1000 FREDERICK LANE, MORGANTOWN, WV 26508 • 304.285.5916

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Executive Summary

On April 21, 2020, a 43-year-old male career fire engine operator (FEO) died during a physical fitness training run while on-duty. The engine company consisted of a four-person crew, including a lieutenant (LT), the FEO and two firefighters. On the day of the incident, the FEO arrived at his regular single engine company fire station. The crew began their shift by conducting ladder inspections and training, followed by flushing the engine pump just prior to dinner. At approximately 1830 hours, the crew began physical fitness training that included weight training, pull-ups, stationary bicycling, and running.

As the crew participated in various types of physical fitness training at the station, the FEO chose to run several laps around the fire station neighborhood by himself. Crew members stated that was a change for the FEO, as he normally chose weightlifting and did not typically run for his physical fitness training.

As the LT was doing his own workout, he could see the FEO outside as he passed the fire station. After a few laps the LT noticed the FEO had not passed the fire station as he expected, so he looked down the street and witnessed the FEO fall to the ground. The LT called for the two firefighters working out to assist checking on the FEO. They found him unresponsive with his jaw clenched and arms in rigid extension. The LT immediately called fire dispatch at approximately 1915 and requested an ambulance for a "firefighter down." The transporting ambulance arrived at 1917 hours and assisted the station crew initiate advanced life support (ALS). ALS efforts were continued en-route to the nearest hospital, located two blocks away. On arrival to the Emergency Department, the FEO became pulseless. Resuscitation efforts were continued but were unsuccessful and the FEO was pronounced dead at 1952 hours. The autopsy revealed the cause of death to be exercised induced pulmonary hemorrhage (EIPH).

Key Recommendations

NIOSH investigators offer the following recommendations to prevent similar fatal events, and to address general health and safety issues among firefighters at this and other fire departments across the country.

Key Recommendation 1: Consider including information on training intensity and EIPH on physical fitness training materials

Key Recommendation 2: Provide annual medical evaluations consistent with National Fire Protection Association (NFPA) 1582 Standard on Comprehensive Occupational Medical Program for Fire Departments, which includes an evaluation of aerobic capacity in all individuals prior to engagement in any strenuous physical activity by conducting an exercise stress test [NFPA 2018].

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Key Recommendation 3: Implement a mandatory wellness and fitness program for fire department members consistent with NFPA 1583 Standard on Health-Related Fitness Programs for Fire Departments Members and the IAFF/IAFC Wellness-Fitness Initiative, which includes determining intensity of exercise [IAFF/IAFC 2018; NFPA 2015].

Key Recommendation 4: Consider methods to stay in communication during physical exercise such as carrying a department radio or exercising in pairs when possible.

For further information, visit the program Web site at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Introduction

On April 21, 2020, a 43-year-old male career firefighter suffered a medical emergency while participating in a physical fitness run and died. The U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this fatality on April 24, 2020. NIOSH contacted the affected department to gather additional information and initiate the investigation. A medical officer, investigator, and a firefighter safety specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) conducted the investigation.

During the investigation, the NIOSH investigators interviewed the following agency personnel:

- *Assistant Chief*
- *Crew members*
- *Department physician*
- *Family member*

NIOSH personnel reviewed the following documents:

- *Fire department standard operational procedures*
- *Facility incident reports*
- *Department medical policies*
- *Emergency medical service (ambulance) report*
- *Autopsy and toxicology reports*
- *Agency physician records*

Fire Department

The department is a full-service municipal fire department with 34 fire stations, 918 career firefighters and 240 civilian employees and has an ISO (Insurance Services Offices) Class 1 rating. The department serves a population of approximately 680,000 over 260 square miles and responds to more than 70,000 calls annually. The calls include fires, medical emergencies, and hazardous materials incidents within the city, as well as paramedic and ambulance transport to the community. The

department also responds to water, mountain, and technical rescues. In addition, the department responds to the county and neighboring military base through a mutual aid agreement.

Employment and Training

The hiring process consists of:

- Written examination-minimum score of 70% to advance
- Physical agility test-the department utilizes the candidate physical ability test (CPAT)
- Background investigation
- Fire department oral interview
- Physical examination-City appointed physician will perform exam to the standards of the National Fire Protection Association (NFPA) 1582-Standard on Comprehensive Occupational Medical Program for Fire Departments.

The departments physical fitness training policy allows for one hour of physical training per 24-hour shift.

Preplacement/Periodic/Return to Work Medical Evaluation

Preplacement

After selection is made by the fire chief, applicants are given a conditional offer of employment and scheduled for a physical exam by a city appointed physician to determine whether or not an applicant is able to perform the tasks required of a firefighter. Additionally, applicants will be screened for drugs. All physical examinations will be performed to the standards of *NFPA 1582: Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2018].*

Periodic

All personnel complete an annual physical exam administered by a third-party provider. Operations personnel must complete their annual physical by October 31st of each year. To meet this goal, a minimum of 10% of line personnel will complete their physical each month. Personnel assigned to a 40-hour position will complete their annual physical in November and December of each year. Personnel will coordinate with their respective battalion chief or division head when scheduling their physicals. The only exceptions to this policy will be for personnel on long-term protected leave.

Return to Work

After a “lost time” injury, a physician must provide a statement that the employee has sufficiently recovered to return to duty. An employee who has returned to work after a “lost time” injury may not take additional days off because of the injury without certification by a doctor of a continuing disability.

Wellness/Fitness Programs

The Wellness/Fitness Initiative of the department has incorporated the fitness initiative outlined in NFPA 1500. The program recognizes that at least three hours per week must be dedicated to a fitness

routine for the employee to be productive in their fitness effort. To accomplish this, employees who work the 56-hour schedule will exercise for at least one hour per shift. All other uniformed employees may organize their workout times into a format conducive to their work schedule. The exercise program will consist of:

- a proper warm-up
- stretching to improve flexibility
- cardiovascular exercise to improve endurance
- weight-training to improve strength
- a proper cool-down

Investigation

The station is in the central part of a city and serves a combination of residential, commercial, and institutional districts. Daily staffing for the engine company at this station includes a lieutenant (LT), fire engine operator (FEO), and two firefighters. A 43-year-old male career firefighter arrived at the station as scheduled for his regular 24-hour shift on April 21, 2020. He was permanently assigned as the driver/operator (also known as the FEO), for the engine at the single company fire station.

The crew began their 24-hour shift at 1145 hours. According to the fire department incident report activities for the crew began at 1415 hours with the monthly drill and inspection of the ground ladders, followed by refresher training for the firefighters on pump operations and flushing the pump. The crew had dinner at 1700 hours. The crew had not responded to any emergency calls since they started their shift.

At approximately 1830 hours the crew began their physical fitness training. According to Weather Underground, the ambient temperature at 1856 was 86 degrees Fahrenheit [Weather Underground no-date]. The FEO chose to run around the neighborhood, while the LT and firefighters did weight training, pull-ups, and bicycling in the station's indoor gym. The crew noted that the FEO normally chose to weightlift for physical training, and they had not seen him run for years while at the station.

The FEO began his run going east from the fire station for one block on a slight incline, then made a left running north for two blocks on a slight decline, made another left turn running west for one block on a decline, and made a final left turn running south for two blocks on an incline back to the fire station. The course was essentially a rectangle, beginning and ending at the fire station for a total distance of 0.33 miles. The department's investigation found that the FEO had almost completed 11 laps around the two-block area for a total distance of approximately 3.6 miles. Each lap had an elevation gain/loss was +57.2 feet (ft), -57.2 ft with a maximum slope of 24.7% and average slope of +3.9% and -4.9% (see Figure 1).

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

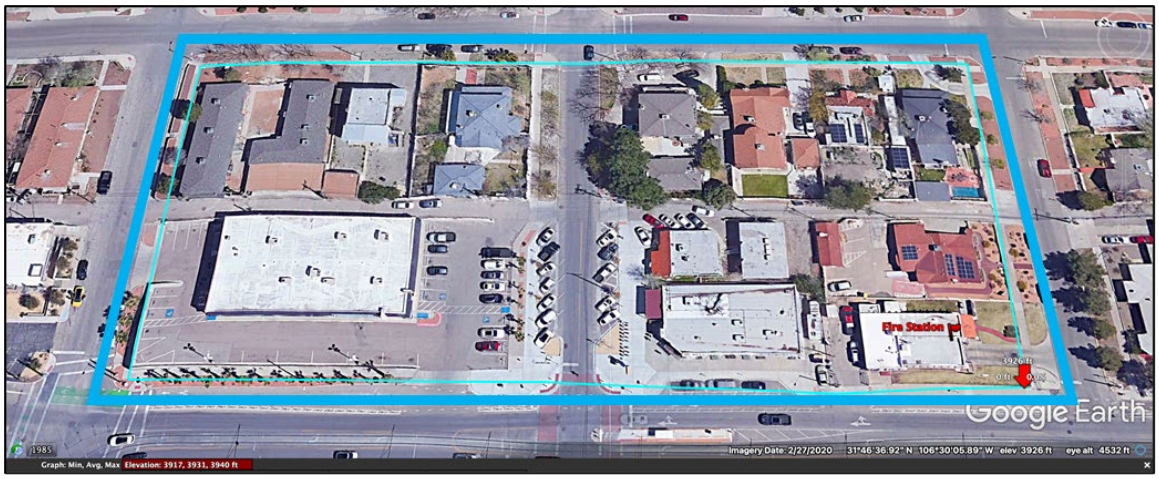

Figure 1. The physical training run path (marked in blue). Photo adapted from Google Earth.

As the LT was doing his own physical training, he noticed the FEO as he ran past the station completing a lap. After several laps, the LT realized that the FEO was taking longer than normal to pass the station again and decided to step out and look for him down the street. At approximately 1911 hours he noticed the FEO about 40 yards from the station and witnessed him slowly drop to the ground and lay supine on the sidewalk. The LT called for the other firefighters to help him check on the FEO. On initial examination, his teeth were clenched, his arms in full extension, his head turned to the right and eyes looking to the right. The LT immediately ran back to the station and contacted fire dispatch from the fire station phone. The LT requested an ambulance for a "firefighter down", while the crew took vitals, monitored breathing and maintaining the FEO's airway. The LT returned from calling for assistance with an airway bag and medical bag. The crew started an intravenous (IV) line and ventilated him with a bag valve mask (BVM). There was no apparent upper airways obstruction. The firefighter ventilating with the BVM noted that there was a lot of pressure, so they did a head tilt chin lift to improve the airway.

The transport ambulance, a fire department rescue ambulance unit, arrived at approximately 1917 hours at the station. The ambulance crew assisted the LT and two firefighters to load the FEO into the rescue ambulance. ALS care was continued as they responded to the closest hospital approximately one-half mile away. Upon patient transfer at the hospital, the FEO became pulseless. Cardiopulmonary resuscitation (CPR) was unsuccessful and he was pronounced dead at 1952 hours.

Medical Findings

The most recent physical for the FEO was in February of 2019. He was 78" tall and weighed 253 pounds resulting in a body mass index (BMI) of 30.0. His resting blood pressure was 122/77 millimeters of mercury (mmHg) and resting pulse was 80 beats per minutes (bpm). His BMI was in the borderline obese range and his blood pressure was normal (Table 1).

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Table 1. Cardiovascular (CVD) Risk Factors (RFs)

Risk Factor	Interpretation	Category Guidelines
Systolic BP[1]	Normal Elevated Stage 1 Hypertension Stage 2 Hypertension	< 120 mmHg 120–129 mmHg 130–139 mmHg ≥ 140 mmHg
Diastolic BP[1]	Normal Elevated Stage 1 Hypertension Stage 2 Hypertension	< 80 mmHg > 80 mmHg 80–89 mmHg ≥ 90 mmHg
Total Cholesterol[2]	Desirable Borderline High High	< 200 mg/dL 200–239 mg/dL ≥ 240 mg/dL
HDL[2]	Low High (Desirable)	< 40 mg/dL ≥ 60 mg/dL
LDL[2]	Optimal Above normal Borderline high High	< 100 mg/dL 100–129 mg/dL 130–159 mg/dL > 160 mg/dL
Triglycerides[3]	Normal Hypertriglyceridemia Severe hypertriglyceridemia	> 175mg/dL 175–499mg/dL ≥ 500mg/dL
Blood Glucose[4]	Normal Prediabetes Diabetes	< 100 mg/dL 100–125 mg/dL ≥ 126 mg/dL
BMI[5]	Underweight Normal weight Overweight Obesity	< 18.5 kg/m^2 18.5–24.9 kg/m^2 25–29.9 kg/m^2 ≥ 30 kg/m^2

Note: References for Table 1: [1]Whelton et al. 2017; [2]Kratz et al. 2004; [3]Grundy et al. 2019; [4]ADA 2014; [5]CDC 2020.

The February 2019 medical evaluation also included an exercise stress test during which the FEO exercised for 7:02 minutes achieving a work level of 11.80 max metabolic equivalents (METs). His resting heart rate of 100 bpm rose to a maximal heart rate of 173 bpm. This value represents 97% of the maximal, age predicted heart rate. His resting blood pressure of 122/77 mmHg rose to

134/95 mmHg. The exercise was stopped when the FEO achieved his target heart rate of 171 bpm. The overall impression was a normal stress test. Due to COVID-19 issues, physicals for fire department employees were delayed in 2020 and the FEO was scheduled for a physical the week following his death.

Cause of Death

According to the death certificate, the medical examiner listed the FEO's cause of death as EIPH.

Discussion

EIPH is a rare syndrome that can occur following intense physical activity and is where the air sacs of the lungs fill with blood and impede oxygen delivery. It is important to distinguish EIPH from diffuse alveolar hemorrhage (DAH) caused by chronic heart disease (heart failure or mitral valve problems), where bleeding occurs from high venous pressure that causes stress failure of the capillaries in the lungs. [Marak et al. 2013; Saha and Chong 2021; Sakamoto et al. 2020]. EIPH is similar to exercise-induced pulmonary edema, described in swimmers for decades, though cases have been described in runners as well. It is most studied in the veterinary literature as occurring in thoroughbred horse racing, where racehorses have leakage of fluids into their lungs following an intense race [Hinchcliff et al. 2015]. Studies of athletes with this condition show that following intense exercise, there are increased concentrations of red blood cells and proteins in the lungs, indicating a problem with the exchange of gas between the air and the bloodstream [Ghio et al. 2006; Hopkins et al. 1997; West 2004].

The blood-gas barrier of the human lung is fragile, and so if there is any structural changes or damage to the capillary walls this can cause increase leakage of fluid into the air sacs. Studies in both humans and animals show that there can be increased capillary pressures during intense exercise because of the higher pressures that are needed in the left ventricle of the heart. Tests of the heart and lungs in elite athletes after they exercise can show more red cells in the lungs even while their lungs are otherwise normal [Diwakar and Schmidt 2014; Spencer et al. 2018].

The majority of reported cases of exercise-induced pulmonary hemorrhage recover with temporary lack of oxygen or bleeding into the lung that can be treated immediately with oxygen and other emergency support. However, on rare occasions this condition can be severe and cause death even when proper emergency measures are taken. It is not known why some individuals can have very severe exercise-induced pulmonary hemorrhage, and others survive. It appears from studies that EIPH in athletes happens after intense and/or maximal exercise [Hohmann et al. 2018; McKechnie et al. 1979; Weiler-Ravell et al. 1995], but research is still ongoing to find the exact medical risk factors that can help predict why this occurs. At this time, there are currently no tests of the lungs or heart that can screen for this condition or predict whether intense exercise will trigger the lung problem in specific individuals.

Recommendations

Since it is not yet known what medical tests or examinations can reliably predict who may develop EIPH, NIOSH investigators can only offer the following recommendations to address general health and safety issues among fire fighters at this and other fire departments across the country.

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Recommendation #1: Consider including information on EIPH on physical fitness training materials and/or conducting an in-service on this rare medical condition.

Discussion: While EIPH is a relatively rare condition, firefighters should be aware that this can cause sudden collapse and the need for emergency response. The presence of pink frothy secretions or blood may indicate lung hemorrhage and require immediate intubation and supplemental oxygen, followed by in-hospital medical treatment. In many cases, individuals can recover from EIPH without permanent organ damage.

Recommendation #2: Provide annual medical evaluations consistent with NFPA 1582, which includes an evaluation of aerobic capacity in all individuals prior to engagement in any strenuous physical activity by conducting an exercise stress test. Testing shall be conducted using maximal or sub-maximal protocol. (Appendix A).

Discussion: In this case, the department does perform annual medical evaluations consistent with NFPA 1582. It is important to note that maximal annual exercise stress test is recommended to be performed by qualified medical personnel conducted in a medical care setting. It is unknown if the annual exercise stress test would have identified any anomalies for the FEO. The FEO's last exercise stress indicated a VO_2 max of 11.80. NFPA 1582 states that individuals with levels below 12 MET's shall receive counseling to improve his/her fitness. Individuals below 10 MET's shall participate in an aerobic fitness program and individuals below 8 MET's shall be prescribed an aerobic fitness program and the authority having jurisdiction shall be advised to consider restriction from essential job tasks.

Recommendation #3: Implement a mandatory wellness and fitness program for fire department members consistent with NFPA 1583 and the IAFF/IAFC Wellness-Fitness Initiative, while being mindful of the intensity of exercise [IAFF/IAFC 2018; NFPA 2015]. Consider restricting maximal effort exercise to non-workdays as work-related strenuous tasks may place firefighters into higher risk category for EIPH in addition to physical fitness training done during work hours.

Discussion: It is important to note that studies indicate EIPH typically follows intense exercise. When determining the proper intensity of exercise, the following must be considered:

1. Level of fitness
2. Medications that affect heart rate
3. Environmental conditions
4. Risk of cardiovascular or orthopedic injury
5. Individual objectives and preferences
6. Job specificity

NFPA 1583 states that how hard an individual exercises can be determined by monitoring exercise heart rate, perceived exertion, or caloric expenditure. The American College of Sports Medicine (ACSM) recommends that fire department members exercise at a heart rate between 70 and 90 percent of maximal heart rate or 60–80 percent of ones VO_2 Max [Riebe et al. 2018].

For moderate-intensity physical activity, your target heart rate should be between 64% and 76% of your maximum heart rate. You can estimate your maximum heart rate based on your age. To estimate

your maximum age-related heart rate, subtract your age from 220. For example, for a 43-year-old person, the estimated maximum age-related heart rate would be calculated as 220 – 43 years = 177 bpm. The 64% and 76% levels would be:

- 64% level: 177 x 0.64 = 113 bpm, and
- 76% level: 177 x 0.76 = 134 bpm

This shows that moderate-intensity physical activity for a 43-year-old person will require that the heart rate remain between 113 and 134 bpm during physical activity.

For vigorous-intensity physical activity, your target heart rate should be between 77% and 93% of your maximum heart rate. To figure out this range, follow the same formula used above, except change "64 and 76%" to "77 and 93%". For example, for a 43-year-old person, the estimated maximum age-related heart rate would be calculated as 220 – 43 years = 177 beats per minute (bpm). The 77% and 97% levels would be:

- 77% level: 177 x 0.77 = 136 bpm, and
- 93% level: 177 x 0.97 = 172 bpm

This shows that vigorous-intensity physical activity for a 43-year-old person will require that the heart rate remain between 136 and 172 bpm during physical activity.

Recommendation #4: Consider methods to stay in communication during physical exercise such as carrying a department radio or exercising in pairs when possible.

Discussion: In this incident, the FEO was on a training exercise by himself when he collapsed. Although emergency response measures were timely and appropriate, it may be advisable to be able to call immediately for assistance and/or to have another person on the scene to initiate resuscitative measures.

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Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac/Medical Team, in Cincinnati, Ohio. TJ Welch is a Firefighter Safety Specialist and worked in volunteer, industrial and municipal fire departments and co-authored the report. Mr. Welch is a State Certified Fire Officer, founding member of the California Incident Command Certification System, and chaired the CICCS committee on Physical Fitness Standards. Dr. Robert Harrison MD, MPH (California Department of Public Health) provided medical consultation, and Laura Styles, MPH (Public Health Institute) also contributed to this report.

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Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Appendix A
Exercise Stress Testing

The term exercise stress test refers to stressing the body by putting an exercise load on it and measuring the response. Exercise stress tests can be done in several ways; however, most people relate the term to just cardiovascular testing. Exercise stress testing is an important tool used by physicians and exercise specialists to:

- Determine whether an individual is physically fit to perform essential job duties without undue risk of harm to self or others.
- Monitor the effects of exposure to specific biological, physical, or chemical agents that may be related to hazardous working conditions.
- Detect any patterns of disease in the workforce that might indicate underlying work- related problems.
- Provide the fire fighter with information about his/her current health.
- Provide a cost-effective investment in the early detection, disease prevention, and health promotion of the fire fighter.
- Develop recommendations for exercise prescription and rehabilitation.
- Comply with federal, state, provincial, and local requirements.

An exercise stress test is just one diagnostic test that a physician may use in a fitness for duty determination. The determination of fitness for duty must not be made based on a single test, but rather on a comprehensive evaluation of the individual that includes diagnostic testing, personal medical history, and other indicators of health status.

There are two levels of evaluating aerobic exercise capacity, either maximal or sub-maximal.

Maximal aerobic exercise testing makes the fire fighter work until exhaustion to directly determine VO_2 max and maximum heart rate. These tests must only be performed by qualified medical personnel under the supervision of the fire department physician and must be conducted in a medical care setting.

Sub-maximal exercise stress testing makes the fire fighter work until a pre-determined heart rate is achieved. The pre-determined heart rate is typically 85 percent of the predicted maximum heart rate. Such testing only allows for a prediction of maximum exercise capacity. The IAFF/IAFC Fire Service Joint Labor/Management Wellness-Fitness Initiative recommends a sub-maximal exercise stress test without EKG because of the safety of the test, they are relatively inexpensive, are easier to administer by an exercise specialist, and they provide the sufficient information needed for the evaluation of cardiopulmonary fitness [IAFF/IAFC 2018]. (Note: The IAFF/IAFC Fire Service Joint

Firefighter Dies from Exercise Induced Pulmonary Hemorrhage During Physical Fitness Training – Texas

Labor/Management Wellness-Fitness Initiative also recommends a resting EKG as part of an emergency responders' annual medical evaluation.)

Exercise stress test can be administered in conjunction with many different physiologic monitoring devices. Monitoring devices will be selected based upon the goal of the test and the depth of data necessary to achieve the goals.

Exercise Stress Testing with heart rate monitoring measures the heart's performance and determines exercise capacity (VO_2 max). This information is used to determine safe levels of exercise. Such testing may be either maximal or sub-maximal. Maximal capacity testing must only be performed by qualified medical personnel under the supervision of the fire department physician and must be conducted in a medical care setting.

Exercise Stress Tests with EKG allow the physician and exercise specialist to determine maximal exercise capacity (VO_2 max) and detect early signs of coronary artery disease. An EKG (electrocardiogram, also called ECG) is a non-invasive test that records the heart's electrical impulses. It can identify abnormalities in heart rate and rhythm, and it can help to establish whether the heart muscle is receiving enough oxygen. Some early signs of angina or myocardial infarctions can be seen on a 12-lead EKG. Such testing can be either a sub-maximal or maximal test. Maximal capacity testing must only be performed by qualified medical personnel under the supervision of the fire department physician and must be conducted in a medical care setting.

Exercise Stress Test with EKG and direct respiratory gas analysis allows the physician and exercise specialist to determine exercise capacity (VO_2 max), determine safe levels of exercise, detect early signs of coronary artery disease and to determine maximal oxygen consumption, respiratory gas exchange ratio, and ventilatory equivalent for oxygen. Such testing will require the individual to breath into a tube during the test. Such testing can be either a sub-maximal or maximal test. Maximal capacity testing must only be performed by qualified medical personnel under the supervision of the fire department physician and must be conducted in a medical care setting.

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