Fitness Self-Perception and $\dot{V}O_2$max in Firefighters

W. F. Peate, MD, MPH
Linda Lundergan, MD, MPH
Jerry J. Johnson, PA-C, MS (exercise)

Firefighters work at maximal levels of exertion. Fitness for such duty requires adequate aerobic capacity (maximum oxygen consumption [$\dot{V}O_2$max]). Aerobic fitness can both improve a worker's ability to perform and offer resistance to cardiopulmonary conditions. Inactive firefighters have a 90% greater risk of myocardial infarction than those who are aerobically fit. Participants (101 firefighters) completed a questionnaire that asked them to rank their fitness level from 0 to 7; eg, Level 0 was low fitness: "I avoid walking or exertion, eg, always use elevator, drive whenever possible." The level of activity rating increased to Level 7: "I run over 10 miles per week or spend 3 hours per week in comparable physical activity." Each participant then completed two measures of $\dot{V}O_2$max: a 5-minute step test and a submaximal treadmill test. There was no association between the firefighters' self-perception of their level of fitness and their aerobic capacity as measured by either step test or submaximal treadmill. Because of the critical job demands of firefighting and the negative consequences of inadequate fitness and aerobic capacity, periodic aerobic capacity testing with individualized exercise prescriptions and work–community support may be advisable for all active-duty firefighters.
(J Occup Environ Med. *2002;44:546–550*)

Increased physical activity can lower overall mortality and cardiovascular disease and improve cardiovascular disease risk factors such as high density lipoprotein cholesterol, blood pressure (BP), glucose levels, and sensitivity to insulin.[1–5] Being physically active contributes to a lower risk of colon cancer, osteoarthritis, osteoporosis, non-insulin dependent diabetes mellitus,[6] and illness-related absenteeism.

Many occupational groups perform at a high level of physical activity during all or part of the workday. How closely does such workers' self-perception of fitness correspond to their actual fitness level or aerobic capacity, and what are the implications for clinical or work community interventions?

Background

Firefighters at times work at maximal levels of exertion.[7–9] Aerobic fitness can both improve a firefighter's ability to perform and offer resistance to cardiopulmonary conditions. Fitness for such duty requires adequate aerobic capacity and sufficient reserve. Oxygen consumption during firefighting tasks ranges from 60% to 80% of maximum with significant cardiopulmonary and thermoregulatory strain.[10] Inactive personnel have a 90% greater risk of myocardial infarction than those who are aerobically fit.[11] According to the International Association of Fire Fighters Death and Injury Surveys, the leading occupation-related cause of premature termination of service from firefighting is cardiopulmonary disease.[12] Firefighters have increased cardiovascular disease in ep-

From the College of Public Health, Family and Community Medicine, Clinical (Dr Peate); Quality Assurance, Campus Health (Dr Lundergan); and Occupational Health, Campus Health (Mr Johnson); University of Arizona.

Address correspondence to: Dr W. F. Peate, Associate Professor of Public Health, Associate Professor of Family and Community Medicine, Clinical, University of Arizona, 1435 N. Fremont, Tucson, AZ 85719; peate@u.arizona.edu.

idemiological investigations.[12] Furthermore, 45% of deaths in firefighters that occur during active duty are due to myocardial infarction, and the majority had a previous history of cardiovascular disease.[13] Firefighters with early cardiopulmonary disease may be without symptoms such as chest pain, although they might report a decreased tolerance for physical activity.[13]

The Fire Service Joint Labor Management Wellness/Fitness Initiative was developed to address the above concerns and to foster lifelong fitness among firefighters. The Initiative advises an aerobic capacity at or greater than 42 mL/kg/min maximum oxygen consumption ($\dot{V}O_2$max) to provide for sufficient reserve capacity. Firefighters with a $\dot{V}O_2$max >33.5 mL/kg/min have been found to be unlikely to safely perform expected work tasks for longer than a few minutes.[14] Given the potential adverse effects of inadequate fitness in firefighters, we sought to determine whether a firefighter's perceived level of fitness, exercise, and physical activity level matched his or her actual aerobic capacity.

In addition, we aimed to determine the benefits of provider counseling about physical activity as a preventive measure for firefighters' risk of cardiopulmonary disease. Several studies have suggested the benefits of such counseling in individuals as part of a clinical practice[15,16] but have not explored the effects in occupational settings. Public health guidelines advise health care providers to recommend at least 30 minutes of physical activity, preferably every day.[17–20] Albright et al found that provider physical activity advice was minimally disruptive of routine care, even among busy practitioners who perceived that participation in this activity was beneficial.[21]

Methods

Participants

The participants (n = 101) were all active-duty members of a fire department who participated in this study as part of their annual physical examination. They ranged in age from 20 to 58 years; 9% were female and 91% were male.

Medical surveillance examinations were conducted at the University of Arizona in Tucson. All examinations were conducted in a similar manner and included a health risk appraisal with questionnaire, detailed history, anthropometric measurements, physical examination, resting 12-lead electrocardiogram, and two measures of aerobic capacity or $\dot{V}O_2$max: the submaximal graded exercise test Bruce Protocol[22] and the 5-minute step test.[23]

Approval for the review of human subjects was obtained from the institutional review board of the University of Arizona. All firefighters were examined on a confidential basis. Participants signed a consent form and had an opportunity to present their questions and concerns about the study.

$\dot{V}O_2$max is milliliters of oxygen per kilogram of body weight per minute (1 met = 3.5 mL/kg/min). The results were entered into a computerized medical record.

The health risk appraisal questionnaire asked the participants to rank their fitness level from 0 to 7; eg, Level 0 was low fitness: "I avoid walking or exertion, eg, always use elevator, drive whenever possible." The level of activity rating increased to Level 7: "I run over 10 miles per week or spend 3 hours per week in comparable physical activity."

All participants were medically cleared with the health risk appraisal, history, physical examination, and electrocardiogram prior to participating in the measures of aerobic capacity. To avoid fatigue, each participant completed a 5-minute step test and on a subsequent day a submaximal treadmill, Bruce Protocol. Participants were advised not to eat, imbibe, ingest caffeine-containing products, or smoke or chew tobacco 2 hours before either test.

5-Minute Step Test

The 5-minute step test was originally developed for firefighters working in forestry. Research determined the aerobic capacity necessary to conduct firefighting tasks effectively and with sufficient reserve capacity.[14]

A step test bench that measures 15¾ inches (40.4 cm) in height was used. If the subject is shorter than 5 feet 2 inches (159 cm) tall, the 12-inch (31-cm) side of the box was used. The testing room was well ventilated, of comfortable temperature, and lighting was adequate. The procedure was reviewed with participants, and they were given an opportunity to voice concerns or questions.

The participants were given 5 minutes to stretch. A metronome set at 90 beats per minute was used to set the pace. The metronome was played for 30 seconds before the test so that the firefighter could march in place to practice the beat. The stepping procedure was demonstrated to the participants. They were instructed to step up and down for 5 minutes at a pace set by the metronome, and they were advised that if they felt any chest discomfort, numbness, or radiating pain or could not continue the test, they should stop. At completion of the test, they were informed to sit on a chair next to the step apparatus. The participant's pulse was ascertained at 15 seconds.

$\dot{V}O_2$max was determined using the Sharkey et al procedure.[23] The participant's weight was rounded to the nearest 10 pounds (4.5 kg). The intersection of the rounded weight and the 15-second heart rate (HR) was noted[23] (Table 1, finding the weight-adjusted $\dot{V}O_2$max).

Next, age was rounded to the nearest 5-year category (25, 30, 35, etc). Using Sharkey (Table 2), the weight-adjusted $\dot{V}O_2$max and the age intersect equals the estimated $\dot{V}O_2$max (age-adjusted), which was recorded (Table 2, finding the estimated $\dot{V}O_2$max age-adjusted using the weight-adjusted $\dot{V}O_2$max from Table 1).[23]

TABLE 1
Self-Rated Fitness Level*

	Mean $\dot{V}O_2$ max Treadmill (mL/kg/min)	Mean $\dot{V}O_2$ max 5-Min Step (mL/kg/min)
Less fit to more fit		
0	0	0
1	42.5 ± 3.5 (n = 2)	37.4 ± 1.4 (n = 2)
2	35.0 ± 7.1 (n = 2)	47.5 ± 21.9 (n = 2)
3	40.5 ± 9.4 (n = 13)	40.7 ± 6.3 (n = 13)
4	37.7 ± 10.4 (n = 7)	38.3 ± 7.3 (n = 7)
5	41.7 ± 8.2 (n = 34)	44.3 ± 8.7 (n = 30)
Categories combined		
I	42.5 ± 3.5 (n = 2)	37.0 ± 1.4 (n = 2)
II	39.7 ± 9.1 (n = 15)	41.6 ± 8.6 (n = 15)
III	41.0 ± 8.6 (n = 41)	43.1 ± 8.7 (n = 37)

* $\dot{V}O_2$ max, maximum oxygen consumption. Values are expressed as mean ± SD.

TABLE 2
Self-Rated Fitness Level by Quartiles of Treadmill $\dot{V}O_2$ max*

	Fitness Level					
Quartiles of Treadmill $\dot{V}O_2$ max (ml/kg/min)	0, 1 (n = 2)		2, 3 (n = 15)		4 (n = 41)	
	n	%	n	%	n	%
22–37	0		5	33	12	29
38–42	1	50	3	20	9	22
43–45	1	50	5	33	10	24
46–68	0		2	13	10	24

* $\dot{V}O_2$ max, maximum oxygen consumption.

The Submaximal Treadmill Test, Bruce Protocol

Submaximal treadmill testing[22] uses an endpoint based on a predetermined HR, in this study, 85% of predicted HR reserve ([maximal HR − resting HR) × 0.85] + resting HR). The treadmill was a Burdick device capable of a 25% grade with cushioning shock-absorption capabilities to diminish musculoskeletal stress.

Pretest Procedure

The pretest procedure was follows:

- The test procedure was reviewed, and the participants were given time to present questions or concerns.
- BP level and pulse rate were taken immediately before the test began.
- HR, BP, and rate of perceived exertion were taken at regular intervals during the test and recovery period.
- The recovery period was 5 minutes long.
- Low-intensity exercise was continued until HR and BP stabilized.
- BP was measured with the arm relaxed and not touching the treadmill rail.
- The electrocardiogram was used to determine the HR.

The following procedures were adhered to for cessation of the test:

- Significant drop (20 mm Hg) in systolic BP or failure of the systolic BP to increase with an increase in exercise level.
- Chest pain or angina or angina-like symptoms.
- Noticeable alteration of heart rhythm.
- Failure of the HR to increase with exercise intensity.
- Failure of the equipment.
- Signs of poor perfusion: confusion, ataxia, pallor, cyanosis, nausea, or cold and clammy skin.
- Physical of verbal manifestations of fatigue or musculoskeletal complaints.
- Excessive rise in BP: systolic BP greater than 260 mm Hg or diastolic BP greater than 115 mm Hg.
- Request to stop testing by the subject.

Fortunately, none of the above occurred for any participants. The $\dot{V}O_2$max for each participant was based on the number obtained on the submaximal test divided by 0.75.[14]

Results

A total of 101 firefighters performed the treadmill test, with a mean $\dot{V}O_2$max of 41.8 ± 8.8 mL/kg/min; 92 performed the 5-minute step test with a mean $\dot{V}O_2$max of 42.8 ± 8 mL/kg/min. The mean age of the firefighters was 32 ± 7.8 years; 96 (95%) were male and 5 (5%) were female.

Self-rated fitness level was not significantly associated with aerobic capacity, as measured by either the submaximal treadmill or the 5-minute step test (Table 1). This result did not vary when fitness level groups were combined and category 1 was excluded because of a low number of subjects (n = 2). Although when the levels were combined and category 1 was excluded, there was a nonsignificant increase in aerobic capacity as the self-rated fitness level increased.

Most activity categories had a wide range of aerobic capacity results. Similarly, when aerobic capacity was divided into quartiles, the quartiles contained statistically similar proportions of firefighters per ac-

TABLE 3
Activity Level by Clinically Relevant Treadmill $\dot{V}O_2$ max*

Clinically Relevant Treadmill $\dot{V}O_2$ max (mL/kg/min)	Fitness Level 0, 1 ($n = 2$)		2, 3 ($n = 15$)		4 ($n = 41$)	
	n	%	*n*	%	*n*	%
<33.5	0		3	20	7	17
33.5–41.5	1	50	5	33	11	27
≥42	1	50	7	46	23	56

* $\dot{V}O_2$ max, maximum oxygen consumption.

tivity level (Table 2). For example, five (33%) of the firefighters in the second activity level had aerobic capacity of 22 to 37 mL/kg/min, as did nine (21%) of the firefighters in the fourth (highest) level ($P = 0.60$ by chi-squared test).

We also looked at a clinically relevant division of aerobic capacity (Table 3), measured by treadmill testing, and found similar results: three (20%) firefighters in the second highest activity level had $\dot{V}O_2$max <33.5 mL/kg/min, as did seven (16%) firefighters in the highest activity level ($P = 0.74$ by chi-squared test).

Data Analysis

Population characteristics were described using values expressed as mean ± SD. One-way analysis of variance was used to examine the relationship between independent variables (self-rating on questionnaire) and dependent variables (aerobic capacity as determined by treadmill and step test results). The self-rating scales were analyzed with the eight levels in the original scale and then collapsed into four levels or categories. The first collapsed category contained only two subjects, so analyses were done while including and excluding this category. All tests met the criteria for using one-way analysis of variance: variances were homogeneous with 95% confidence levels, and the samples were normally distributed.

Self-reported ratings were also evaluated by dividing the treadmill results into quartiles and performing chi-squared tests with Fisher exact test if indicated. All analyses were conducted with Epi Info software using a 2-sided P value with < 0.05 as significant.

Discussion

There was no association between the firefighters' self-perception of their level of fitness and their aerobic capacity as measured by either step test or submaximal treadmill. Because of the critical job demands of firefighting and the negative consequences of inadequate fitness and aerobic capacity, periodic aerobic capacity testing with individualized exercise prescriptions (and further medical evaluation as indicated) may be advisable for all active-duty firefighters.

Study limitations included (1) small sample size; (2) timing of the test (some firefighters had just completed a work shift and were tired or may have ingested caffeine-containing products, thus altering their cardiovascular response); (3) the self-rating scale possibly at too low a level of physical activity to discriminate among groups for this population; and (4) self-reporting bias. Firefighters may have reported inaccurate information regarding their fitness, either intentionally or unintentionally, though self-reporting has been found to be generally valid in some studies.[24] Certain generalizations for predicting functional capacity from treadmill performance that were followed may not be valid universally under all circumstances, such as a genetically low $\dot{V}O_2$max.[25] Because of the small number of women, we were unable to make conclusions about the effect of gender.

Our review of the literature showed the current study to be the first to investigate a worker's self-perception of fitness and lack of correlation with a quantifiable measure of fitness ($\dot{V}O_2$max).

Firefighters with diminished aerobic capacity may not be able to successfully perform the physical demands of their occupation.[26–28] Because of the critical job demands of firefighting, the negative consequences of inadequate fitness and aerobic capacity, and an apparent lack of correlation between a firefighter's self-perception of fitness and $\dot{V}O_2$max, periodic aerobic capacity testing with individualized exercise prescriptions (and further medical evaluation as indicated) and organizational support may be advisable for all active-duty firefighters. Such programs have been effective in improving ergonomics and other outcomes.[29]

In addition, improving modifiable risk factors such as fitness can have a positive impact on medical expenses,[30] which may be compelling for management, particularly when resources for employee benefits are limited.

Conclusions, Recommendations, and Implications for Application

More work must be done to promote fitness in occupational groups. In particular, what characterizes those workers such as firefighters who change, maintain, or sustain fitness? Standard algorithms characterize individuals according to their motivational readiness for change using the categories of precontemplation, contemplation, preparation, action (eg, currently exercising but for less than the prior 6 months), and maintenance (eg, regularly exercising more than the prior 6 months).[31] On the other hand, how do we address a lack of correlation between an individual's self-perception of fitness and reality based on a quantifiable fitness measure? Will greater individual awareness of such a disparity, in concert with provider guidance, promote a change from precontemplation to action?

We plan future qualitative and quantitative research on the following issues:

1. To what degree does the availability of exercise equipment at home and work improve fitness?

2. If equipment is available, what are the reasons for using or not using this resource?

3. To what extent does management support enhance fitness in occupational settings?

4. What are the benefits of provider-offered exercise prescriptions in work communities?

References

1. Fagard RH, Tipton CM. Physical activity, fitness and hypertension. In: Bouchard C, Shepard RJ, Stephens T, eds. *Physical Activity, Health and Fitness: International Proceedings and Consensus Statement*. Champaign, IL: Human Kinetic Publishers; 1994:663–665.
2. Reitman JS, Vasquez B, Klimes I, et al. Improvement of glucose homeostasis after exercise training in non-insulin dependent diabetes. *Diabetes Care*. 1984;7:432–441.
3. Trovati M, Carta Q, Cavalot F, et al. Influence of physical training on blood glucose control, glucose tolerance, insulin secretion, and insulin action on non-insulin dependent diabetic patients. *Diabetes Care*. 1984;7:416–420.
4. Blair SN, Kohl HW III, Barlow CE, Paffenbarger RS Jr, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *JAMA*. 1995;273:1093–1098.
5. Holloszy JO, Schultz J, Kusnierkiewicz J, et al. Effects of exercise on glucose tolerance and insulin resistance: brief review and preliminary results. *Acta Medica Scandinavia*. 1986;711(suppl):55–65.
6. US Department of Health and Human Services. *Physical Activity and Health. A Report of the Surgeon General*. Atlanta, GA: USDHHS, Centers for Disease Control and Prevention; 1996.
7. Gledhill N, Jamnik VK. Characterization of the physical demands of fire fighting. *Can J Sport Sci*. 1992;17:207–213.
8. Horowitz MR, Montgomery DL. Physiological profile of fire fighters compared to norms for the Canadian population. *Can J Public Health*. 1993;84:50–52.
9. Davis PO, Dotson, CO. Physiological aspects of fire fighting. *Fire Technol*. 1987;23:280–291.
10. Lemon PWR, Hermiston RT. The energy cost of fire fighting. *J Occup Med*. 1997;19:337–340.
11. Powell KE, Thompson PD, Caspersen CJ, Kendrick JS. Physical activity and the incidence of coronary artery disease. *Ann Rev Public Health*. 1987;8:253–287.
12. National Fire Protection Association. 1582: *Standard on Medical Requirements for Firefighters*. Quincy, MA: NFPA; 1997.
13. National Institute for Occupational Safety and Health, National Fire Protection Association. US fire fighters: population at risk—1996 estimates. Available at: http://www.cdc.gov/niosh/slides.html. Accessed Feb 11, 1998.
14. International Association of Fire Fighters. *Fire Service Joint Labor Management Wellness Fitness Initiative*. Washington DC: IAFF; 1997.
15. Calfas JK, Long BJ, Sallis JF, Wooten WJ, Pratt M, Patrick K. A controlled trial of physician counseling to promote the adoption of physical activity. *Prev Med*. 1996;25:225–233.
16. Lewis BS, Lynch WD. The effect of physician advice on exercise behavior. *Prev Med*. 1993;22:110–121.
17. Pate R, Pratt M, Blair S, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995;273:402–407.
18. Canadian Task Force on the Periodic Health Examination. The periodic health examination:2. 1987 update. *Can Med Assoc J*. 1988;138:618–626.
19. Preventive Services Task Force. *Guide to Clinical Preventive Services: Report of the US Preventive Services Task Force*. 2nd ed. Baltimore: Williams and Wilkins; 1996.
20. American Heart Association. AHA position statement. Benefits and recommendations for physical activity for all Americans. *Circulation*. 1992;86:26–74.
21. Albright CL, Cohen S, Gibbons L, et al. Incorporating physical activity advice into primary care. *Am J Prev Med*. 2000;18:225–235.
22. Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and normographic assessment of functional aerobic impairment in cardiovascular disease. *Am Heart J*. 1973;85:546–562.
23. Sharkey BJ, Jukkala A, Putnam T, Tietz J. *Fitness and Work Capacity: Wildland Firefighting*. Missoula, MT; 1978.
24. Colditz GA, Martin P, Stampfer MJ, et al. Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. *Am J Epidemiol*. 1986;123:894–900.
25. Foster C, Jackson AS, Pollock ML, et al. Generalizations for predicting functional capacity from treadmill performance. *Am Heart J*. 1984;108:1229–1234.
26. Kilbom A. Physical work capacity of firemen. *Scand J Work Environ Health*. 1980;6:48–57.
27. Jacobson BH, Aldana SG. Relationship between frequency of aerobic capacity and illness-related absenteeism in a large employee sample. *J Occup Environ Med*. 2001;43:1019–1025.
28. Davis PO, Dotson CO, Laine-Santa Maria D. Relationship between simulated fire fighting tasks and physical performance measures. *Med Sci Sport Exer*. 1982;14:65–71.
29. Reichelt PA, Conrad KM. Musculoskeletal injury: ergonomics and physical fitness in firefighters. *Occup Med*. 1995;10:735–756.
30. Goetzel RZ, Andeerson DR, Whitmer RW, et al. The relationship between modifiable health risks and health care expenditures. *J Occup Environ Med*. 1998;40:843–854.
31. Marcus BH, Simkin LR. The stages of exercise behavior. *J Sports Med Phys Fitness*. 1993;33:83–88.