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NIOSH

Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *August 24, 2005*

Career Fire Fighter/Emergency Medical Technician Suffers Sudden Death 5 Hours After Participating in Emergency Response – South Carolina

SUMMARY

A 43-year-old male career Fire Fighter/Emergency Medical Technician (FF/EMT) began his 24-hour shift on April 9, 2004, at 0745 hours. During his tour, his crew responded to five calls. The first four calls were EMS runs and the fifth a false alarm fire run. The last call occurred at 0658 hours on April 10 and entailed a false alarm call in a warehouse-type building. The FF/EMT responded in his bunker gear and donned SCBA for the walk-through/size-up. After walking throughout the one-story building (approximately 5 minutes) he returned to the engine. He returned to quarters with the engine, and he departed the station at approximately 0745 hours with no complaints. Later that day, at approximately 1235 hours, he died suddenly while driving his personal vehicle. Witnesses described the FF/EMT slumping over the steering wheel of his car as it jumped a curb and came to a stop.

The death certificate, completed by the Medical Examiner, listed "atherosclerotic coronary artery disease" as the immediate cause of death. The autopsy listed "acute cocaine intoxication" as the immediate cause of death with hypertension and atherosclerotic coronary heart disease as contributing factors. The NIOSH investigators concluded that, given the autopsy findings and the FF's past medical history, his sudden death could have been due to any combination of the following:

- Myocardial infarction (MI) related to underlying coronary artery disease (CAD)
- MI, triggered by the stress of responding to the earlier alarm or cocaine use
- Cardiac arrhythmia, triggered by MI or cocaine use

NIOSH investigators offer the following recommendations to prevent similar episodes from occurring in this and other fire departments (FD).

- ***Provide pre-placement and annual medical evaluations consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medicine Program for Fire Departments, or equivalent to determine FF medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Phase in a mandatory wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at **www.cdc.gov/niosh/firehome.html** or call toll free **1-800-35-NIOSH**

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- ***Perform a pre-placement physical performance (physical ability) evaluation to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.***
- ***Ensure that the fire department physician who is knowledgeable about the physical demands of fire fighting, the medical requirements of fire fighters, and the various components of NFPA 1582 makes the final determination of a FF's return-to-work status following an injury or illness.***
- ***Provide a member assistance program that identifies and assists members with substance abuse problems.***

INTRODUCTION & METHODS

On April 10, 2004, a 43 year-old male FF/EMT left his duty station after responding to a false alarm call. Five hours later he collapsed while driving his personal vehicle. The FF/EMT had voiced no complaints and left his station at approximately 0745 hours at the end of his shift. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) treatment at the scene, in the ambulance, and at the hospital's emergency department (ED), the FF/EMT died. NIOSH was notified of this fatality on April 15, 2004, by the United States Fire Administration. NIOSH contacted the affected FD on April 19, 2004, to obtain further information. On August 4, 2004, an Occupational Nurse Practitioner and Occupational Physician from the NIOSH Fire Fighter Fatality Investigation Team traveled to South Carolina to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met and/or interviewed the following people:

- Fire Chief
- Crew member on duty with the FF/EMT
- FF/EMT's girlfriend
- FD Physician
- County Medical Examiner

During the site-visit NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- FD annual report for 2003
- FD incident reports
- Emergency medical service (ambulance) incident report
- Hospital emergency department (ED) report
- FF/EMT's past medical records
- FD Medical report
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

On April 9, 2004, the FF/EMT arrived at his fire station at approximately 0745 hours for his 24-hour tour of duty. During his shift he responded to five calls. The first four calls were EMS runs and the last a false alarm fire run. The last EMS run was on April 9 at 2107 hours and the false alarm call was on April 10 at 0658 hours. During the false alarm call the FF/EMT responded in his bunker gear and donned SCBA for the walk-through/size-up. After walking throughout the one-story warehouse-type building (approximately 5 minutes) he returned to his engine. The driver/engineer stated that the FF/EMT expressed anger because he personally forgot to electronically cancel the mutual aid system. He returned to quarters with his engine, and ended his shift at approximately 0745 hours with no complaints.

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After returning home and changing clothes (no witnesses can provide details of his time spent between the shift change and his death, a period of approximately 4 hours), the FF/EMT collapsed while driving his personal vehicle. His vehicle rolled to a stop at approximately 1235 hours; witnesses checked him and called 911. Two minutes later the first dispatched unit arrived, an EMT-Intermediate with a local FD department. The EMT found the FF/EMT slumped over the steering wheel, unresponsive with no pulse or respirations. The EMT removed the FF/EMT from the vehicle, attached an automatic external defibrillator (AED) and began ventilations with a bag valve mask and supplemental oxygen. The AED advised and subsequently delivered three shocks. After the shocks, the EMT initiated CPR. On the second attempt, the EMT successfully intubated (inserted an endotracheal breathing tube into the FF/EMT's throat), with placement confirmed by the auscultation of bilateral breath sounds. The AED then advised and delivered three more shocks, at which time the ambulance arrived at 1246 hours.

The paramedics from the ambulance placed their cardiac monitor and defibrillator on the FF/EMT and found pulseless electrical activity with ventricular escape beats (a heart rhythm incompatible with life). The paramedics established an intravenous line and administered advanced life support medications followed by defibrillation attempts. No change in the heart rhythm was noted. The FF/EMT was moved to an ambulance, which departed for the local hospital's ED at 1311 hours. En route to the hospital, his heart rhythm changed to asystole (no heart beat), and he was administered advanced life support medications with no change in his condition.

The ambulance arrived at the ED at 1319 hours. Evaluation in the ED found the FF/EMT to have no heart beat (asystole), no spontaneous breathing (apneic), no pulse, and being oxygenated with an endotracheal tube. Following hospital policy, because the FF/EMT was moved, intubation was confirmed using auscultation of bilateral breath sounds. Multiple advanced cardiac life support medications were utilized in the ED, with no change in his condition. At 1342 hours, the FF/EMT was pronounced dead, and resuscitation efforts stopped.

Medical Findings. The death certificate completed by the County Medical Examiner listed "atherosclerotic coronary artery disease" as the immediate cause of death. The autopsy, also completed later by the medical examiner, listed acute cocaine intoxication as the immediate cause of death with the contributing factors of hypertension and atherosclerotic coronary artery disease. Pertinent findings from the autopsy included:

- Extensive atherosclerotic coronary artery disease with near total occlusion of three coronary arteries (left anterior descending, first diagonal, and right coronary artery)
- Acute thrombus ("acute organizing occlusive fibrin thrombi")
- Old myocardial infarction of the posterior left ventricle
- Cardiomyopathy
  - A. Cardiomegaly (an enlarged heart) weighing 680 grams (upper limit of normal is 400 grams)
  - B. Hypertensive cardiovascular disease
  - C. Biventricular dilatation

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- Acute Cocaine Intoxication
  - A. Cocaine, Blood: 0.48 mg/L
  - B. Ecgonine methyl ester, blood: 0.67 mg/L
  - C. Benzoylecgonine, blood: 0/76 mg/L
  - D. Benzoylecgonine, urine: 4.9 mg/L

In September 2001, the FF/EMT had a respirator medical clearance examination that showed an elevated blood pressure (160/100 millimeters of mercury [mmHg]). No medical follow-up or treatment was given.

In September 2002, the FD began conducting medical evaluations using guidance provided by the NFPA 1582, *Standard on Comprehensive Occupational Medicine Program for Fire Departments*. During this FD medical evaluation, his blood pressure was again elevated (148/94 mmHg). An electrocardiogram (EKG) found the FF/EMT in normal sinus rhythm. The FF/EMT underwent an ergometer fitness test (described below) which he tolerated well. The estimated metabolic equivalent (METS) of physical activity was 13 while the estimated maximum volume of oxygen consumption per unit of time (MVO_2) was 45.96. These estimates were based on extrapolations from his heart rates at three workloads (75, 100, and 125 watts).[1] Lipid levels were also drawn which showed a slightly lowered high density lipoprotein-cholesterol (HDLC) of 39 milligrams per deciliter (mg/dL) (normal is greater than 40 mg/dL), with normal total cholesterol (< 200 mg/dL), normal low density lipoprotein-cholesterol (<130 mg/dL), and a normal cholesterol/HDLC ratio (< 5.0). The physician who conducted this medical evaluation for the FD recommended placing the FF/EMT on restricted duty due to elevated blood pressure. FD records, however, could not verify that he was actually placed on restricted duty at this time.

In September 2003, the FF/EMT underwent his second FD annual medical evaluation. Again, his blood pressure was elevated (152/111 mmHg), and his EKG was normal. The FD physician would not clear him for the bicycle ergometer fitness test, due to the elevated blood pressure. The FF/EMT was then evaluated by his primary care physician who cleared him for the bicycle ergometer fitness test. The FF/EMT's estimated METS were 7 while the estimated MVO_2 was 24.95. These estimates were extrapolations from his heart rates at two workloads (50 and 75 watts). Although considered a poor effort, he tolerated the test well and was asymptomatic. Due to his hypertension, the FF/EMT was placed on restricted duty by the FD physician. His primary care physician, who described his hypertension as very mild and gave him a prescription for a diuretic, released him to unrestricted duty. It is unclear if the FF/EMT took the anti-hypertensive medication.

His last FD physical examination in September 2003 revealed a height of 78 inches and a weight of 249 pounds, giving him a body mass index (BMI) of 29 kilograms per square meter (kg/m^2). (A BMI between 25 and 29.9 kg/m^2 is considered overweight).[2] According to the FF/EMT's girlfriend and FD personnel, the FF/EMT did not exercise. In the days or hours before his death he reported no symptoms to his family or coworkers.

The bicycle ergometer fitness test gauges fitness by examining blood pressure and heart rate at

specific times while pedaling on a stationary bicycle. At no time was an EKG conducted on the FF/EMT while exercising to identify signs of ischemic heart disease. The FF/EMT's second bicycle ergometer fitness test showed an abnormal response. His systolic blood pressure rose less than 25 mmHg from his resting blood pressure. In addition, his systolic blood pressure fell greater than 10 mmHg from his maximum blood pressure.[3-5] This abnormal finding was not noted in the fitness test summary, and no follow-up evaluation was recommended.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this FD consisted of 60 uniformed personnel (20 volunteer, 20 part-time, and 20 career). The FD's three fire stations serve 17,000 people in a 19-square mile area. In 2003, the FD responded to 906 calls: 57 structure fires, 23 vehicle fires, 72 wildland fires, 8 rubbish fires, 573 medical calls, 127 false alarms, 12 mutual aid calls, 19 hazmat responses, and 15 other calls. Career FFs work the following schedule: 24 hours on duty, 48 hours off duty, 0800 hours to 0800 hours.

Training. The FD requires all career FF/EMT applicants to be at least 21 years of age; possess a valid state driver's license; pass a written exam, an oral interview, and a background check; and have previous firefighting experience, a state Fire Fighter I certificate, and a current state EMT certificate prior to selection. The member must then pass an illicit drug screening. The member is then sent to Fire Fighter II class at the state fire academy.

The FD requires volunteer FF applicants to pass an oral interview prior to selection. The member then begins a 6-month training program, including the state FF-I program. Training occurs twice weekly for 6-months, after which training occurs once weekly. At the end of the 6-month period, the member must pass the written FF-I exam and a skills test to become a full member. The FD requires a minimum of 20 hours of training for a member to ride fire apparatus.

The state requires 100 hours of training annually for career FF recertification, and 20 hours annually for volunteer FF recertification. Paramedics, EMTs, and First Responders must recertify every 2 years according to state guidelines.

The FF/EMT was Hazmat certified, a FF-II, and had 8 years of fire fighting experience.

Pre-placement Medical Evaluations. The FD does not require pre-placement medical evaluations or physical ability tests for candidates.

Periodic Evaluations. Annual medical evaluations are required for all members. Components of this medical evaluation include the following:

- Complete medical history
- Physical examination
- Vital signs
- Vision screening
- Audiogram
- Pulmonary function test (spirometry)
- Blood analysis: chemistry panel, CBC, lipid panel
- Urinalysis (dipstick)
- Stress EKG per NFPA 1582 guidelines
- EKG
- Hepatitis B vaccine immunization
- Tuberculosis (TB) skin test
- Urine drug screen

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If employee injury or illness results in an absence from work, their private physician must clear them for "return to work."

Fitness/Wellness Programs. Exercise (strength and aerobic) equipment is located in the fire station. No physical ability test is required for either candidate or current fire department members. There is no comprehensive mandatory wellness/fitness program in place. The yearly medical evaluation includes a cycle ergometer fitness test, a body fat analysis, flexibility evaluation, grip test, and a test of the number of push-ups/sit-ups in 1 minute.

DISCUSSION

Coronary Artery Disease (CAD) and the Pathophysiology of Sudden Cardiac Death: In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[6] Risk factors for CAD development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure (systolic >140 mmHg or diastolic > 90 mmHg), high blood cholesterol (total cholesterol > 240 mg/dL), obesity/physical inactivity, and diabetes.[7,8] The FF/EMT had three of these risk factors (male gender, hypertension, and physical inactivity).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[9] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[10] Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply.[11] This sudden blockage is primarily due to blood clots (thrombosis) forming on top of atherosclerotic plaques. The FF/EMT had an occlusive thrombi on autopsy and near total occlusion of three coronary arteries.

Atherosclerosis in a coronary artery may cause ischemic heart disease, which occurs when the blood flow within a coronary artery is limited to the point where the oxygen needs of the heart muscle cannot be met. Chronic ischemic heart disease causes hypertrophy of the heart muscle and cardiomegaly. All of these factors, independently and in combination (ischemia, cardiomegaly, or myocardial infarction), increase the risk of cardiac arrhythmia and sudden cardiac death.

Fire fighting is widely acknowledged to be a physically demanding and hazardous occupation.[12] Fire fighting tasks are strenuous and often require fire fighters to work at or near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and persist through the course of fire suppression activities.[13-15] Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing.[16] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[17-20] The FF/EMT responded to a call and, while wearing his turnout gear and SCBA, he walked around inside the building doing walk-through/size-up. This is considered a moderate level of physical exertion.[21-22] Although the emergency response did not appear to involve heavy physical exertion, the stress of responding to this alarm along with his underlying atherosclerotic

coronary artery disease probably contributed to this FF/EMT's cardiac arrest and sudden death.

Occupational Medical Standards and the Use of Exercise Stress Tests (EST) to Screen for CAD. Could this FF/EMT's underlying CAD have been identified earlier? Conducting EST on asymptomatic individuals is controversial. NFPA 1582 recommends, not as a part of the requirements but for informational purposes only, that all fire fighters with two or more risk factors for CAD take an EST. The Standard goes on to list the criteria for CAD risk factors: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).[23] In this instance, this FF/EMT would not have been recommended for an EST by NFPA (he had only one of the NFPA-identified CAD risk factors) or the American College of Cardiology/ American Heart Association (ACC/AHA) criteria.

The bicycle ergometer fitness test the FF/EMT performed was designed as a gauge of physical fitness, not a diagnostic tool for identifying ischemic heart disease or CAD. He was not encouraged to reach 85% of his targeted heart rate, which is needed as part of a sub-maximal test, and he was not continuously monitored using a 12 lead EKG. On the other hand, the FF/EMT did have his BP heart rate monitored during the test. During his second bicycle fitness test he had an abnormal blood pressure response. Perhaps if this finding was noted by the practitioners administering the test, he could have been referred to a specialist for further evaluation (e.g., a maximal EST). A maximal EST may have identified his underlying cardiac disease, possibly leading to further evaluation and treatment.

Other Issues. The medical examiner who conducted the autopsy listed biventricular dilatation. No heart chamber measurements were given, other than 680 grams (normal 400 grams) for the heart weight. The finding of biventricular dilatation probably represents a condition called dilated cardiomyopathy. Although a variety of acquired or hereditary disorders can cause the disorder, most cases are of unknown etiology and therefore labeled idiopathic dilated cardiomyopathy. Listed in Table 1 are some of the potential causes, one of which is cocaine.[24]

Role of Cocaine in the FF's Sudden Cardiac Death: Cocaine can accelerate CAD and can induce an MI in individuals with or without CAD.[25-28] For this FF/EMT, we know neither the amount of cocaine used, nor the frequency of use. Any amount of cocaine could have aggravated or induced his CAD, triggered an MI with his underlying CAD, or triggered an arrhythmia leading to sudden cardiac death.[25-27,29-33]

RECOMMENDATIONS

NIOSH investigators offer the following recommendation to prevent similar episodes from occurring in this and other fire departments.

Recommendation #1: Provide pre-placement and annual medical evaluations consistent with National Fire Protection Association (NFPA) 1582 or equivalent to determine FF medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

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We applaud the department's efforts for implementing a comprehensive medical evaluation program. In addition to annual medical evaluations, we recommend adding pre-employment/pre-placement physical examinations. These evaluations detect most medical conditions that present a significant risk to the safety and health of FFs or others. Comparing the current FD program with NFPA 1582 may identify components that can be eliminated/added.

Applying NFPA 1582 involves legal and economic repercussions and must be carried out in a nondiscriminatory manner. Appendix B of NFPA 1582 provides guidance for FD Administrators regarding legal considerations in applying the standard.[23]

Economic repercussions go beyond the costs of administering the medical program. Department administrators, unions, and fire fighters must also deal with the personal and economic costs of the medical testing results. NFPA 1500 addresses these issues in Chapter 8-7.1 and 8-7.2.[34] The success of medical programs may hinge on protecting the affected fire fighter. For FFs in rehabilitation programs, the FD should provide alternate duty positions. If the fire fighter is not medically qualified to return to duty after repeat testing, the Department should pursue supportive and/or compensated alternatives for the fire fighter.

Recommendation #2: Phase in a <u>mandatory</u> wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

We applaud the department for implementing a beginning Fitness/Wellness Program. Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States and is independently associated with obesity and diabetes.[35] A comprehensive fitness program, such as NFPA 1583 *Standard on Health-Related Fitness Programs for Fire Fighters*, also provides health promotion activities for preventing health problems and enhancing overall well-being.[36] Another example of a comprehensive fitness/wellness program is the Fire Service Joint Labor Management Wellness/Fitness Initiative published by the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) in 1997.[37] We recommend the FD review these documents to identify elements that could be added to strengthen the existing program.

Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[38-39] Cost savings have been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment significantly reduced disability pension costs.[40]

Recommendation #3: Perform a pre-placement physical performance (physical ability) evaluation to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, requires fire department candidates to meet physical performance requirements prior to beginning a FF training program as identified in NFPA 1583.

Recommendation #4: Following an injury/illness, the final determination of a fire fighter's return-to-work status should be made by the

fire department physician who is knowledgeable about the physical demands of fire fighting, the medical requirements of fire fighters, and the various components of NFPA 1582.

Physicians providing input regarding medical clearance for fire-fighting duties should appreciate the physical demands of fire fighting and know that fire fighters frequently respond to incidents in environments that are immediately dangerous to life and health.[12-16] They should also be familiar with the consensus guidelines published by NFPA 1582, *Standard on Comprehensive Occupational Medicine Program for Fire Departments*.[23] To ensure physicians are aware of these guidelines, we recommend that the FD provide the contract physician with a copy of NFPA 1582. We recommend the FD physician consider, but not necessarily "rubber stamp" the opinions of the treating physician regarding return-to-work. This decision requires knowledge not only of the medical condition, but also of the fire fighter's job duties. Personal physicians may not be familiar with an employee's job duties, or guidance documents, such as NFPA 1582. In addition, they may consider themselves as patient advocates and dismiss the potential public health impact of public safety officials who may be suddenly incapacitated. Therefore, we recommend that the FD contract physician review all return-to-work clearances to make the final decision regarding medical clearance. Although this FD physician did identify the FF's hypertension, this department does not have all return-to-work clearances reviewed by a FD physician.

Recommendation #5: Provide a member assistance program that identifies and assists members with substance abuse.

NFPA 1500 requires departments to have a program that identifies and assists their members with substance abuse, stress, and personal problems that affect their ability to work. The standard spells out the components of the program in its appendix.[34] We recommend the FD review this standard to develop an appropriate program.

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Career Fire Fighter/Emergency Medical Technician Suffers Sudden Death 5 Hours After Participating in Emergency Response – South Carolina

Table 1. Known Causes of Dilated Cardiomyopathy[24]

Toxins
- Ethanol
- Chemotherapeutic agents (doxorubicin, bleomycin)
- Cobalt
- Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
- Phenothiazines
- Carbon monoxide
- Lead
- Cocaine
- Mercury

Metabolic Abnormalities
- Nutritional deficiencies (thiamine, selenium, carnitine)

Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis, Cushing's Disease, pheochromocytoma, diabetes mellitus)
- Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious
- Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
- Rickettsial
- Bacterial (diphtheria)
- Mycobacterial
- Fungal
- Parasitic (toxoplasmosis, trichinosis, Chagas' disease)

Noninfectious
- Collagen vascular disorders (scleroderma, lupus erythematosus, dermatomyositis)
- Hypersensitivity myocarditis
- Sarcoidosis
- Peripartum dysfunction

Neuromuscular Causes
- Duchenne's muscular dystrophy
- Facioscapulohumeral muscular dystrophy
- Erb's limb-girdle dystrophy
- Myotonic dystrophy

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