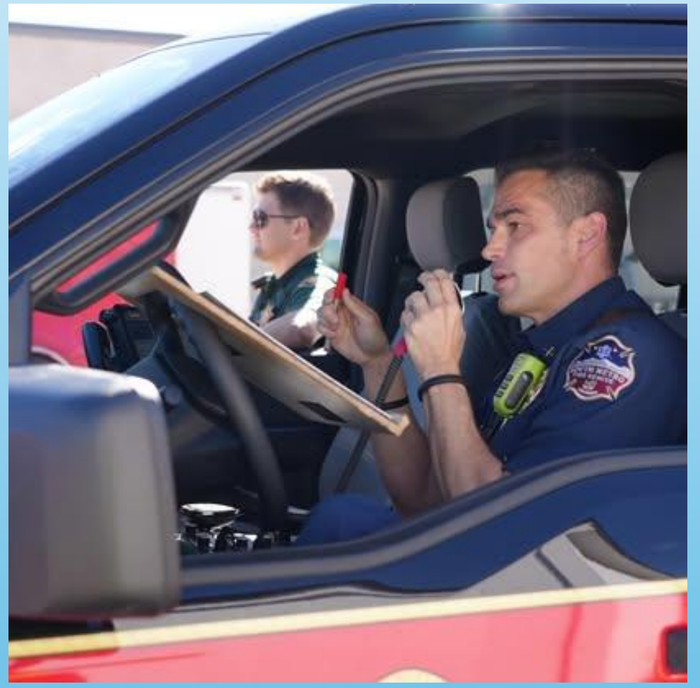
The Measurement Spectrum of Aerobic Fitness. How Do We Find Out Who is Fit Enough?

Introduction

-Nick Grosch, Battalion Chief, South Metro Fire Rescue: MS, EFO, CFO, FSCEO, MIFireE, Veteran



Annual Report on Firefighter Fatalities in the United States

U.S. Fire Administration
Working for a fire-safe America

On-duty firefighter deaths in 2022

38 career	49 volunteer	7 wildland

94 Firefighters died while on duty.
6 firefighters died from COVID-19.

62 Firefighters died from activities related to an emergency incident.

17 Firefighters died from activities at a non-fire scene.

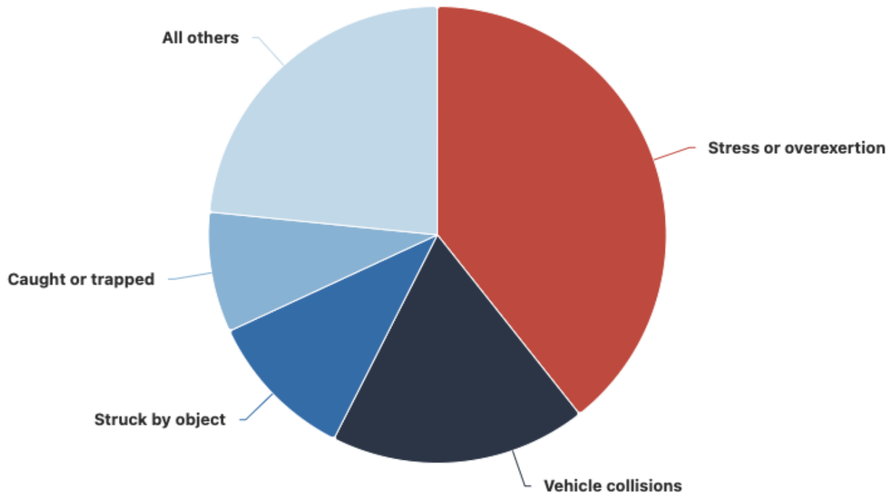
35 Firefighters died from activities at a fire scene.

33 Firefighters died from heart attacks.

14 Firefighters died while responding to or returning from emergency incidents.

9 Firefighters died while participating in training activities.

Firefighter fatality causes (2022)

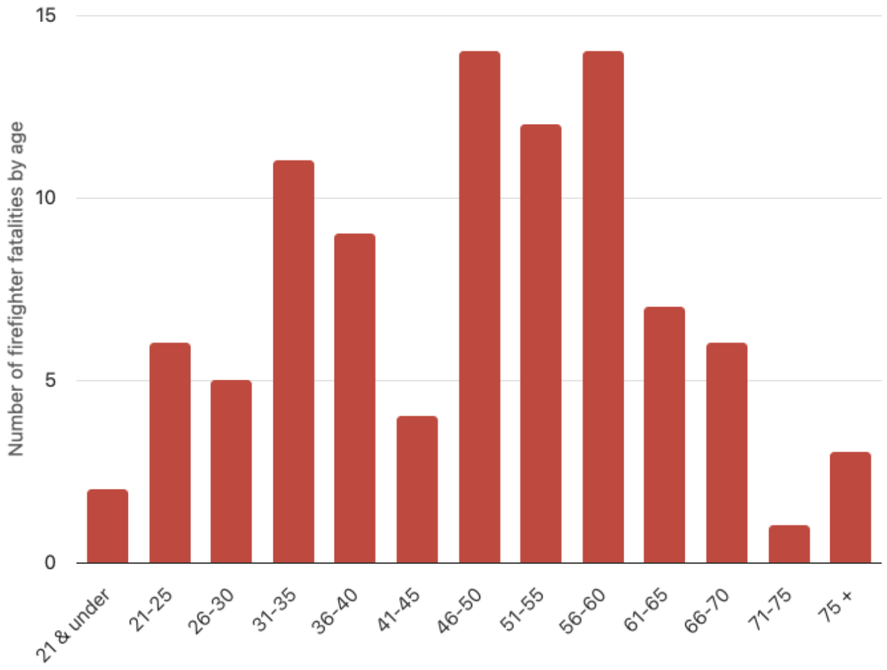


Cause	Fatalities
Stress or overexertion	37
Vehicle collisions	17
Struck by object	10
Caught or trapped	8
Unknown	7
Collapse	6
Exposure (COVID-19)	6
Fall	2
Other	1

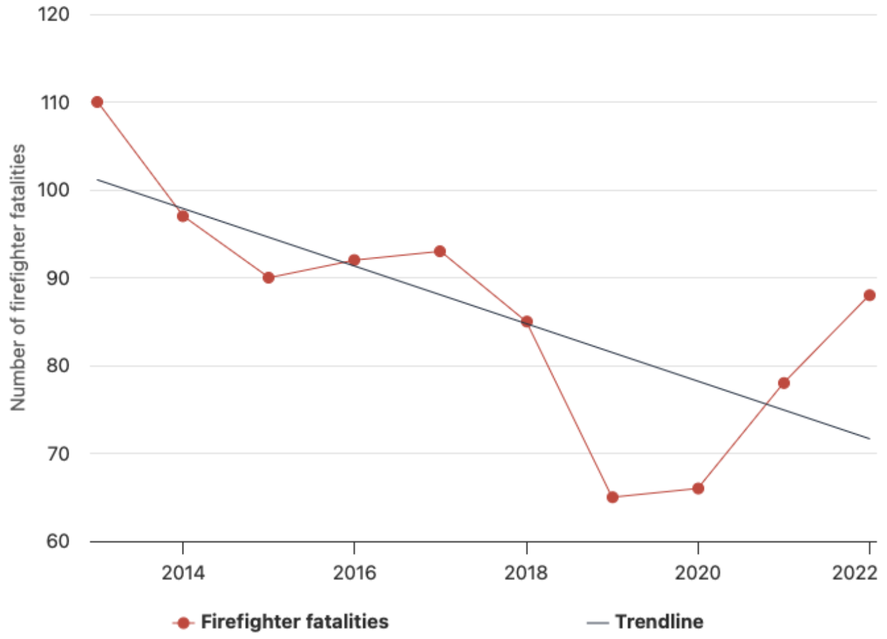
Ages and Trends

U.S. Fire Administration
Working for a fire-safe America

Firefighter fatalities by age (2022)›



On-duty firefighter fatalities (2013-2022)
Does not include COVID-19 fatalities for purposes of trend analysis



Nature of Fatal Injury

Figure 9 shows the distribution of the 94 firefighter deaths that occurred in 2022 by the medical nature of the fatal injury or illness. In 2022, heart attack was the leading type of nature of fatal injury, followed by trauma. Crushed was the third leading type of nature of fatal injury.

Figure 9. Firefighter fatalities by nature of fatal injury (2022)

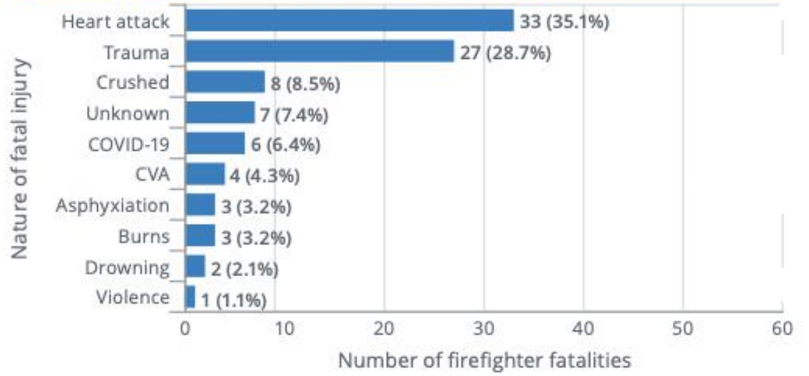
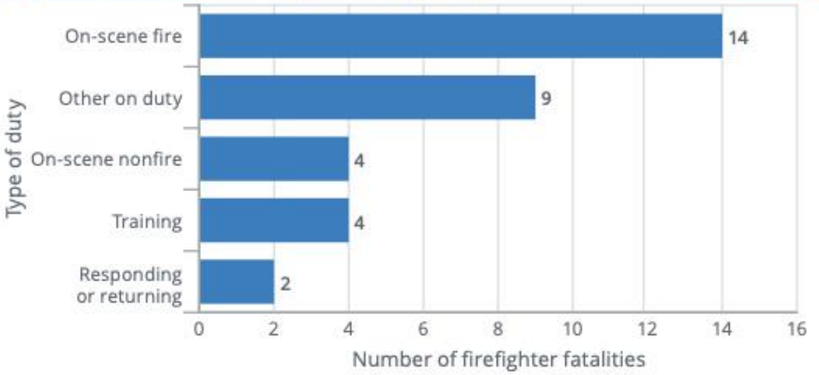


Figure 10 shows the type of duty involved for the 33 firefighters who died of a heart attack.

Figure 10. Heart attacks by type of duty (2022)



NFPA 1582 Essential Job Tasks (2022)

5.1.1 Essential Job Tasks Revised – minor edits and addition of #15 - EMS

The fire department shall evaluate the following essential job tasks against the types and levels of emergency services provided to the local community by the fire department, the types of structures and occupancies in the community, and the configuration of the fire department to determine which tasks apply to their department members and candidates:

1. Wearing personal protective equipment (PPE) and self-contained breathing apparatus (SCBA) while performing firefighting tasks (e.g., hose line operations, extensive crawling, lifting and carrying heavy objects, ventilating roofs or walls using power or hand tools, forcible entry), rescue operations, and other emergency response actions under stressful conditions, including working in extremely hot or cold environments for prolonged time periods
2. Wearing the respirators required by the jurisdiction (e.g., N-95, half-face elastomeric, PAPR, SCBA), which includes a demand-valve-type positive-pressure facepiece or filter respirator, achieving a successful fit-test and tolerating increased respiratory workloads
3. Exposure to toxic fumes, irritants, particulates, biological (i.e., infectious) and nonbiological hazards, or heated gases, despite the use of PPE and SCBA
4. Climbing at least six flights of stairs or walking a similarly strenuous distance and incline in jurisdictions without tall buildings while wearing PPE and SCBA, commonly weighing 40–50 lb (18–23 kg) and carrying equipment/tools weighing an additional 20–40 lb (9–18 kg)

NFPA 1582 Essential Job Tasks (2022)

5. Wearing PPE and SCBA that is encapsulating and insulated, which will result in significant fluid loss that frequently progresses to clinical dehydration and can elevate core temperature to levels exceeding 102.2°F (39°C)
6. Working alone while wearing PPE and respirators required by the jurisdiction, searching, finding, and rescue-dragging or carrying victims to safety in hazardous conditions and low visibility
7. While wearing PPE and SCBA, advancing water-filled hose lines up to 1 3⁄4 in. (45 mm) in diameter from fire apparatus to occupancy [approximately 150 ft (50 m)], which can involve negotiating multiple flights of stairs, ladders, and other obstacles
8. While wearing PPE and SCBA, climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces that might be wet or icy, and operating in proximity to electrical power lines or other hazards
9. Unpredictable, prolonged periods of extreme physical exertion as required by emergency operations without benefit of a warm-up period, scheduled rest periods, meals, access to medication(s), or hydration
10. Operating fire apparatus or other vehicles in an emergency mode with emergency lights and sirens

NFPA 1582 Essential Job Tasks (2022)

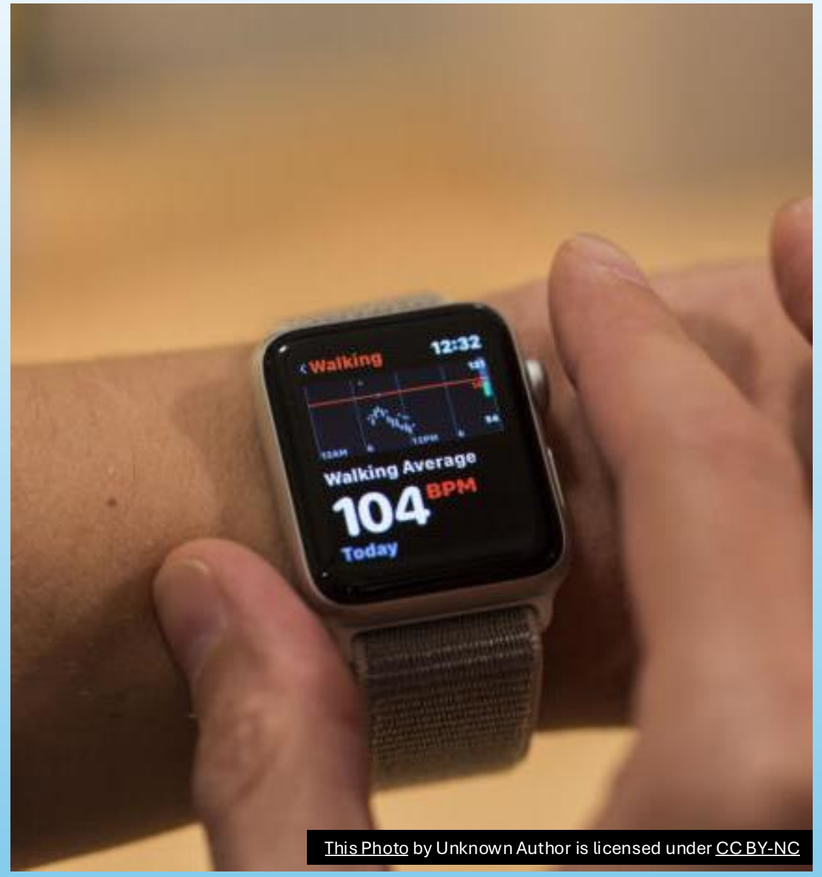
11. Critical, time-sensitive, complex problem solving during physical exertion in stressful, hazardous environments, including hot, dark, tightly enclosed spaces, that is further aggravated by fatigue, flashing lights, sirens, and other distractions
12. Ability to communicate (i.e., give and comprehend written or verbal orders) while wearing PPE and respirators required by the jurisdiction, under conditions of high background noise, poor visibility, and drenching from hose lines or fixed protection systems (e.g., sprinklers)
13. Functioning as an integral component of a team, where sudden incapacitation can result in mission failure or in risk of injury or death to members of the public or other team members
14. Working in shifts, including during nighttime, that can extend beyond 12 hours (15)Performing EMS tasks, such as CPR or lifting or moving patients, while wearing PPE and respirators required by the jurisdiction
15. Performing EMS tasks, such as CPR or lifting or moving patients, while wearing PPE and respirators required by the jurisdiction

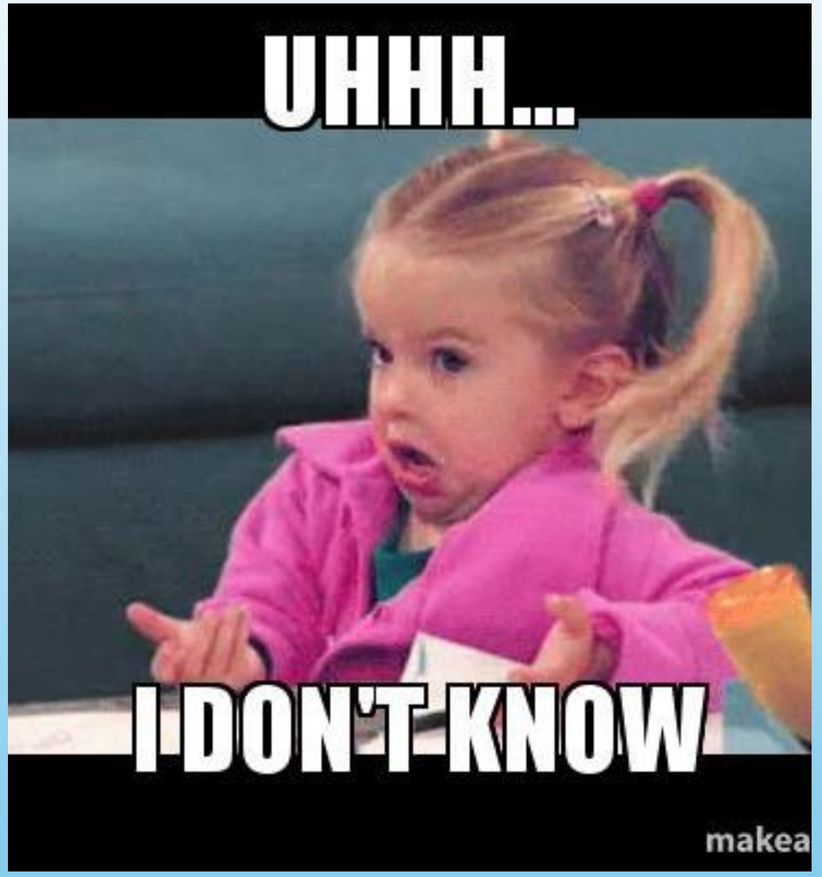
Special teams: In addition to the essential job tasks, individuals of specialized teams, such as hazardous materials units, dive teams, technical rescue teams, EMS teams, or units supporting tactical law enforcement operations, shall be evaluated for their ability to perform essential job tasks and wear specialized PPE related to the duties of those specialized teams.

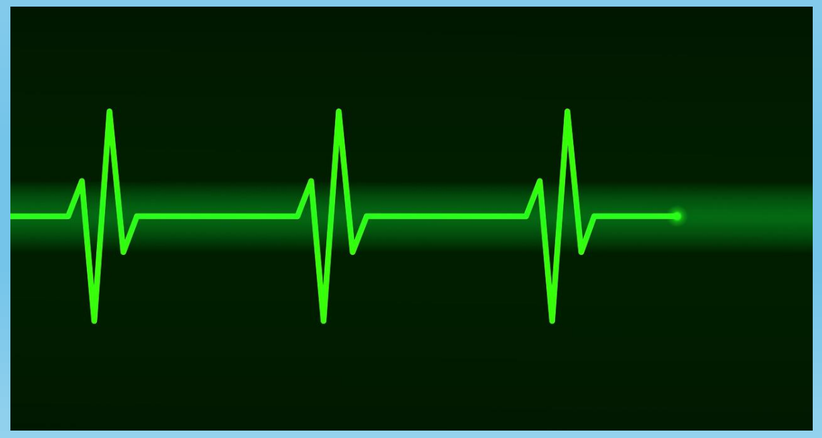
Guessing game

-1957 VW bug: How many horses? How about the quarter mile?

-How many MET’s do you need to complete these tasks?







How can we measure fitness?

Measurement Spectrum of Fitness

Direct VO_2 Testing

(Submaximal and Maximal)

Heart Rate Testing

(Submaximal and Maximal)

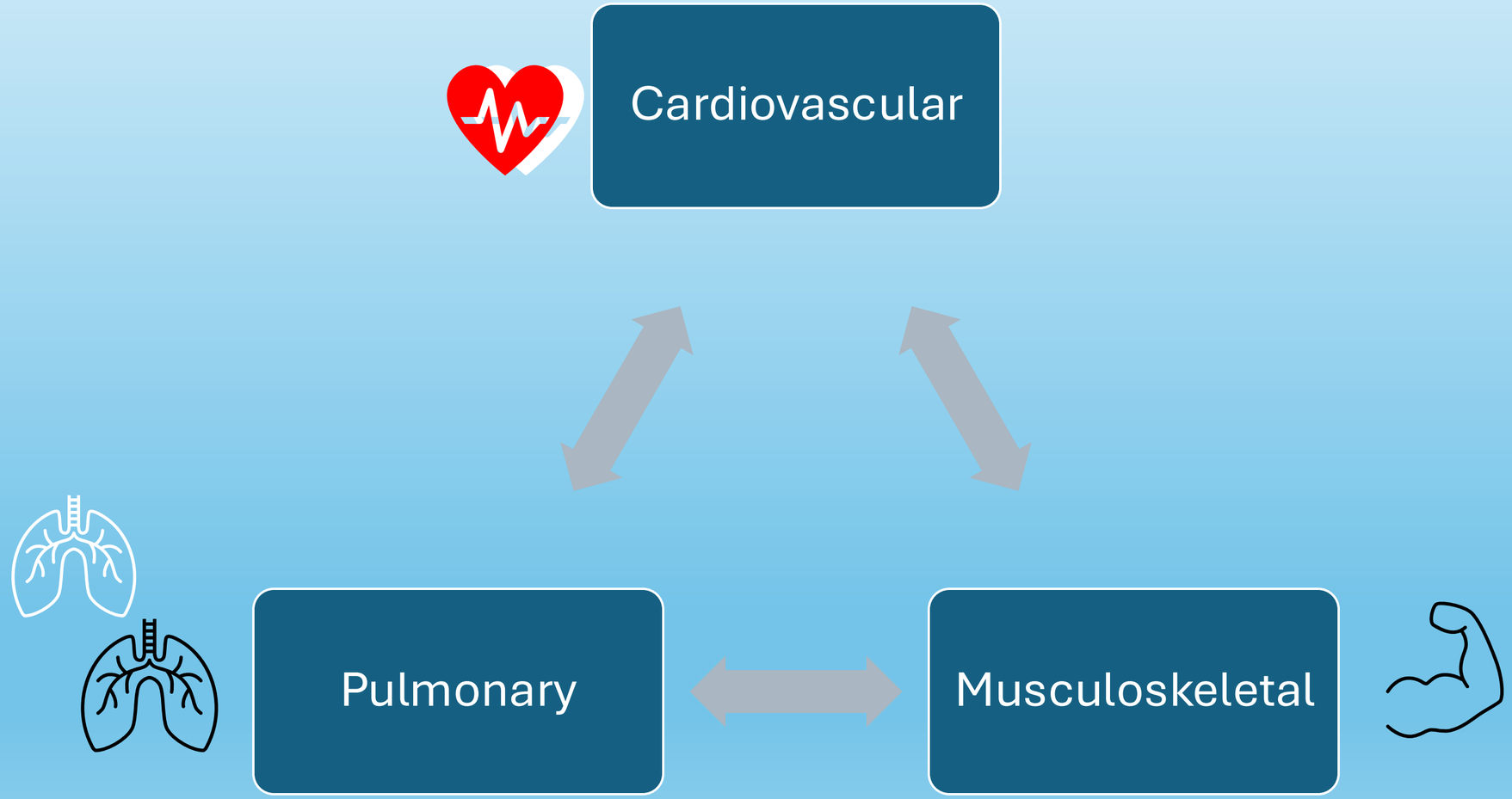
Field Testing

What is VO_2?
Ability to do work

- Definition:
  - Rate at which oxygen can be taken up, distributed, and used by the body in the performance of exercise that utilizes large muscle mass.

  - **VO_{2max}** is the **<u>maximal</u>** rate at which oxygen can be taken up, distributed, and used by the body in the performance of exercise that utilizes large muscle mass.
- Reported in the units:
  - mL O2 per kg body weight per minute
  - METs

Aerobic capacity (VO_2) relies on:

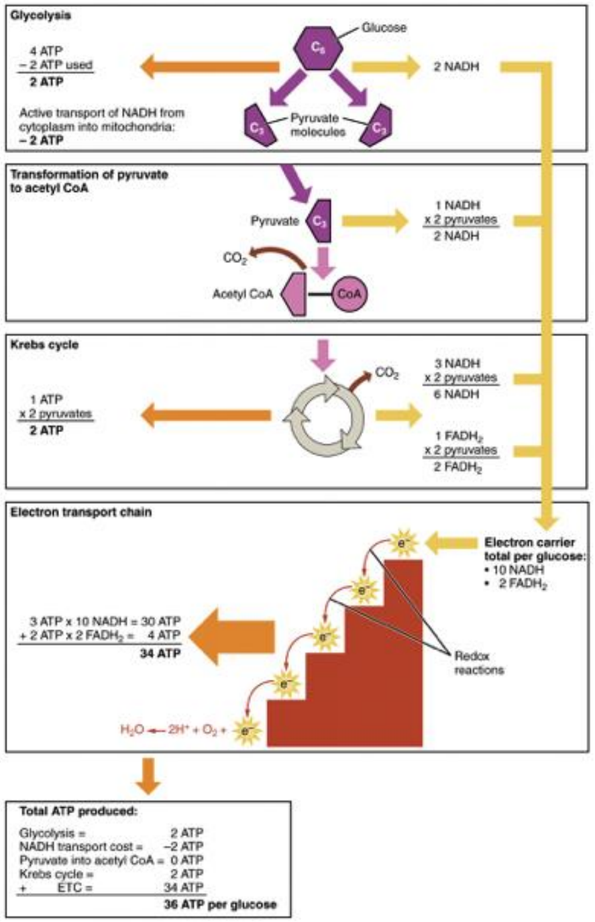


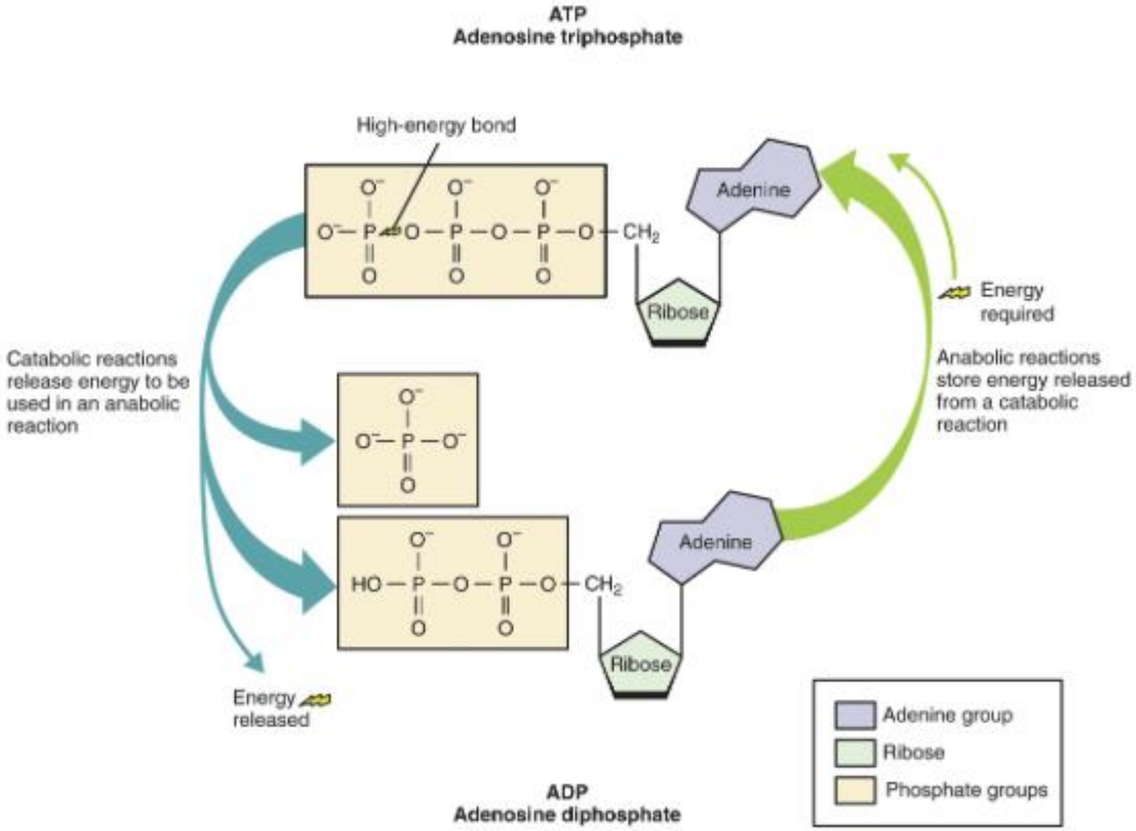
Let's talk VO_2

- Direct measurement of VO_2 requires:
  - Gas analysis machine
  - Knowledgeable personnel to administer and interpret the test
  - If doing maximal testing, medical supervision may be required.
- What about METs?
  - MET = Metabolic Equivalent of Task
  - 1 MET = 3.5 mL/kg/min
  - NFPA 1582 (2022) identifies 12 METs as a standard for firefighters
    - 12 METs = 42 mL/kg/min

What about Adenosine Triphosphate (ATP)

- Adenosine triphosphate (ATP), the energy currency of cells, can be used immediately to power molecular machines that support cells, tissues, and organ function. This includes building new tissue and repairing damaged tissue. ATP can also be stored to fulfill future energy demands.





Why is a VO2 score significant?

- The Four Horseman of Death: Cardiovascular and Cerebrovascular disease, Cancer, Neurodegenerative disease and Metabolic diseases. (Dr. Peter Attia)
- Metabolic syndrome is a group of conditions that increase the risk of heart disease, stroke and type 2 diabetes. These conditions include high blood pressure, high blood sugar, too much fat around the waist, and high cholesterol or triglyceride levels. (3 or more)
- Can we do our jobs?

Background: Physical Fitness- MET's

- What is a MET: Metabolic Equivalent of Task: Is defined as the amount of oxygen consumed while sitting at rest.
- Simplest form is a VO2 measurement divided by 3.5 = a MET score. Ex: a VO2 of 42 = 12 MET's.
- National Fire Protection Agency (NFPA) 1582
  - 2022: Standard identifies that firefighters meet a measurement of 12 MET's

FSTAR FACTOIDS

www.fstaresearch.org/resource/?FstarId=11405

MET's: Light to Moderate Exercise

ENERGY REQUIRED (METs) FOR LIGHT TO MODERATE EXERCISE

from the Compendium of Physical Activities

Light gardening	2.3
General cleaning & straightening up	2.5
Washing dishes, clearing the table	2.5
Putting away groceries	2.5
Walking 2.0 mph	2.8
Walking 3.0 mph	3.3
Scrubbing the floor	3.8
Gardening, weeding	4.0
Multiple household tasks at once with vigorous effort	4.3
Salsa or swing dancing	4.5
Softball	5.0
Walking 4.0 mph*	5.0
Walking with a light (15 lb) load	5.0
Walking 3.0 mph at 3-5% grade (uphill)	5.3
Golf: walking and pulling clubs	5.3
Mowing the lawn	5.5
Moving furniture and carrying boxes	5.8
Biking 9-10 mph	5.8

**Energy ratings are based on METs (metabolic equivalent). Light exercise is less than 3.0 METs. Moderate exercise is 3.0-5.9 METs. Vigorous exercise is 6.0 METs and above.*

Intensity levels in sports and activities vary from person to person. Visit https://sites.google.com/site/compendiumofphysicalactivities/home for a more complete list of activities.

whyiexercise.com

Tentative Interim Amendment (TIA) No. 1761 on NFPA 1582- 21-Dec-2023

The Standards Council decision means that NFPA 1582 will include revisions to the aerobic fitness requirements as part of TIA No. 1761, including:

- New requirements for firefighter aerobic capacity adjusted for age and biological sex
- Specific thresholds, below which a physician shall recommend restriction from more than half of the essential job tasks of a firefighter as described in NFPA 1582.

Table 8.2.2.3(a) Cardiorespiratory Fitness and Aerobic Capacity Standard for Firefighters, Adjusted for Age and Biological Sex of the Individual (50th Percentile), Using Treadmill Protocol

Age	METs	
	Male	Female
20–29	13.7	10.7
30–39	12.1	8.6
40–49	10.8	7.6
50–59	9.3	6.7
60–69	8.1	5.7

8.2.2.4* For an individual whose cardiorespiratory fitness falls below the 35th percentile for the general population standardized by biological sex and age *[see Tables 8.2.2.4(a) and 8.2.2.4 (b)]*, the fire department physician shall do both of the following:

- 1: Recommend to the AHJ that the individual be restricted from performing essential job tasks 1,2,4,5,6,7,8,9, and 13.
- 2: Require the individual to participate in prescribed cardiorespiratory (aerobic) fitness program.

Age	METs	
	Male	Female
20–29	12.4	9.6
30–39	11.0	7.8
40–49	9.9	6.9
50–59	8.4	6.1
60–69	7.3	5.3

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

- Overview: • The purpose of this study is to better understand the metabolic demands of fire evolutions cumulatively and fire tasks individually. •
- The VO2 Master, a portable, wireless device, was used to measure VO2 max, ventilation, heart rate, respiratory rate, and tidal volume.
- The evolutions were created to simulate fireground activities that respective crews would normally be assigned to perform.
- Rest periods were included between all assignments and tasks to simulate being on deck, receiving a new assignment or changing tasks as an incident evolves while collecting recovery data after physical exertion.
- Evolutions were completed in either pairs or as a crew.
- Tasks were completed either individually or in pairs.

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

Timeline:14-18 November 2022

Sex & Age	*N = 60*	%
Male	55	91.67%
Female	5	8.33%
20-24 y/o	2	3.33%
25-29 y/o	8	13.33%
30-34 y/o	14	23.33%
35-39 y/o	14	23.33%
40-44 y/o	9	15.00%
45-49 y/o	4	6.67%
50-54 y/o	6	10.00%
55-59 y/o	3	5.00%

Position	*N = 60*	%
Firefighter	22	36.67%
Paramedic	14	23.33%
Engineer	11	18.33%
Lieutenant	10	16.67%
Captain	3	5%

Day	Session A *N=28*	Session B *N=32*	Location
1	1	1	JSF
2	2	1	JSF
3	3	0	JSF
4	0	2	St 32
5	0	3	St 32

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

What about South Metro's MET's

1. Session A Layout (at JSF):

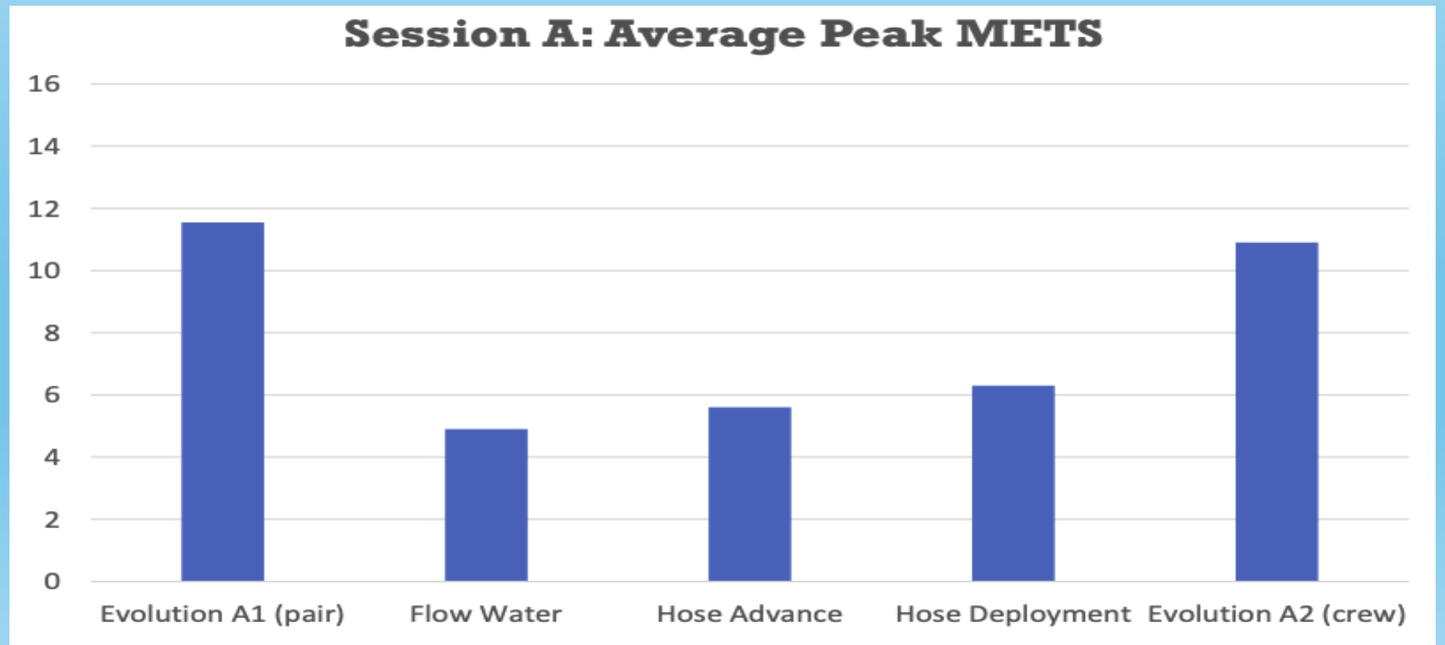
- *Evolution A1 – PAIRS:* Deploy pre-connect, conduct 360, advance hose, 5s hit on stairs, push to 2nd floor, flow and move to fire room, hydraulic ventilation, & overhaul.
- *Task 1 – PAIRS:* Hose advance with 90-degree turn (70ft)
- *Task 2 – IND:* Hose deployment
- *Task 3 – IND:* Flow for 10s, flow and move 15ft, flow 10s
- *Evolution A2 – CREW:* Deploy 2 1⁄2 line, conduct 360, advance hose, 5s hit on stairs, push to 2nd floor, flow and move to fire room, hydraulic ventilation, & overhaul.

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

SESSION A					
Tasks	***Mean***	***Min***	***Max***	***Deviation***	***N***
Flow Water METs	4.9	1.9	7.3	1.9	16
Flow Water VO2 [mL/kg/min]	16.3	6.7	25.8	7.4	16
Hose Advance METS	5.6	2.5	8.7	2.0	20
Hose Advance VO2 [mL/kg/min]	19.4	8.8	30.4	7.3	20
Hose Deployment METs	6.3	2.4	11.1	2.7	15
Hose Deployment VO2 [mL/kg/min]	22.1	8.3	38.9	9.1	15

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

EVOLUTIONS	***Mean***	***Min***	***Max***	***Deviation***	***N***
Evolution A1 (pairs) METs	11.6	5.2	15.8	2.9	25
Evolution A1 (pairs) VO2 [mL/kg/min]	39.6	18.2	55.4	11.1	25
Evolution A2 (crew) METs	10.9	4.5	18.2	3.7	25
Evolution A2 (crew) VO2 [mL/kg/min]	37.3	15.6	67.3	13.5	25



EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

Session B

Session B Layout (at St 32):

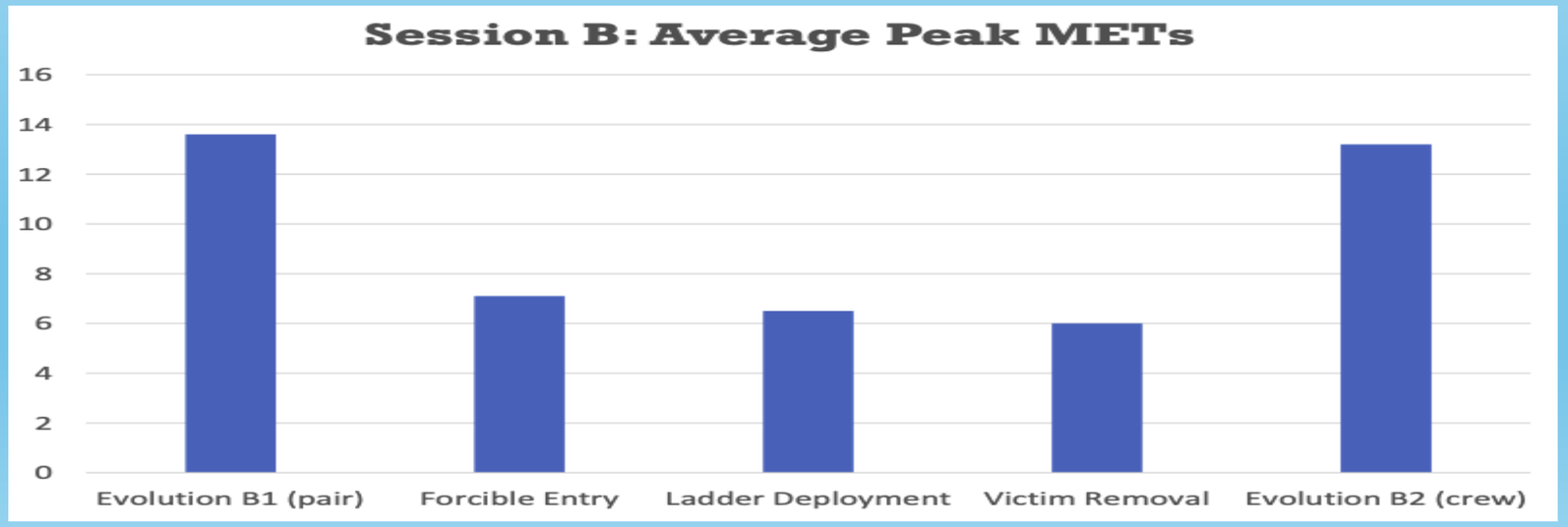
- *Evolution B1 – PAIRS:* Throw two 14ft ladders and one 24ft ladder, forcible entry, primary search, live victim removal to top of stairs.
- *Task 1 – PAIRS:* Forcible entry with one on the halligan and one on the axe
- *Task 2 – IND:* Ladder deployment, either two 14ft ladders or one 24ft ladder
- *Task 3 – PAIRS:* Victim drag approx. 40ft
- *Evolution B2 - CREW*: Throw two 14ft ladders and one 24ft ladder, forcible entry, primary search, live victim removal to bottom of stairs.

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

SESSION B					
TASKS	***Mean***	***Min***	***Max***	***Standard Deviation***	***N***
Forcible Entry METs	7.1	2.3	12.3	2.1	28
Forcible Entry VO2 [mL/kg/min]	24.8	8.0	43.1	7.4	28
Ladder Deployment METS	6.5	2.2	12.0	2.4	28
Ladder Deployment VO2 [mL/kg/min]	22.7	7.7	42.1	8.4	28
Victim Removal METs	6.6	1.8	14.1	2.4	28
Victim Removal VO2 [mL/kg/min]	21.0	6.4	49.5	9.0	28

EVALUATION OF VO2 CONSUMPTION FOR FIRE SPECIFIC TASKS

EVOLUTIONS	*Mean*	*Min*	*Max*	*Standard Deviation*	*N*
Evolution B1 (pairs) METs	13.6	4.5	18.9	2.9	22
Evolution B1 (pairs) VO2 [mL/kg/min]	47.8	15.8	66.4	10.2	22
Evolution B2 (crew) METs	13.2	4.7	16.9	2.7	19
Evolution B2 (crew) VO2 [mL/kg/min]	46.0	16.3	59.3	9.4	19



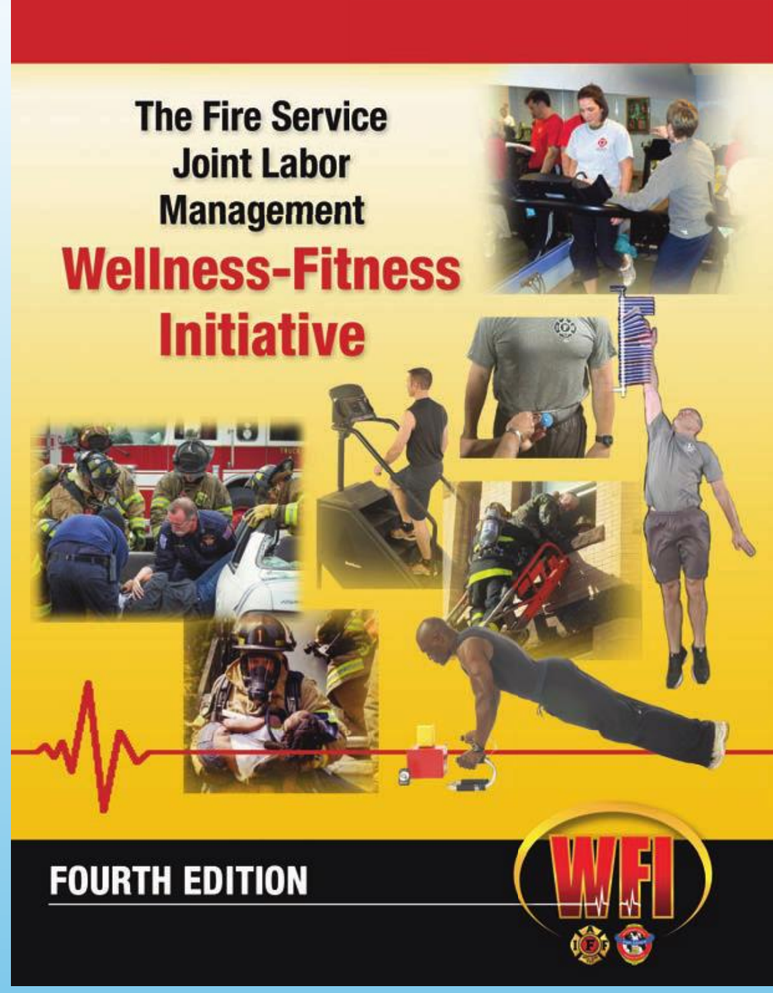
Using a Submaximal Test to Predict Maximal Performance

- Submaximal = Ability to do work at a submaximal level
- Pitfalls of using a submaximal test to predict maximal performance
  - **Assumes** a linear relationship between heart rate and VO_2
  - WFI / Gerkin
    - Uses an age **predicted** maximal heart rate
      - Variance = ± 25 beats per minute
    - Includes body mass index (BMI)(height and weight) within the prediction equations
      - Two people with same performance time but different BMIs will have different $VO2_{max}$s
    - Some studies have identified **36%** of sampled firefighters categorized incorrectly as fit for duty.

(Klaren, R. E., Horn, G. P., Fernhall, B., & Motl, R. W. (2014). Accuracy of the VO2peak prediction equation in Firefighters. *Journal of Occupational Medicine and Toxicology*, Article 17. https://doi.org/10.1186/1745-6673-9-17

Wellness Fitness Initiative

- Created by the Fire Service Joint Labor Management.
- Supports predictive health and wellness initiatives and standards
- Outlines two sub-maximal tests that calculate a VO2 measurement: based on heart rate response during the graded exercise.
- Time in minutes (TT), and body mass index (BMI) to estimate VO2: VO2 max (ml/kg/min) = 56.981 + (1.242 x TT) – (0.0805 x BMI).
- Simply put: once an individuals reaches 85% of their target heart rate and maintains it for 15 seconds the test is stopped. The remaining 15% of the results are predicted.



Measurement Spectrum of Fitness

Direct VO_2 Testing

(Submaximal and Maximal)

Heart Rate Testing

(Submaximal and Maximal)

Field Testing

Maximum Heart Rate

Age	Target HR Zone 50-85%	Age-predicted Maximum Heart Rate
20 years	100-170 beats per minute (bpm)	200 bpm
30 years	95-162 bpm	190 bpm
35 years	93-157 bpm	185 bpm
40 years	90-153 bpm	180 bpm
45 years	88-149 bpm	175 bpm
50 years	85-145 bpm	170 bpm
55 years	83-140 bpm	165 bpm
60 years	80-136 bpm	160 bpm
65 years	78-132 bpm	155 bpm
70 years	75-128 bpm	150 bpm

American Heart Association.

Measurement Spectrum of Fitness

Direct VO_2 Testing

(Submaximal and Maximal)

Heart Rate Testing

(Submaximal and Maximal)

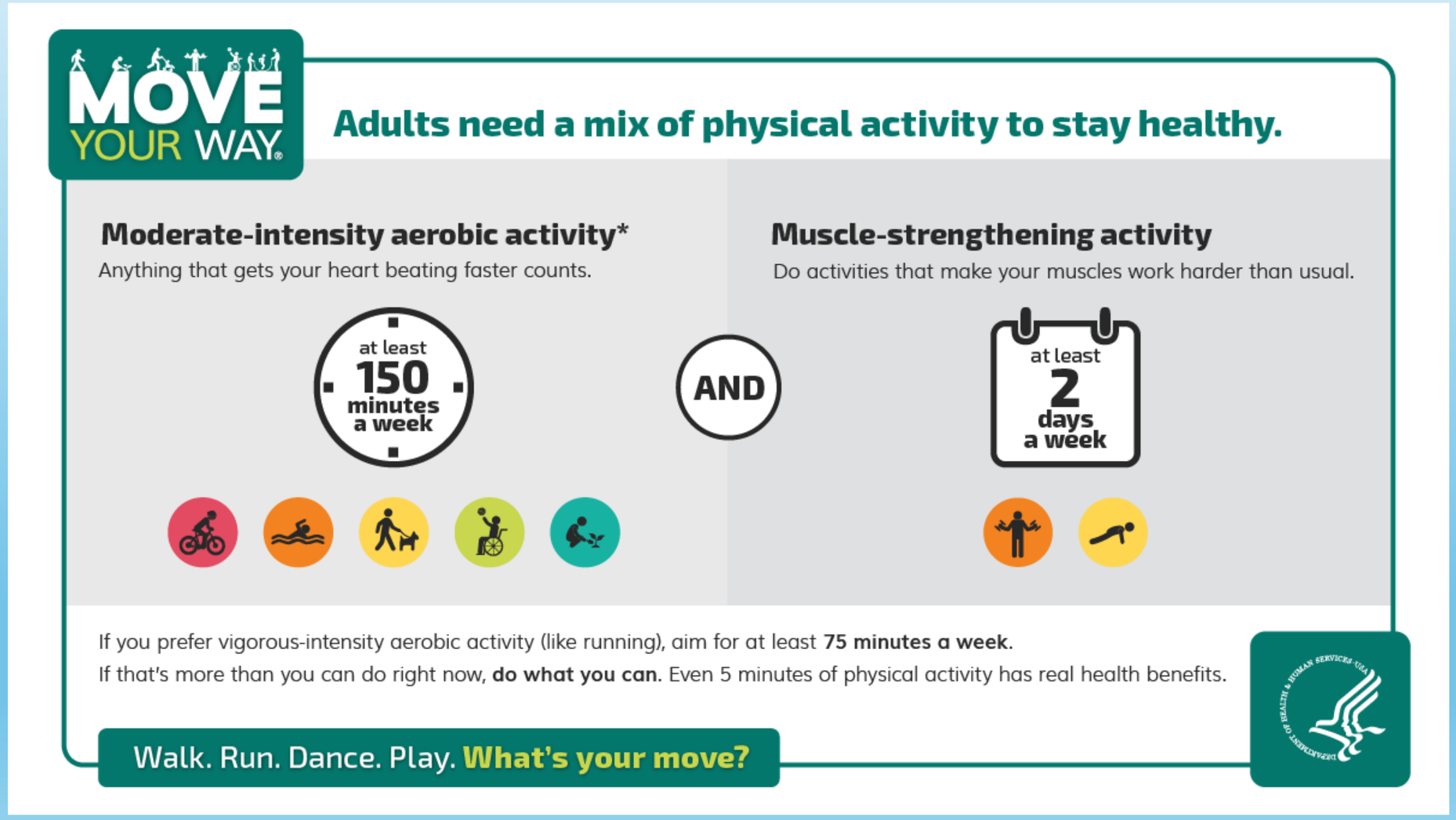
Field Testing

What if I am not doing any testing?

Use a field test:

- Pack test- Arduous (6-10 MET's –predictive)
- Field Test-Moderate duty
- Walk test- Light duty
- 1.5-mile run/walk test
  - VO_{2max} (mL/kg/min) = 3.5 + (483/1.5-mile time in minutes)
- 12-minute walk test
  - VO_{2max} (mL/kg/min) = (distance in meters – 504.9)/44.73

Where do you start?



Everyone Goes Home®

Firefighter Life Safety Initiatives by the National Fallen Firefighters Foundation

16 FIREFIGHTER LIFE SAFETY INITIATIVES

6. Medical & Physical Fitness

Develop and implement national medical and physical fitness standards that are equally applicable to all firefighters, based on the duties they are expected to perform.

Questions / Contact Information

Email: nick.grosch@southmetro.org

Leading into the Future