decreased alertness (eg, excess daytime sleepiness due to obesity-related sleep disorders[8,9]). Obesity has also been shown in recent employer and health maintenance organization–based studies to be associated with increased health care and other associated costs.[14,15]

Given the potential adverse health, safety, and economic consequences of obesity, we determined the prevalence of overweight status and obesity and investigated the effects of increasing BMI on physiologic, metabolic, and morbidity profiles in a large cohort of hazardous materials (HAZMAT) firefighters.

Methods

Subjects

The subjects were all members ($n = 340$) of six regional HAZMAT teams of the Commonwealth of Massachusetts. They included 268 (79%) HAZMAT technicians and 72 (21%) support members. The population included four women (1%). The team members' ages ranged from 21 to 58 years, with a mean of 39 and a standard deviation of 6.9.

Baseline and Periodic Medical Examinations

Medical surveillance examinations for all subjects were performed at three hospitals—Massachusetts Respiratory, Marlborough, or Holyoke Hospitals—in 1996 or 1997 in the first year of a statewide surveillance program. All examinations were conducted in a similar fashion. Examinations included a detailed medical, smoking, and environmental/occupational history tailored to emergency responders; physical examination; visual and audiometric testing; routine laboratory tests (complete blood count, blood urea nitrogen, creatinine, alkaline phosphatase, aspartate aminotransferase [AST] and alanine aminotransferase [ALT], and urinalysis); and spirometry.

Summary results of each firefighter's examination, including a face problem sheet and the attending physician's determination of fitness for duty, were transferred to the Massachusetts Respiratory Hospital, where they were entered into a statewide computerized medical records repository.

Gestalt Morbidity Rating

The face problem sheet of each subject was reviewed by a board-certified internist (E.O.L.). The internist never examined any of the firefighters and was blinded to the subjects' fitness for duty outcomes. The face problem sheet lists gender, age, height and weight, medical problems, medications, allergies, immunizations, and smoking history. Each subject was rated on a scale of 1 to 10 for increasing morbidity. A rating of 1 was considered most healthy, and 10, least healthy. This parameter was labeled "fit rank." This rating is not blind to BMI status because the face sheet includes height and weight and obesity may be listed as a medical problem.

Body Mass Index

The BMI of each subject was calculated and reported in kilograms per meter^2 from his/her height in inches and weight in pounds, using the following formula[16]: BMI = 703.1 × (weight in pounds)/(height in inches).^{2}

Statistical Analyses

For the purposes of statistical comparisons, the cohort was divided into three groups. The low BMI group was defined as those subjects with a BMI <27, the medium BMI group as those with a BMI of 27 to <30, and the high BMI group as those with a BMI ≥ 30.

Because of the small number of women in the cohort ($n = 4$), only males were included in multivariate models. Smoking information was obtained from the face problem sheets, where it was categorized as "never," "former," or "current." Ethanol consumption was quantified as the number of drinks per week. Ethanol consumption information was available for the male firefighters who were examined at the Massachusetts Respiratory Hospital (35% of total cohort; 114 of 329). Because ethanol intake is not listed on the face problem sheets, the centralized database does not contain ethanol intake information for the remaining firefighters.

Analyses of variance were used to compare the means of the three groups (low, medium, and high BMI). If these analyses demonstrated a significant difference ($P < 0.05$) among the means, then independent t tests were used to compare the mean of the low BMI group with the means of the other two groups.

Results

Distribution of Body Mass Indices for the Cohort

Heights and weights were available for 333 of 340 subjects (98%).

The mean BMI was 28.9 ± 4.1 for these 333 firefighters. The mean BMI for the four women was 27.7 ± 6.6 (range, 22.6 to 36.9), and 29.0 ± 4.0 (range, 19.3 to 43.8) for the 329 males. Eighty-seven percent (290 of 333) of the firefighters were overweight, with BMIs of 25 or greater. Fifty-nine percent (198 of 333) were above the previous US guidelines for overweight: BMI 27.8 and 27.3 for men and women, respectively. Obesity (BMI ≥ 30) was present in 34% of the cohort (113 of 333). Finally, 2% ($n = 7$) met the criterion for morbid obesity (BMI ≥ 39).

Thirty-two percent (106 of 333) of the firefighters with measured BMIs fell into the low BMI category, with a mean BMI of 24.7 ± 1.9; 34% (114 of 333) comprised the medium

TABLE 1
Correlates of Body Mass Index: Males and Females*

Variable	Low BMI	Medium BMI	High BMI	ANOVA *P*
Age	38 ± 6 *n* = 100	40 ± 7 *n* = 108	40 ± 7 *n* = 107	<0.05
SBP	119 ± 13 *n* = 106	123 ± 13 *n* = 114	125 ± 13 *n* = 113	<0.005
DBP	77 ± 9 *n* = 106	79 ± 9 *n* = 114	80 ± 9 *n* = 113	<0.05
FVC %	105 ± 13 *n* = 104	104 ± 13 *n* = 112	100 ± 13 *n* = 111	<0.05
FEV_1 %	103 ± 14 *n* = 104	104 ± 14 *n* = 112	102 ± 14 *n* = 111	NS
ALKPHOS	82 ± 22 *n* = 103	81 ± 22 *n* = 113	85 ± 22 *n* = 113	NS
CHOL	219 ± 39 *n* = 57	224 ± 39 *n* = 69	242 ± 39 *n* = 62	<0.005
BUN	15 ± 4 *n* = 105	16 ± 4 *n* = 114	16 ± 4 *n* = 113	NS
CR	1.08 ± 0.16 *n* = 105	1.13 ± 0.16 *n* = 114	1.13 ± 0.16 *n* = 113	<0.05
AST	24 ± 10 *n* = 104	24 ± 10 *n* = 114	27 ± 10 *n* = 112	<0.05
ALT	31 ± 20 *n* = 104	35 ± 20 *n* = 114	43 ± 20 *n* = 112	<0.001
FITRANK	3.2 ± 1.3 *n* = 106	3.7 ± 1.3 *n* = 114	4.2 ± 1.3 *n* = 113	<0.001

* Unadjusted data. SBP, systolic blood pressure; DBP, diastolic blood pressure; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; ALKPHOS, alkaline phosphatase; CHOL, cholesterol; BUN, blood urea nitrogen; CR, creatinine; AST, aspartate aminotransferase; ALT, alanine aminotransferase; FITRANK, increasing morbidity parameter.

BMI group, with a mean BMI of 28.5 ± 0.8; and 34% (113 of 333) comprised the high BMI group, with a mean BMI of 33.3 ± 2.8.

Physiologic, Metabolic, and Morbidity Profiles of Firefighters, Classified by Body Mass Indices (BMI)

Table 1 describes the metabolic, physiologic, and morbidity profiles of the cohort, grouped by low, medium, and high BMI. Table 2 describes the same profiles for males only, adjusting for the confounding influence of age.

The low BMI group was significantly younger than both the medium and high BMI groups (both, $P < 0.05$). Greater BMI was consistently associated with higher resting blood pressures. Mean systolic resting blood pressure ($P < 0.001$) and diastolic resting blood pressure ($P < 0.05$) were both significantly higher in the high BMI group, compared with the low group. When we adjusted for age, the low BMI class still exhibited significantly lower systolic ($P < 0.005$) and diastolic ($P < 0.05$) blood pressure values than did the high BMI group. The unadjusted difference was also statistically significant for systolic pressure between the low and medium BMI groups ($P < 0.01$) and remained so when the effect of age was adjusted ($P < 0.01$).

Firefighters in the high BMI group had a significantly lower mean percent predicted forced vital capacity (FVC) versus the low BMI group ($P < 0.05$). This difference became more significant when we adjusted for the effect of age ($P < 0.01$). In both the univariate and the age-adjusted models, there were no significant differences between the spirometric function of the low and medium BMI groups.

Increasing BMI was associated with increasing serum cholesterol levels. The age-adjusted differences were less marked. The mean serum cholesterol level of the high BMI group was significantly higher than the mean of the low group, whether unadjusted ($P < 0.01$) or adjusted ($P < 0.05$) means were considered.

The mean creatinine values for the medium and high BMI groups were significantly higher ($P < 0.05$ for both) than those of the low BMI group, although the differences were quite small. Adjusting for age had little effect on the groups' mean creatinine values. In the age-adjusted models, the creatinine value for the low BMI group remained significantly lower versus the high group ($P < 0.05$) and nonsignificantly lower versus the medium group at the trend level ($P < 0.10$).

Increasing BMI was consistently associated with increasing serum transaminase levels. Significant increases in AST ($P < 0.05$) and ALT ($P < 0.001$) levels were seen in the high BMI group versus the low group. When we adjusted for age, both differences between the low BMI and high BMI groups were still present at the same levels of significance. A second multivariate model for transaminase values adjusted for the influences of both age and cholesterol. In this model, only the mean ALT value for the high BMI group remained significantly higher than that of the low group ($P < 0.05$).

Reported ethanol consumption data were available for 114 males. There was no significant relation between the number of alcoholic drinks consumed per week and AST ($r = 0.05$; $P = 0.58$), ALT ($r = 0.16$; $P = 0.085$), or alkaline phosphatase ($r = 0.05$; $P = 0.601$). When AST and ALT were examined for the three BMI groups and adjusted for ethanol intake, alcohol consumption had no significant effect ($P = 0.57$ and $P = 0.12$, respectively). In this model, the effect of BMI on AST and ALT was reduced to the trend level in both cases (both $P < 0.10$), prob-

TABLE 2

Correlates of Obesity: Males Only*

Variable	Low BMI	Medium BMI	High BMI	ANOVA *P*
SBP	119 ± 13 *n* = 99	123 ± 13 *n* = 107	125 ± 13 *n* = 106	<0.003
DBP	77 ± 9 *n* = 99	79 ± 9 *n* = 107	80 ± 9 *n* = 106	NS
FVC %	105 ± 13 *n* = 97	105 ± 13 *n* = 105	100 ± 13 *n* = 104	<0.01
FEV_1 %	103 ± 14 *n* = 97	104 ± 13 *n* = 105	102 ± 13 *n* = 104	NS
ALKPHOS	82 ± 21 *n* = 96	80 ± 21 *n* = 106	86 ± 21 *n* = 106	NS
CHOL	223 ± 38 *n* = 50	223 ± 38 *n* = 66	241 ± 38 *n* = 57	<0.05
BUN	16 ± 4 *n* = 98	16 ± 4 *n* = 107	16 ± 4 *n* = 106	NS
CR	1.09 ± 0.17 *n* = 98	1.14 ± 0.16 *n* = 107	1.14 ± 0.16 *n* = 106	NS (*P* = 0.089)
AST	24 ± 10 *n* = 97	24 ± 10 *n* = 107	27 ± 10 *n* = 105	<0.05
ALT	30 ± 20 *n* = 97	35 ± 20 *n* = 107	42 ± 20 *n* = 105	<0.001
FITRANK	3.4 ± 1.2 *n* = 99	3.6 ± 1.2 *n* = 107	4.1 ± 1.2 *n* = 106	<0.001

* Age-adjusted data.

ably because of the decreased sample size ($n = 112$).

The mean fit rank of the low BMI group was significantly lower than the means for the high group ($P < 0.001$) and the medium BMI group ($P < 0.01$). In the age-adjusted models, only the mean fit rank of the high BMI group remained significantly higher than that of the low group ($P < 0.001$).

Smoking and Body Mass Index

Complete data on smoking history were available for 82% (269 of 329) of the male firefighters. The mean BMI was 29.1 ± 4.3 for the never-smokers ($n = 180$), 28.3 ± 3.1 for the former smokers ($n = 57$), and 27.7 ± 3.6 for the current smokers ($n = 32$). When the BMI of never-smokers was compared with the BMI of the other two groups, neither difference was statistically significant. However, the mean BMI of the never-smokers was significantly higher ($P < 0.05$) when compared with the mean BMI of the combined group of current and former smokers ($n = 89$) (28.1 ± 3.3).

To control for the effects of smoking, we examined the same physiologic, metabolic, and morbidity profiles as above for all male never-smokers ($n = 180$). These data are presented in Table 3. The age-adjusted means for each of the three BMI groups and their rank orders were similar to the age-adjusted means in Table 2. The exception was for mean fit rank scores, which improved for all three groups. Overall, the significance level of the differences was attenuated most likely by the decrease in sample size.

The high BMI group continued to have a significantly higher mean serum cholesterol level ($P < 0.05$), ALT level ($P < 0.01$), and fit rank score ($P < 0.001$) than the low group. The magnitude of the differences between the high and low groups for creatinine level and percent predicted FVC decreased to the trend level ($P < 0.10$). The medium group had significantly higher creatinine values ($P < 0.05$) and a trend toward a higher percent predicted forced expiratory volume in one second (FEV_1) ($P < 0.10$) than did the low group. When adjustments were made for both age and smoking, the medium group had the highest mean percent predicted FEV_1 and FVC.

Discussion

This study documented high prevalence of both overweight status (87%) and obesity (34%) in our cohort. Morbid obesity was present in 2% of the cohort. The mean BMI was 28.9 ± 4.1 kg/m^2. This mean is above the 85th percentile for both men and women for BMI, based on National Health and Nutrition Examination Survey data.[17] In addition, the majority of the cohort (59%) was above the 85th percentile for BMI.

The results of our investigation are consistent with the literature in demonstrating adverse associations between increasing BMI and resting systolic and diastolic blood pressures; FVC; AST, ALT, and serum cholesterol levels; and overall morbidity.[4–7,10]

Increasing age was also associated with increasing BMI, and therefore the physiologic and metabolic effects of BMI were confounded by age. Nonetheless, in multivariate models that adjusted for age, all of the adverse associations with increasing BMI remained statistically significant, with the exception of resting diastolic blood pressure. Smoking, conversely, was associated with having a lower BMI. When the confounding effects of smoking were eliminated by examining never-smokers only, the results were similar, but the significance level of the differences was attenuated most likely by the large decrease in sample size.

There are, however, some limitations to the study. First, although BMI is a reliable and cost-effective measure of obesity and its related risks, it does not distinguish between excess weight due to body fat and weight as a result of bone and muscle mass.[12] We did find a positive association between BMI and creatinine, which suggests that muscle mass increases in addition to increased adi-

TABLE 3
Correlates of Obesity: Male Never-Smokers Only*

Variable	Low BMI	Medium BMI	High BMI	ANOVA *P*
SBP	120 ± 12 *n* = 62	122 ± 12 *n* = 50	124 ± 12 *n* = 66	NS
DBP	78 ± 9 *n* = 62	78 ± 9 *n* = 50	80 ± 9 *n* = 68	NS
FVC %	104 ± 14 *n* = 61	106 ± 14 *n* = 49	99 ± 14 *n* = 67	<0.05
FEV_1 %	102 ± 14 *n* = 61	107 ± 14 *n* = 49	102 ± 14 *n* = 67	NS
ALKPHOS	82 ± 22 *n* = 60	80 ± 22 *n* = 50	86 ± 22 *n* = 68	NS
CHOL	217 ± 42 *n* = 30	224 ± 41 *n* = 31	244 ± 41 *n* = 31	<0.05
BUN	16 ± 4 *n* = 61	16 ± 4 *n* = 50	16 ± 4 *n* = 68	NS
CR	1.10 ± 0.17 *n* = 61	1.18 ± 0.17 *n* = 50	1.16 ± 0.16 *n* = 68	<0.05
AST	23 ± 11 *n* = 61	25 ± 11 *n* = 50	27 ± 11 *n* = 68	NS (*P* = 0.068)
ALT	29 ± 20 *n* = 61	34 ± 20 *n* = 50	41 ± 20 *n* = 68	<0.01
FITRANK	2.9 ± 1.0 *n* = 62	3.0 ± 1.0 *n* = 50	3.9 ± 1.0 *n* = 68	<0.001

* Age-adjusted data.

pose tissue as BMI increases. Moreover, BMI measurements do not describe a subject's fat distribution, which is an important consideration in obesity-related risk factors.[4,5,12] Central fat distribution appears to enhance the risk for several obesity-related conditions, including coronary artery disease, hypertension, blood lipids, and diabetes.[4]

Overall, however, BMI measurements correlate strongly to body-fat percentage[18,19] and to the waist-to-height ratio, a measure of abdominal fat distribution.[12] BMI is widely recognized as a good epidemiologic measurement of obesity, with strong relationships to various health risks.[4,5,10,12] Indeed, when we analyzed data from only non-overweight subjects (BMI of 19 to <25), resting blood pressures, serum cholesterol levels, serum transaminase levels, and morbidity ratings were all even lower than those for the low group (BMI < 27). Finally, the literature documents a direct association between BMI and mortality and morbidity risk in adult men.[4,5,10]

Second, because of limitations in our database, we were unable to control completely for some confounding factors. Our database provided qualitative smoking data, ie, "current," "former," or "never," but not quantitative smoking information, ie, cigarettes/day or pack-years. Also, information on ethanol consumption was available for only about one third of our cohort. Ethanol consumption may also have been underreported because the subjects were public safety officers undergoing fitness for duty examinations. Lastly, our study population was predominantly white and male, and therefore, we could not investigate the effects of race and gender.

Several of our findings deserve further discussion. The prevalences of both overweight status and obesity among our HAZMAT firefighters were strikingly high and greater than those of the US adult population. Thus our cohort would appear to be at a heightened risk for morbidity and mortality when compared with the general US population. Within the cohort, there was a clear and consistent increase in morbidity scores with increasing BMI. This is consistent with the findings of previous studies.[4,10] It must be acknowledged, however, that the internist-generated morbidity ratings were not blinded to height and weight.

Another important finding is the adverse relationship between BMI and liver transaminases: AST and, especially, ALT. Our results, including the more marked effect of increasing BMI on ALT, compared to AST, are consistent with the results of other investigators' cross-sectional studies of BMI and liver enzyme activity.[6,7] These studies provide further support that obesity is a risk factor for the development of fatty liver. In addition, this current study in HAZMAT firefighters, the investigation of hazardous waste workers by Hodgson et al,[6] and the study by Burns et al[7] of chemical workers demonstrate that obesity definitely confounds medical surveillance for potential hepatotoxins.

Consistent with other studies, we found that BMI was significantly and consistently associated with increasing cholesterol levels.[4] Although the mean differences were small, BMI was also associated with higher resting systolic and diastolic blood pressures, which is also consistent with the literature.[4,12] Epidemiologic studies suggest increased cardiac mortality rates for firefighters.[20] In addition, fatality statistics have consistently shown that myocardial infarctions account for approximately 45% of firefighter deaths in the line of duty.[21] They also demonstrate that most of these persons have a prior history of heart and/or other vascular disease. Others have shown obesity to be associated with insulin resistance, type II diabetes, and cardiovascular disease itself.[4] Therefore, the high prevalence of obesity in our cohort and its adverse associations with heart disease and documented cardiac risk factors provide strong arguments for the development of effective fitness and health-promotion programs for firefighters.

Numerous studies have examined the association between obesity and other problems not investigated in this study. The Jette and Sidney[12] study documented decreased muscular endurance and diminished aerobic and anaerobic capacity in obese military personnel. Similar results have been found in firefighters.[22–24] Therefore, some obese firefighters may not be able to meet the well-documented physical demands of their jobs.[24–26] Decreased work capacity and higher energy expenditures for the same work also predispose obese workers to heat-related disorders.[13]

Other researchers report a strong association, especially in men, between obesity and sleep apnea,[9,27–32] sleep disturbances,[8,9] and increased daytime sleepiness even in the absence of apnea.[8] In obese males with BMIs between 32 and 39 and no primary sleep complaints, Vgontzas et al[9] found a 20% prevalence of obstructive sleep apnea that was severe enough to warrant treatment. Among morbidly obese males with BMIs $\geq$ 39, the prevalence was 50%. These BMI ranges correspond to 17% and 2% of our cohort, respectively. If the results from Vgontzas et al[9] are generalizable to our cohort, we would expect a 4.5% (15 of 329) prevalence of sleep apnea that was severe enough to warrant treatment. Additional sleep deprivation and sleep disturbances due to shift work may potentiate these safety risks. The possible presence of an obesity-related sleep disorder that could impair a firefighter's abilities and heighten the risks to personal and public safety should be addressed in fitness for duty examinations.

Consistent with Jette and Sidney,[12] we found that increasing age was associated with increases in BMI. Because BMI is likely to increase with age, we can reasonably conclude, as did Jette and Sidney[12] with armed forces recruits, that a firefighter who is overweight at hire will probably remain overweight and gain additional weight over time. Again, this likely scenario emphasizes the need for effective fitness and health-promotion programs. A review of several physical fitness intervention programs for firefighters documents that such programs can be effective.[33] Positive outcomes include increased maximum oxygen consumption, muscular strength and flexibility, and a decreased percentage of body fat. In conclusion, the high prevalences of obesity and overweight status, their adverse health and fitness associations, and their potential reversibility argue for the development and implementation of fitness-promotion programs for firefighters.

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My Entourage Is Bigger Than Your Entourage

President Clinton went to China with a staff of 800. President Lincoln began in office with a White House staff of one assistant. By the time he had won the Civil War, it had ballooned to—three people. Imagine what he could have accomplished with 800. The Union would probably still be dug in around Petersburg. For that matter, imagine what Clinton could have accomplished over there with a staff of three. . . . Richard Nixon, Quaker piker that he was, took a measly 200 staffers with him to China in 1972. In 1984, Ronald Reagan, champion of small government, took 350.

In world entourages, the United States rules. When Queen Elizabeth visited Ghana recently, she brought with her a relatively tight retinue of a few dozen. . . . When President Jiang Zemin of China visited the United States in 1997, he came with only 80 people, and he had more than a billion to choose from. The late King Faisal of Saudi Arabia traveled with 100. . . . The Sultan of Brunei (until Bill Gates came along, the richest man on earth) visited London in 1992 with only 20. . . . Another time, while shopping in New York, [the Sultan] wanted to charge some purchases, and the clerk asked him for ID. He didn't carry any—a common trait among those who have entourages—so one of his ten bodyguards produced a wad of Brunei cash with His Majesty's face on it.

—From Buckley C. *Forbes FYI,* Fall 1998, p 31 ff.