International Journal of Occupational Safety and Ergonomics (*JOSE*) 2005, Vol. 11, No. 2, 161–170

Refinery Firefighters: Assessing Fitness for Duty

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Firefighting is a hazardous and physically demanding activity. The demanding nature of the tasks involved in firefighting requires a high level of fitness both for the safety of the firefighting personnel as well as for the adequate performance of their tasks. Here, the characteristics (body weight, lung function, etc.) of a small group of refinery firefighters were investigated using exploratory factor analysis and discriminant analysis. The results indicated that there is a group of factors that characterize those individuals meeting minimum fitness requirements as described previously in the literature. The factors that were identified included those related to anthropometry (such as body composition and weight) and those related to physical capabilities (such as push-ups). Since these data are collected relatively easily in most occupational settings, they may offer an efficient surrogate method to determine fitness for duty among firefighters.

firefighters fitness for duty

1. INTRODUCTION

Firefighting is one of the most physically demanding and hazardous of civilian occupations [1, 2, 3, 4]. Reichelt and Conrad [5] note that the work-related injuries, illnesses, and fatalities for this occupation are among the highest for any occupation. Melius [6] cites a wide range of physical hazards that are faced by firefighters, from acute life-threatening situations to long-term exposures that may result in cancer, cardiovascular diseases, and pulmonary diseases, among others. Of the type of injuries suffered, musculoskeletal strains and sprains number the highest, followed by lacerations and contusions, inhalation of hazardous materials, burns, and eye injuries [7].

Decrements in fitness and conditioning among firefighters have been related to a variety of injuries and illnesses including those to the musculoskeletal system [1, 5], as well as heat and fatigue-related conditions due to the strenuous nature of firefighting [6, 8]. While firefighters have been observed to be more fit than the general population, they do not exhibit fitness at the level of athletes [4]. Lemon and Hermiston [9] enumerated firefighters' physiological requirements, including high aerobic capacity, low body fat, and good muscular strength and flexibility. Therefore, fitness is an important aspect of reducing work-related injuries and illnesses in this profession.

Refinery firefighting is distinct from public firefighting in the type and frequency of fires encountered. Refinery firefighters are specifically required to suppress fires that may occur in the refining process, making the frequency of fires lower than would be encountered by a public firefighting

The authors would like to thank R. Jeffrey Lewis, Ph.D., and Layla Fakhrzadeh, M.P.H., for their invaluable comments during the preparation of this manuscript.

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department. In this study, medical, demographic, anthropometric, and physical agility data for 79 firefighters employed at a refinery were evaluated to determine whether commonly collected metrics may be used to assess fitness for duty in a reliable, reproducible, and efficient way. The metrics that appear important in the results are compared with those metrics that have been related to fitness for duty in the literature.

1.1. Cardiorespiratory Fitness and Fitness Assessment

Maximum aerobic capacity ($\dot{V}O_{2_{max}}$) is a measure of cardiovascular fitness and has been used in sports science and medicine as well as in occupational settings. The $\dot{V}O_{2_{max}}$ may therefore be used as a means of determining a firefighter's ability to withstand high rates of oxygen consumption due to strenuous activities, heavy clothing and equipment (such as self-contained breathing apparatus), and high temperatures. Lemon and Hermiston [9] observed that firefighting elicits oxygen consumption between 60 and 80% of the maximum capacity. This is further exacerbated by the added demands of equipment that can cause an average rise of 0.7 ^{o}C in core temperature over a 20-min period [10]. Sothmann et al. [11] recorded the heart rate and oxygen consumption responses of firefighters under actual working conditions and recommended that the $\dot{V}O_{2_{max}}$ for firefighters range between 33.5 to 42 ml/kg/min.

Kales et al. [12] reviewed the criteria used for fitness evaluations among hazardous materials firefighters. They found that 10% of those firefighters who passed these evaluations showed signs of hypertension (there were also a sizable number who showed abnormal audiometry and visual acuity, although those criteria are not under consideration here). Kales et al. [13] followed up this study with an evaluation of criteria for medical disqualification and found higher blood pressure and lower spirometric ratings among the groups that failed.

The ability to predict aerobic capacity from more easily obtained data could be useful since direct measurement of maximum aerobic capacity requires methods that may not be practical under most circumstances. Therefore, it may be preferable to make inferences about aerobic capacity from submaximal tests such as the bicycle ergometer test, which simply requires measurement of submaximal heart rate [14].

1.2. Weight and Body Mass Index

Body fat has been shown to be more responsible for decrements in performance than age [9]. Several studies have documented excess body fat among firefighter populations. For example, Friel and Stones [15] assessed firefighters from eastern Canada and measured height, weight, triceps skinfold as well as high density lipoproteins, low-density lipoproteins, cholesterol, and tryglycerides. The results indicated that the firefighters were overweight, especially given the stressful nature of the work, and that long term strategies were needed to address this problem. Likewise, Kales, et al. [13] found that 87% of the 340 firefighters in their study were overweight (body mass index [BMI] $\geq$ 25), 34% were obese (BMI $\geq$ 30) and 7% were morbidly obese (BMI $\geq$ 39).

Therefore, body composition and weight are important elements of cardiovascular fitness, and studies have demonstrated that these attributes are problematic among firefighters, particularly among populations of hazardous materials firefighters.

1.3. Musculoskeletal Stressors and Flexibility

Reichelt and Conrad [5] note that musculoskeletal risks account for about half of the occupational injuries among U.S. firefighters. The injuries include strains, sprains, and muscular pains primarily of the back. The authors attribute these injuries to workplace factors, external environmental factors, and personal factors. Among the personal factors listed are age, lifestyle, experience, and physical fitness. The latter is especially important, as near-maximal aerobic capacity must often be sustained during fire suppression tasks. Physical fitness and fatigue also are an important potential determinant in the susceptibility of an individual to musculoskeletal injuries.

Cady et al. [1] studied fitness levels, heart rate, blood pressure, flexibility, and musculoskeletal injury (especially lower back) among firefighters. They found that the best predictors of both fitness and musculoskeletal injury were flexibility, strength, 2-min recovery heart rate, and diastolic blood pressure while exercising at a heart rate of 160 beats per minute.

Hilyer et al. [7] investigated the efficacy of a flexibility-training program as an intervention to reduce musculoskeletal injuries and illnesses. They found that although the training program did not reduce the rates of injuries and illnesses, the severity (as indicated by days away from work) was reduced.

Vingård et al. [16] examined occupational risk factors associated with osteoarthrosis of the hip and knee. They found that male firefighters (along with construction workers, farmers, and food processing workers) had an increased risk of hospitalization due to osteoarthrosis of the hip. The same group, except for the food processors, also showed increased risk of hospitalization due to osteoarthrosis of the knee.

1.4. Pulmonary Function, Smoking, and Cardiovascular Disease

Musk et al. [17] showed that there is a relationship to heavy smoke exposure in the course of duty and reduction in forced expiratory volume among firefighters. Subsequently, the pulmonary function of Boston firefighters was evaluated [18] across the course of a 7-year study. Non-smokers among the cohort of 951 firefighters showed a very low decrement in pulmonary function as determined by forced expiratory volume in one second and forced vital capacity (about 2% for each variable). In contrast, smokers among the group showed greater changes in these variables. As such, this study indicates that the effects of smoking may be more pronounced than the effects of smoke inhaled during firefighting activities. Similar decrements in forced expiratory volume were noted by Betchley et al. [19] among forest firefighters from beginning to end of one season of firefighting activity.

Licciardone et al. [20] considered the risk factors for cardiovascular disease among firefighter from two metropolitan fire departments relative to the risk factors identified in the Framingham Heart Study risk profile. The variables included blood pressure and hypertension, body mass index, smoking status, and exercise performance. They found that risk factors for cardiovascular disease among firefighters were no greater than among the general population. There was, however, a marked age effect in that older members of the firefighting population had a higher prevalence of risk factors.

Coronary heart disease (CHD) is related to fitness-for-duty issues, since many risk factors for CHD also affect fitness for duty. Glueck et al. [21] studied risk factors for coronary heart disease and found that those firefighters (in the Cincinnati, OH, USA, fire department) who later developed coronary heart disease, were older, smoked, and had family histories of CHD. When they adjusted for age, they also found that these men had elevated diastolic and systolic blood pressures, among other risk factors.

2. METHODS

2.1. Variables

Data were collected after obtaining informed consent from and demonstrating the components of fitness testing procedures to a sample of 79 refinery firefighters. Variables that reflect the health status (especially fitness) and demographics of the firefighters were used in this analysis. Table 1 shows summary statistics for these data. Note that due to the large number of missing values, serum cholesterol and serum high-density lipoproteins, although pertinent, could not be included in the analysis. Also, although body mass index and body composition are both shown, only the latter was used in the analyses. Finally, for those variables that are binary (such as hypertension), the mean represents the proportion of the subjects with a value of 1 in the coding scheme. The remaining variables that were used in the final analyses are commonly used for assessing firefighter fitness and for employment screening purposes [8].

Table 1. Variables: Units and Descriptive Statistics

Variable	Units or Coding	Descriptive Statistics					
		n	Missing	Minimum	Maximum	*M*	*SD*
Age	years	79	0	26	50	39.0	5.9
Height	m	77	2	1.52	1.96	1.79	0.08
Weight	kg	79	0	50	145	89.9	16.4
Experience	years	76	3	0	19	7.3	4.9
Hypertension	0 = no 1 = yes (SBP > 160 and DBP > 90)	79	0	0	1	0.20	—
Resting SBP	mmHg	79	0	98	174	126.9	14.6
Resting DBP	mmHg	79	0	50	100	79.9	9.3
Resting heart rate	beats/minute	79	0	47	99	69.8	11.6
Aerobic capacity	ml/kg/min	78	1	22	62	37.9	9.5
Body composition	percent body fat	79	0	8.9	35	20.1	5.5
Body mass index	kg/m2	77	2	19.5	40.0	27.9	4.3
Serum cholesterol	mg/100 ml	58	21	134	261	204.4	30.1
Serum high density lipoproteins	mg/100 ml	58	21	25	78	41.1	9.4
Push-ups	count	79	0	9	60	30.3	10.8
Sit-ups	count	78	1	0	43	28.9	8.9
Trunk flexibility	cm	79	0	33	62.2	47.1	7.4
Race	0 = non-white 1 = white	79	0	0	1	0.78	—
Former smoker	0 = not a former smoker 1 = a former smoker	79	0	0	1	0.09	—
Current smoker	0 = not a current smoker 1 = a current smoker	79	0	0	1	0.30	—

Notes. SBP—systolic blood pressure, DBP—diastolic blood pressure.

2.2. Analytical Techniques

Two analytical techniques were used with these data. The first technique, which is more descriptive than inferential, was exploratory factor analysis. This is a technique that provides more insight into the data set than traditional descriptive statistics. The objective of exploratory factor analysis is to identify underlying dimensions of a data set. It is an iterative method of extracting the best and most interpretable set of underlying factors. Factors are extracted from the data until the maximum amount of variance is explained. However, all of the factors are not used, since there is a point at which each does not explain a meaningful portion of the variance. Typically, the Kaiser-Guttman criterion dictates that the eigenvalue of each factor (the eigenvalue is the amount of variance explained by that factor) have at least a value of 1, meaning that the factor explains as much variability as one variable [22].

The second technique used was discriminant analysis [23]. The purpose of this technique is to identify variables that are most important in classifying the firefighters into one of three fitness categories as determined by the maximum aerobic capacity in units of ml/kg/min. Since it is difficult to collect data on aerobic capacity, this metric is a good candidate for the dependent variable in the discriminant analysis. If aerobic capacity can be inferred from data that are more easily collected, it would assist the effort for determining a firefighter's fitness for duty.

The boundary values for the three fitness categories were based on the results of Sothmann et al. [11]. They assessed the oxygen consumption (among other metrics) responses of firefighters under actual working conditions after previously establishing a baseline for each of the subjects using treadmill testing. The classification scheme used in the current study was:

- low capacity: <31 ml/kg/min,
- recommended or medium capacity: ≥31 ml/kg/min and ≤43 ml/kg/min,
- high capacity: >43 ml/kg/min.

3. RESULTS

3.1. Exploratory Factor Analysis

The results of the exploratory factor analysis are shown in Table 2, which indicates the pattern of the loading for the final model. This model explained 59.9% of the variation in the data set. The variables of race, trunk flexibility, and sit-ups performed were not included in this final model due to the fact that they did not meet retention criteria (i.e., low communalities). All remaining variables are loaded on at least one factor, and the resulting factors are described below.

Factor 1 (see section 4 for a more detailed explanation of the factors) explains 16.5% of the variability in this data set. It loaded most heavily (greater than 0.30) on hypertension, resting systolic blood pressure (SBP), and resting diastolic blood pressure (DBP). To a lesser degree (slightly greater than 0.30), the variables of weight and resting heart rate loaded on this factor. These variables together form a hypertension factor, since weight and heart rate are related to hypertension.

Factor 2 explains 16.2% of the variability in this data set. It loads positively on age, weight, resting heart rate, body composition, and resting diastolic blood pressure. It loads negatively on aerobic capacity and the number of push-ups the subject was capable of performing (negative loading indicates that there is an inverse relationship). This constellation of variables appears to form a cardiovascular fitness factor. It is interesting to note that age does not load heavily (only slightly over 0.30) on this factor. This is consistent with the results of Lemon and Hermiston [9], who noted that performance decrements with increased body fat are more important than decrements due to age.

TABLE 2. Loading Pattern for Final Exploratory Factor Analysis Model

Variable	Factor Loadings					Communalities
	F_1	F_2	F_3	F_4	F_5	
Age	0.046	**0.356**	–0.170	**0.495**	0.279	0.481
Height	0.114	0.037	**0.958**	–0.027	0.108	0.944
Weight	**0.304**	**0.489**	**0.502**	0.012	–0.137	0.603
Experience	–0.044	0.153	0.195	**0.710**	–0.059	0.571
Hypertension	**0.829**	–0.092	0.073	0.063	–0.035	0.707
Resting systolic blood pressure	**0.884**	0.175	0.159	–0.062	–0.012	0.842
Resting diastolic blood pressure	**0.614**	**0.385**	0.029	0.069	0.028	0.531
Resting heart rate	**0.330**	**0.386**	–0.128	–0.049	0.290	0.361
Aerobic capacity	–0.013	**–0.696**	–0.062	–0.104	–0.119	0.514
Body composition	0.265	**0.800**	0.040	0.130	**–0.301**	0.820
Push-ups	–0.011	**–0.497**	–0.223	**–0.389**	–0.065	0.453
Sit-ups	×	×	×	×	×	—
Trunk flexibility	×	×	×	×	×	—
Race[1]	×	×	×	×	×	—
Former smoker[2]	0.050	–0.028	–0.144	**0.444**	–0.162	0.247
Current smoker[3]	–0.022	–0.023	0.081	–0.106	**0.834**	0.715
VARIANCE EXPLAINED						TOTAL
Eigenvalues	2.138	2.101	1.367	1.153	1.029	7.789
Percentage	16.45	16.16	10.52	8.87	7.92	59.92

Notes. All loading values greater than |0.3| are in bold. An "×" indicates that the variable was excluded due to communality less than 0.2. 1—0 = non-white, 1 = white; 2—0 = not a former smoker, 1 = a former smoker; 3—0 = not a current smoker, 1 = a current smoker.

Factor 3 explains 10.5% of the variability in the data set. It loads positively on height and weight, and negatively on the number of push-ups the subject was capable of performing. It is apparently a body size factor. This factor had an eigenvalue of 1.4, and is somewhat distant from Factors 1 and 2.

Factor 4 explains 8.9% of the variability in the data set. It loads positively on age, years of firefighting experience, and being a former smoker. It loads negatively, although less strongly, on the number of push-ups the firefighter was capable of performing. This might imply that quitting smoking may lead to more years on the firefighting force and better fitness. This factor had an eigenvalue of 1.2, close to Factor 3.

Factor 5 loads positively on the variable of status as a current smoker and negatively on body composition. This is consistent with the Spearman rank correlation, where this was the only variable that correlated at $\rho^2 > |0.3|$ with status as a current smoker. This factor had an eigenvalue of only 1.0, explaining 7.9% of the variability. Therefore, this is the least important of the factors, explaining about as much as a rank correlation.

3.2. Discriminant Analysis

Table 3 summarizes the final discriminant model. The table includes the structure matrix as well as the group centroid functions for interpretation and comparison. Function 1 of the model discriminates between the group with low aerobic capacity (<31 ml/kg/min) and the two higher aerobic capacity groups considered together (i.e., medium aerobic capacity, ≥31 ml/kg/min and ≤43 ml/kg/min, and high aerobic capacity, >43 ml/kg/min). Function 2 discriminates between those with medium aerobic capacity and those with high aerobic capacity, and does not include the low aerobic capacity group. Therefore, the first function indicates the metrics that discriminate the least fit group (i.e., the low aerobic capacity group) from the medium and high categories (taken together). The second function indicates the metrics that distinguish the medium fitness group from the highest fitness group. It may be desirable to identify those refinery firefighters on the lowest end of the fitness continuum for the purpose of targeting them for fitness-enhancing interventions.

TABLE 3. Final Discriminant Analysis Model

	Function 1	Function 2
Canonical correlations	.59	.55
Tests of functions		
χ^2 value	49.83	22.77
p <	.003	.030
Functions at group centroids★		
group 1	–1.152	–0.089
group 2	0.380	0.616
group 3	0.526	–0.928
Structure matrix		
push-ups	**0.702**	–0.188
experience	**–0.463**	–0.232
body composition	**–0.451**	**0.385**
age	**–0.385**	0.255
race[1]	0.194	0.095
trunk flexibility	0.076	–0.016
resting heart rate	–0.057	**0.603**
resting DBP	–0.013	**0.514**
weight	–0.218	**0.455**
resting SBP	0.173	**0.453**
sit-ups	0.272	**–0.346**
current smoker[3]	0.075	0.280
former smoker[2]	–0.062	0.089

Notes. Bold type in the structure matrix indicates an influence of ≥ |0.3|. Function 1 discriminates between low versus medium/high and Function 2 discriminates medium versus high aerobic capacity groups. Aerobic capacity group membership is based on boundary values in ml/kg/min. ★—group 1: aerobic capacity <31 ml/kg/min, group 2: aerobic capacity ≥ 31 ml/kg/min and ≤43 ml/kg/min, group 3: aerobic capacity >43 ml/kg/min; 1—0 = non-white, 1 = white; 2—0 = not a former smoker, 1 = a former smoker; 3—0 = not a current smoker, 1 = a current smoker; DBP—diastolic blood pressure; SBP—systolic blood pressure.

In the final model, approximately 73% of original grouped cases were correctly classified. The classifications are shown in Table 4.

In Function 1, those firefighters in the lowest aerobic capacity group (<31 ml/kg/min) are compared to those in the medium (≥31 ml/kg/min and ≤43 ml/kg/min) and the high aerobic capacity (>43 ml/kg/min) groups. Those in the lowest aerobic capacity category (relative to the two higher groups taken together):

- have higher percentage body fat,
- are older and have more years of experience, and

TABLE 4. Classification Results for Final Discriminant Analysis Model

Actual Aerobic Capacity Group Membership*	Predicted Aerobic Capacity Group Membership*			
	Group 1	Group 2	Group 3	Row Totals
Group 1	13	4	3	20
Group 2	4	26	3	33
Group 3	2	4	14	20
Ungrouped cases	0	2	0	2

Notes. ★—group 1: aerobic capacity < 31 ml/kg/min, group 2: aerobic capacity ≥ 31 ml/kg/min and ≤ 43 ml/kg/min, group 3: aerobic capacity > 43 ml/kg/min

- are able to perform fewer push-ups.

Function 2 distinguishes the medium aerobic capacity group (≥31 ml/kg/min and ≤43 ml/kg/min) with the high aerobic capacity group (>43 ml/kg/min). Those with medium aerobic capacity (relative to the high group):

- have higher percentage body fat and weigh more,
- have higher resting blood pressure (both systolic and diastolic),
- have higher resting heart rate, and
- are able to perform fewer sit-ups.

The descriptive statistics for each of the three categories are shown in Table 5. Trends for several variables across the three categories of aerobic capacity are observed. As aerobic capacity increases, the following variables decrease: age, weight (although only at the highest aerobic capacity category), percentage body fat, and the likelihood of being a current smoker. As aerobic capacity increases, the following variables also increase: push-ups performed, sit-ups performed, the likelihood of being a former smoker, and the likelihood of being white.

4. DISCUSSION

The literature suggests that there are a number of important variables that are predictive of fitness, including aerobic capacity, cardiovascular function, flexibility, and behavioral variables such as smoking and diet. Most notably, Schoenfeld

TABLE 5. Descriptive Statistics for Variables by Aerobic Capacity Group Classification (Aerobic Capacity Units Are ml/kg/min)

	Aerobic Capacity						TOTAL	
	<31		≥31 and ≤43		>43			
	n = 20		*n* = 33		*n* = 20		*n* = 73	
Variable	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
Age	41.40	6.20	38.90	4.90	36.30	6.98	38.88	6.08
Weight	91.60	15.90	91.50	15.80	80.70	10.80	88.60	15.30
Experience	9.90	6.80	5.70	3.80	7.10	3.57	7.23	5.01
Resting SBP	123.90	13.40	132.20	15.60	122.60	12.70	127.26	14.78
Resting DBP	79.90	6.40	82.90	9.30	75.80	10.31	80.12	9.30
Resting heart rate	69.20	11.90	72.80	10.60	62.80	9.54	69.07	11.37
Body composition	22.50	3.90	20.30	5.50	16.80	5.99	19.94	5.63
Push-ups	23.40	10.00	32.40	9.60	36.20	8.98	30.96	10.62
Sit-ups	26.50	10.60	28.00	8.50	33.10	7.37	29.00	9.10
Trunk flexibility	46.50	5.90	47.30	8.60	47.50	6.80	47.50	7.30
Race[1]	0.70	—	0.85	—	0.80	—	0.79	—
Former smoker[2]	0.10	—	0.09	—	0.05	—	0.08	—
Current smoker[3]	0.25	—	0.39	—	0.20	—	0.30	—

Notes. SBP—systolic blood pressure, DBP—diastolic blood pressure; 1—0 = non-white, 1 = white; 2—0 = not a former smoker, 1 = a former smoker; 3—0 = not a current smoker, 1 = a current smoker.

et al. [24] demonstrated the importance of age, resting heart rate, weight, and height as important predictors of aerobic capacity as measured by $\dot{V}O_{2_{max}}$. Aerobic capacity is an important determinant of likelihood of injury and is also determined by workplace factors, external environmental factors, and behavioral factors [5]. A number of the metrics related to aerobic capacity and fitness in the literature were found to be related to the aerobic capacity in this group of firefighters. These relationships will be further discussed below.

4.1. Exploratory Factor Analysis

The descriptive results (exploratory factor analysis) indicated that there are five factors account for 60% of the total variation in the data: these factors are groupings of the variables that cluster to form a coherent factor. These factors were found to be:

- a hypertension factor (Factor 1) that includes blood pressure, heart rate, and weight,
- a cardiovascular fitness factor (Factor 2) that includes weight, resting heart rate, body composition, aerobic capacity, and the number of push-ups the subject was capable of performing,
- a body size factor (Factor 3) that includes height and weight,
- a healthy survivor factor (Factor 4) that includes age, years of firefighting experience, and status as an ex-smoker, and
- a smoking factor (Factor 5) that indicates a relationship between higher body fat content and status as a current smoker.

This underlying grouping of the variables is a more efficient method for observing the relationships among variables. These relationships would be much more difficult to infer by only looking at a correlation matrix (which contains much of the same information).

Of the factors, those that contain the most information are the cardiovascular fitness factor [2] and the healthy survivor factor [4]. Factor 2 is consistent with the literature. In particular, Reichelt and Conrad [5] found an inverse relationship between the group of variables including weight, body composition, and heart rate and variables related to aerobic capacity and physical performance (such as the number of push-ups the subject is capable of performing). Factor 4 indicates that as the members of this particular group of firefighters age and acquire seniority, that they are more likely to have quit smoking. This is interesting, since this factor may suggest that those firefighters that remain on the force are the ones who have enhanced their cardiovascular fitness by quitting smoking. Kales and Christiani [25] note that firefighters who are lighter and more fit, are non-smokers, and have stable body weights are much less likely to have medical problems. However, they found that hazardous materials firefighting teams were not as fit, with a 34% prevalence of obesity (BMI ≥ 30) and a 12% prevalence of smoking.

4.2. Discriminant Analysis

The inferential (discriminant analysis) results indicated that traditional measures of fitness in firefighters are related to aerobic capacity. It also indicated that the firefighter fitness categorizations suggested by Sothmann et al. [11] and used in this analysis appear to be appropriate for this population.

The functions outlined in the discriminant analysis model indicate a set of variables that are relatively easy to collect. In turn, these variables may be used to make inferences about the aerobic capacity and the fitness of the firefighters. These can then be used as a fitness for duty metric to target those in need of fitness enhancing interventions as well as for quick, efficient, and low-cost fitness for duty assessments.

This set of results shows that one set of metrics differentiates the medium aerobic capacity group from the high aerobic capacity group (Function 2). The set of metrics consists of body composition, weight, heart rate, systolic blood pressure, diastolic blood pressure, and performance of sit-ups.

However, a slightly different set of metrics (although an intersecting set) differentiates the low aerobic capacity group from the medium and high aerobic capacity groups (taken together, Function 1). This is a more important distinction, since the lowest aerobic capacity group is more important to isolate for potential interventions.

The set of metrics consists of body composition, performance of push-ups, age, and years of experience. Age is the least influential variable, while body composition, push-ups, and years of firefighting experience are the most influential in determining this discriminant function (as determined by the magnitude of the influence of the variable in the structure matrix). Firefighting experience is an important variable differentiating the low group from the medium and high groups.

The fact that trunk flexibility did not figure prominently in any of these results is not surprising, given the findings of Hilyer et al. [7]. Although the relationship is indirect, they found that flexibility training was not effective in reducing the incidence of injury (although it did reduce severity). Injury is closely related to fitness since higher levels of fitness reduce the severity and costs of joint injuries among the firefighting population.

5. CONCLUSION

The most practical application of these results is the use of discriminant function 1, which identifies the variables that differentiate the lowest fitness category from the medium and high fitness categories (when the latter two are considered as an aggregate). The variables that differentiated this least fit group were years of experience, age, body composition (percent body fat), and the ability to perform push-ups.

More experienced (a mean of 10 years for the lowest category versus 6 and 7 years for the medium and upper categories, respectively) and older firefighters (a mean of 41 years of age, versus 38 and 36 years of age for the medium and upper fitness categories, respectively) are more likely to be among the lower fitness group. However, age was not a very influential variable in the discriminant model and experience is not a very useful variable to use as a screening method.

More useful variables are body composition and push-ups. The lower fitness group has a mean body composition of 23% body fat, as compared to means of 20% and 17% for the medium and upper fitness groups, respectively. Finally, and what may be suggested as a good clinical test, is the number of push-ups performed. The average number of push-ups that those in the lower fitness category could perform was only 23, as compared to means of 32 and 36 for the medium and upper categories.

Although these data should not be over-interpreted, these figures may suggest guidelines for making inferences about fitness from body composition and performance of push-ups. In addition, this may suggest a larger, more controlled study that investigates this relationship with a larger number of subjects.

There are several strengths to this research. This population is a working group of refinery firefighters who are distinct from the public firefighter population in the types of fires they are called upon to suppress. However, the demands made upon refinery firefighters are in many ways similar to those made on members of public firefighting departments. Therefore, this study has suggested that these populations are similar and that they suffer from many of the same limitations as do other firefighting departments, particularly obesity and smoking.

The primary limitation of this study was the relatively small number of subjects that were available as well as the paucity of information on blood chemistry (high density lipoproteins and cholesterol) that could have been included in the final analysis.

This study has shown that some anthropometric factors (body composition and weight) and a performance factor (push-ups) may be used to identify firefighters who have less than recommended aerobic capacities (i.e., less than 31 ml/kg/min) as determined by Sothmann et al. [11]. This provides some basis for using these easily obtained metrics for a simple, efficient, and inexpensive initial screening purposes.

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