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Musculoskeletal Injury Risk Among Firefighters: Movement Quality Isn't the Only Factor

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DISCLOSURES

Prior Funding:

- NSCA Foundation

Conflicts of Interest:

- I have no actual or potential conflict of interest in relation to this presentation.

OBJECTIVES

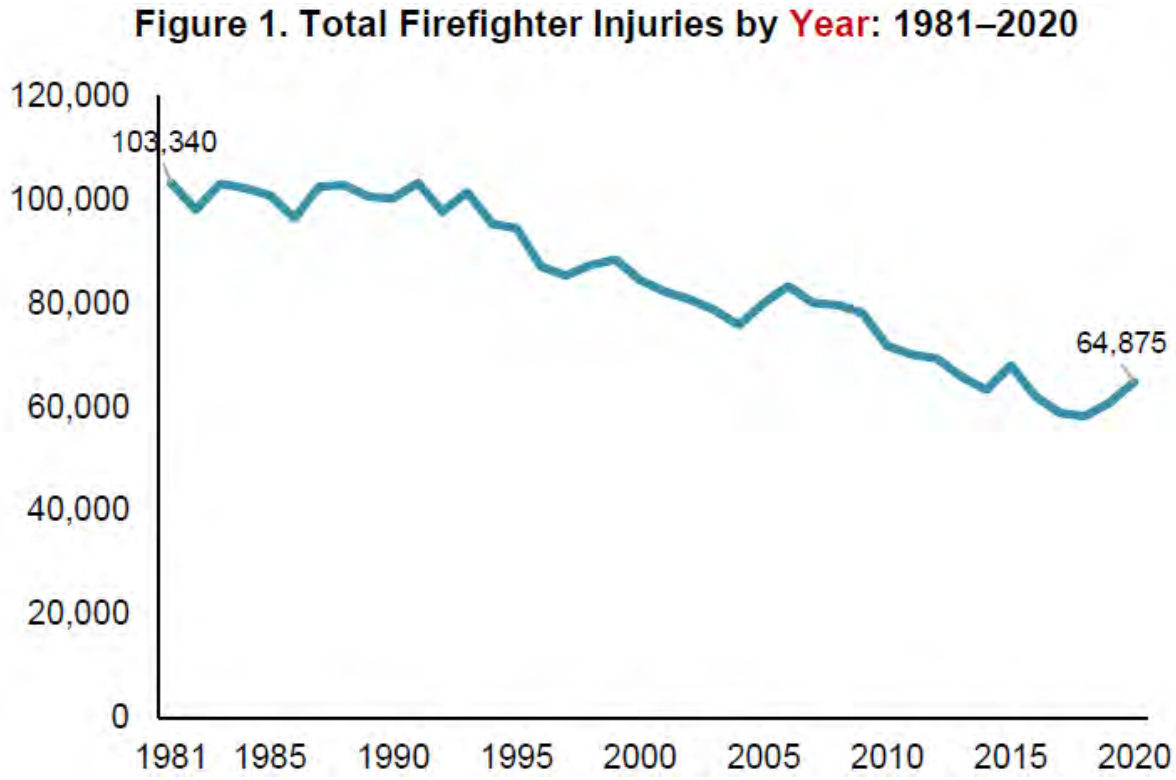
Attendees will be provided with evidence-based information regarding:

1. Which measures of health, fitness, and movement quality have been related to musculoskeletal injury (MSKI) risk among firefighters;
2. How health, fitness, and movement quality of firefighters changes during the course of their careers;
3. Example programming that can be utilized to improve the functional movement quality of firefighters within firehouses.

INJURY STATISTICS

Firefighter Injuries

- Although the National Fire Protection Association (NFPA) reports a ↓ in the total number of injuries among U.S. firefighters…

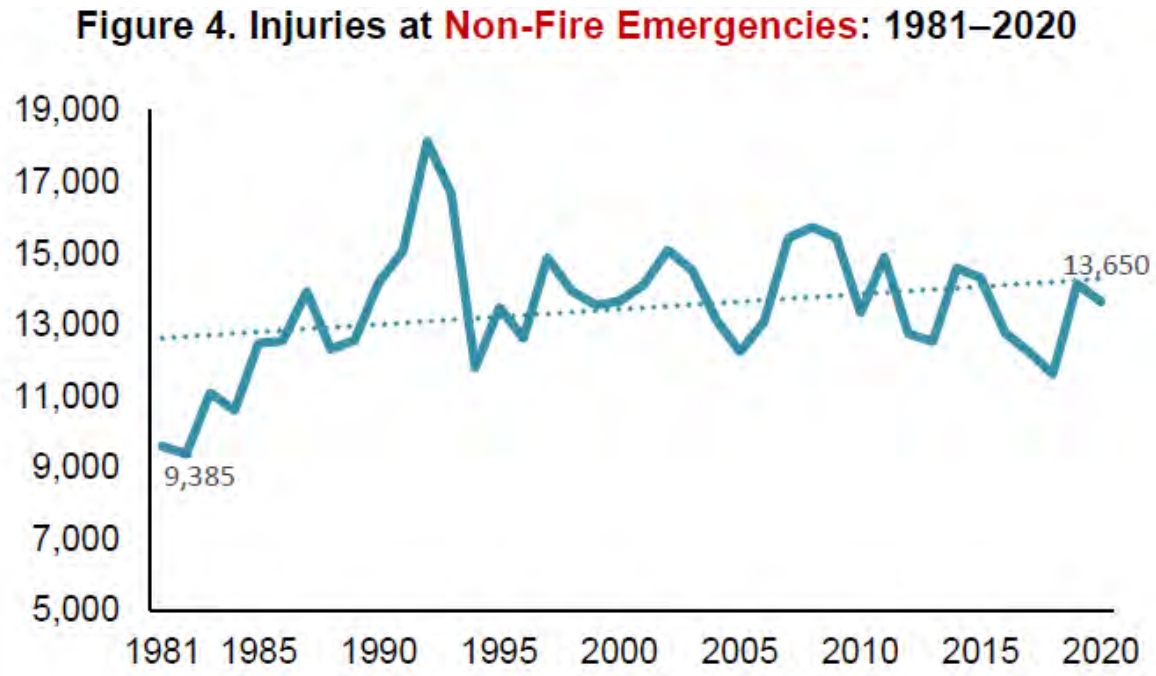


Campbell R, Evarts B. *National Fire Protection Association*. 2021.

INJURY STATISTICS

Firefighter Injuries

- there has been an ↑ in the number of injuries at <u>non-fireground</u> emergencies…
  - An **42%** ↑ since 1981
    (Campbell & Evarts, 2021)

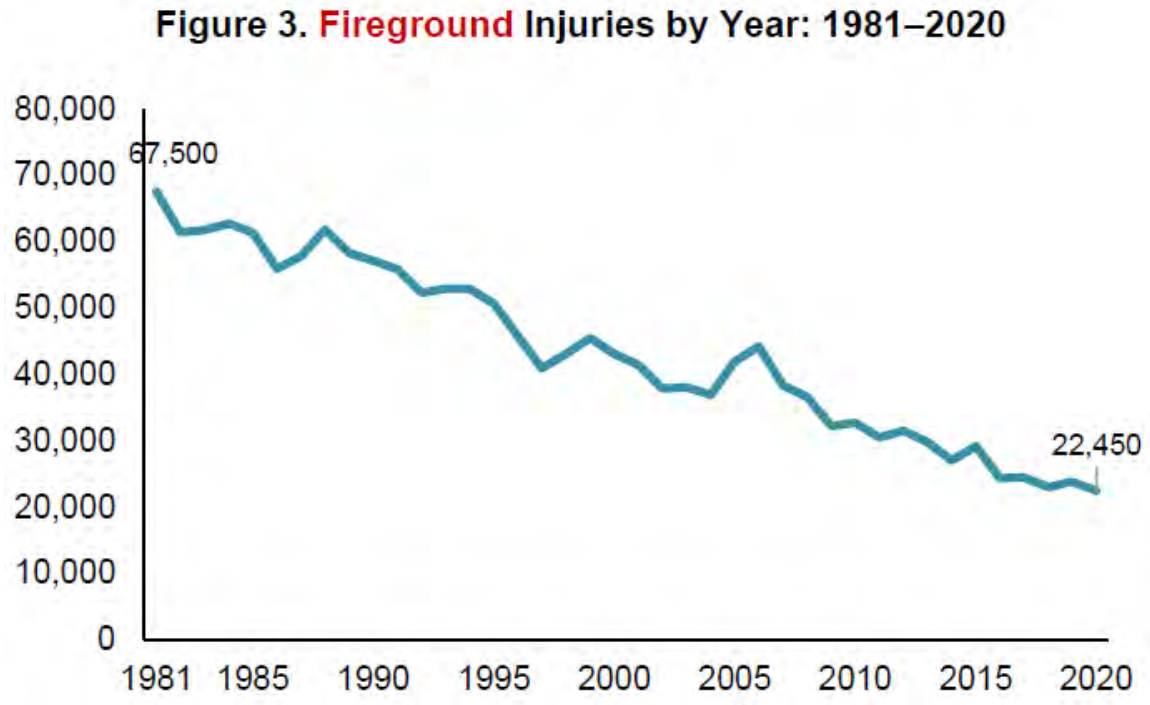


Campbell R, Evarts B. *National Fire Protection Association*. 2021.

INJURY STATISTICS

Firefighter Injuries

- And although there has been a ↓ in the total number of fireground injuries among U.S. firefighters…

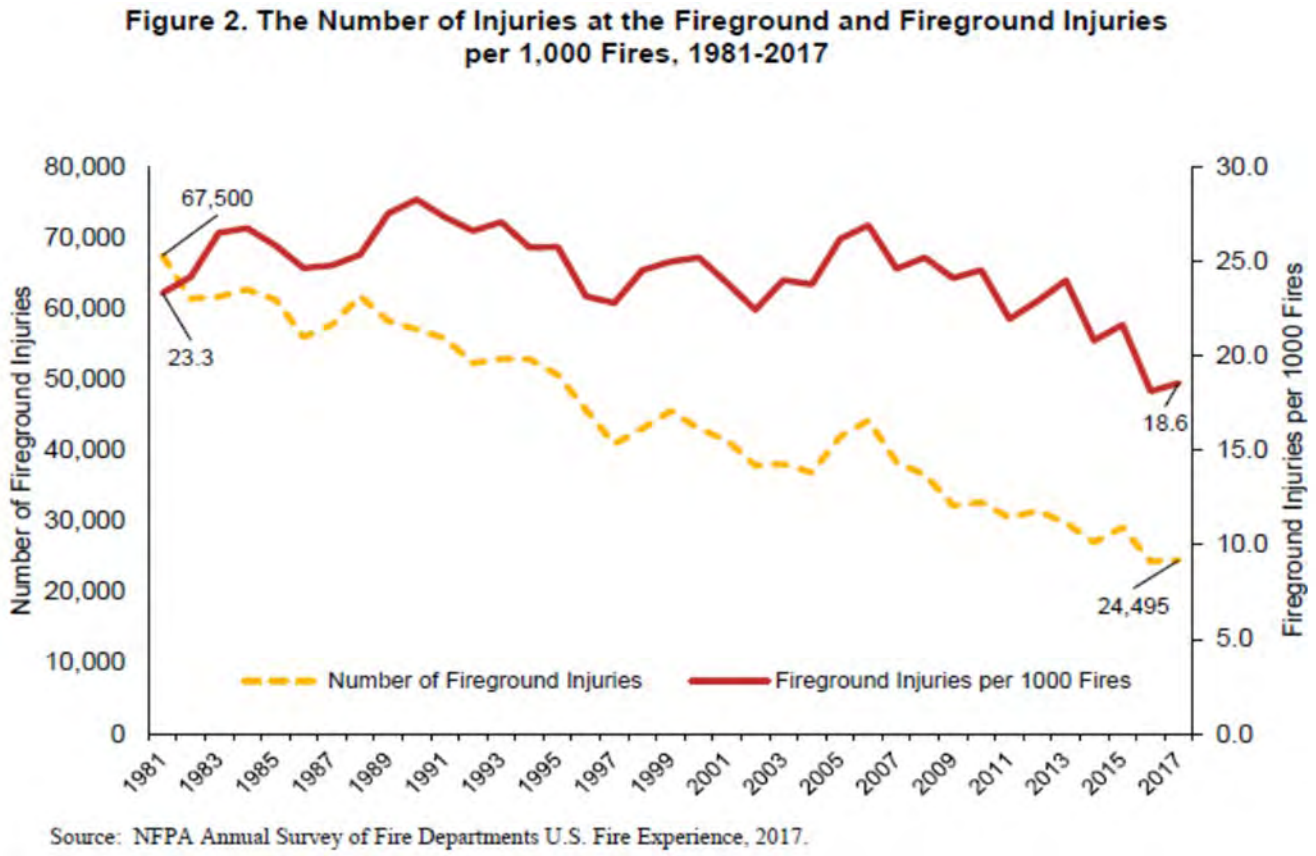


Campbell R, Evarts B. *National Fire Protection Association*. 2021.

INJURY STATISTICS

Firefighter Injuries

- only marginal changes in the **rate** (per fire exposure) of fireground injuries has been observed…
  - **16.2 injuries per 1,000 fires in 2020**
    (Campbell & Evarts, 2021)



Evarts B, Molis JL. *National Fire Protection Association*. 2018.

INJURY STATISTICS

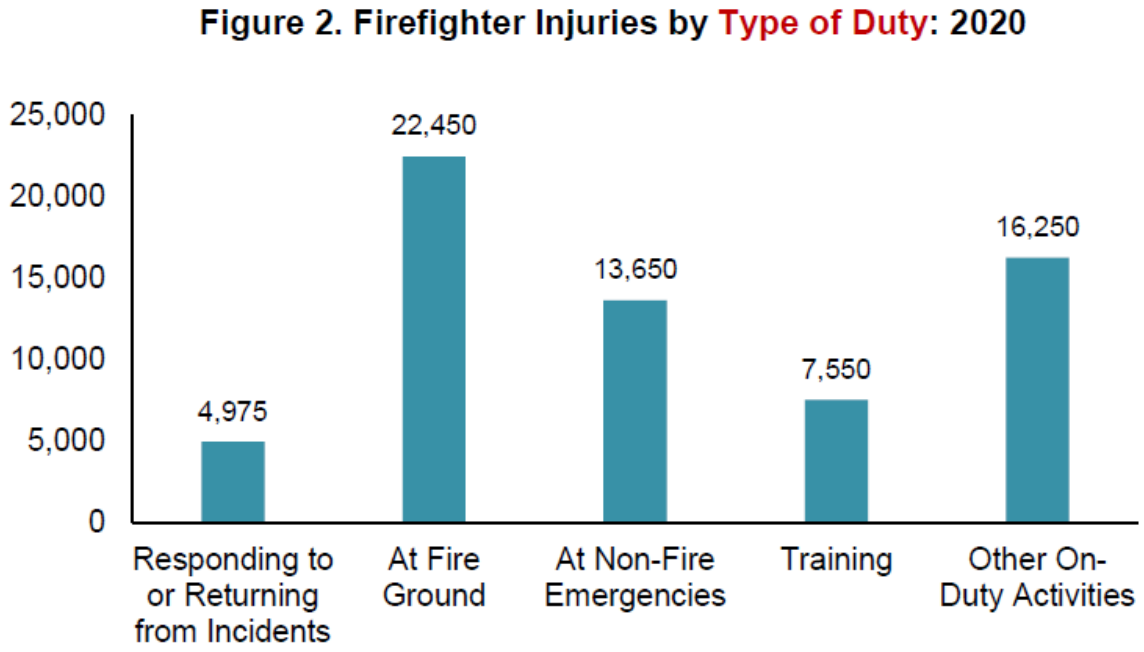
Firefighter Injuries

- 17.7 out of 100 firefighters are injured each year (Poplin et al., 2012)
  - 3.2% report 2 work-related injuries in the past year (Phelps et al., 2018)
  - 1.2% report 3+ work-related injuries in the past year (Phelps et al., 2018)
- Firefighters are **3.8 times more likely** to suffer a musculoskeletal injury than a private sector worker
  (Seabury & McLaren, 2010)
- Injury rates are **7 times higher** than the general population
  (Leffer & Grizzell, 2010)

INJURY STATISTICS

Firefighter Injuries

- Of the nearly 65,000 total injuries that occurred in 2020, the NFPA reports that:
  - 34.6% of injuries occurred on the fireground
    - Meaning **65.4%** of all injuries <u>DO NOT occur on the fireground</u>



Campbell R, Evarts B. *National Fire Protection Association*. 2021.

INJURY STATISTICS

Campbell R, Evarts B. *National Fire Protection Association*. 2021.

Firefighter Injury Types

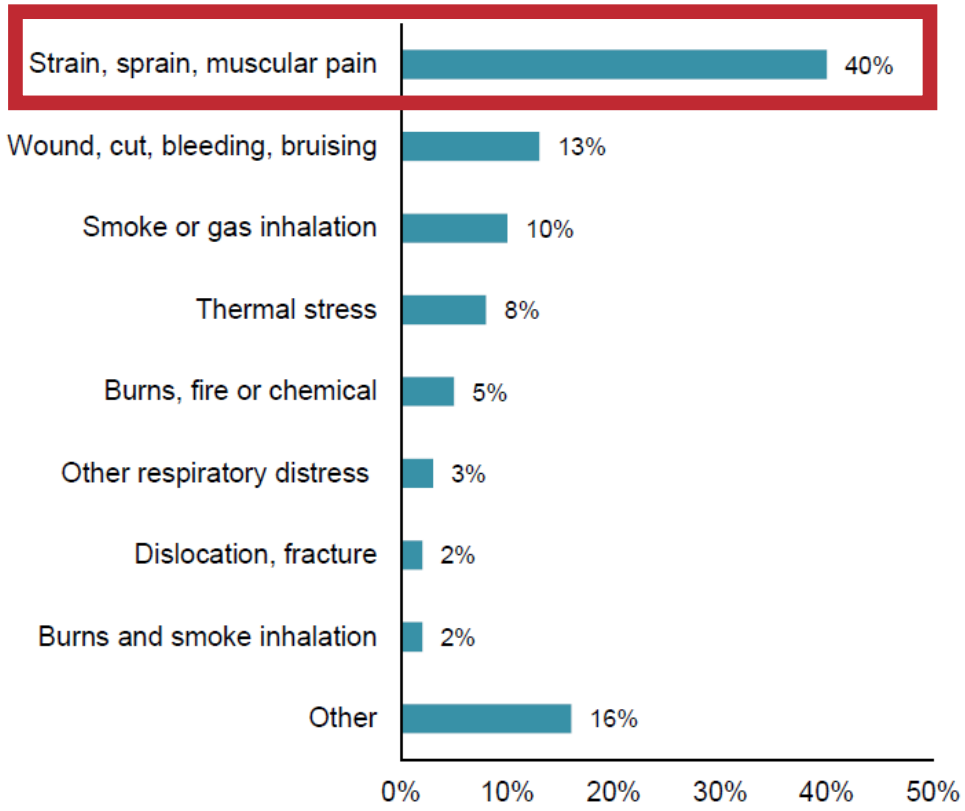
- Of the nearly 65,000 total injuries in 2020:
  - **45.8% of ALL injuries were musculoskeletal in nature**

Table A. Non-Fireground Injuries by Nature of Injury: 2020

Nature of Injury	Responding to, Returning from	Non-Fire Emergency	Training	Other On-Duty
Strain, sprain, muscular pain	43%	3%	62%	41%
Wound, cut, bleeding, bruising	10%	11%	15%	11%
Thermal stress	6%	1%	1%	0%
Other respiratory distress	6%	1%	1%	1%
Smoke, gas inhalation	6%	0%	0%	0%
Dislocation, fracture	5%	1%	4%	2%
Other	23%	31%	12%	40%

Overall: 48.9%

Figure 5. Fireground Injuries by Nature of Injury: 2020

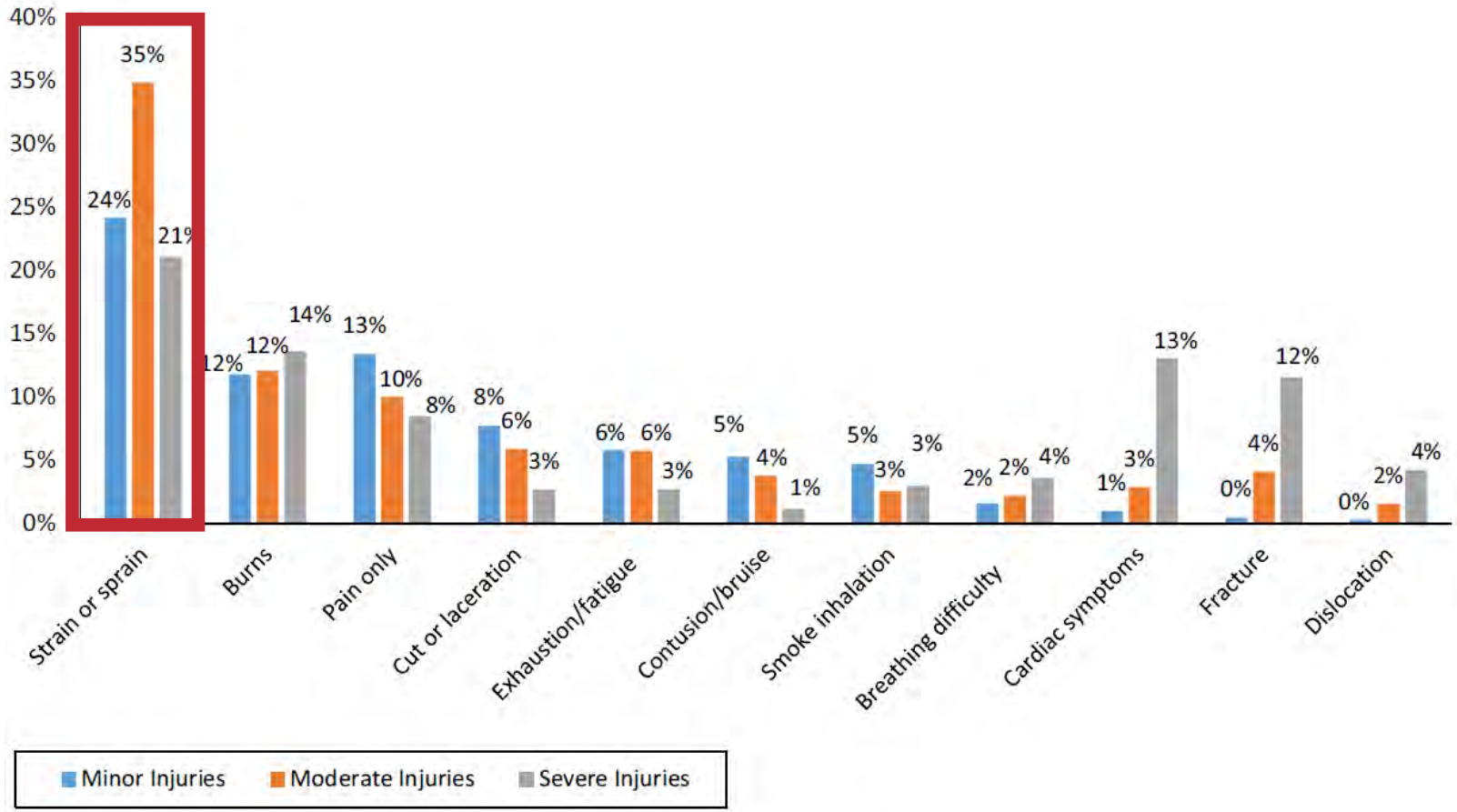


Campbell R. *National Fire Protection Association*. 2021.

INJURY STATISTICS

Firefighter Injury Types

- Sprains/Strains
  - 35% of all moderate injuries
  - 21% of all severe injuries



Moderate and **Severe** Injuries = **Lost Time**

Campbell R. *Fire Technol*. 2018;54(2):461-477.

INJURY STATISTICS

Firefighter Injury Areas

- NFPA routinely reports primary areas of injury as:
  - **Upper Extremities**
  - **Lower Extremities**
  - **Neck/Shoulders**

51%

Campbell R. *National Fire Protection Association*. 2021.

Table A. Fireground Injuries by Body Part, 2015–2019 Annual Average

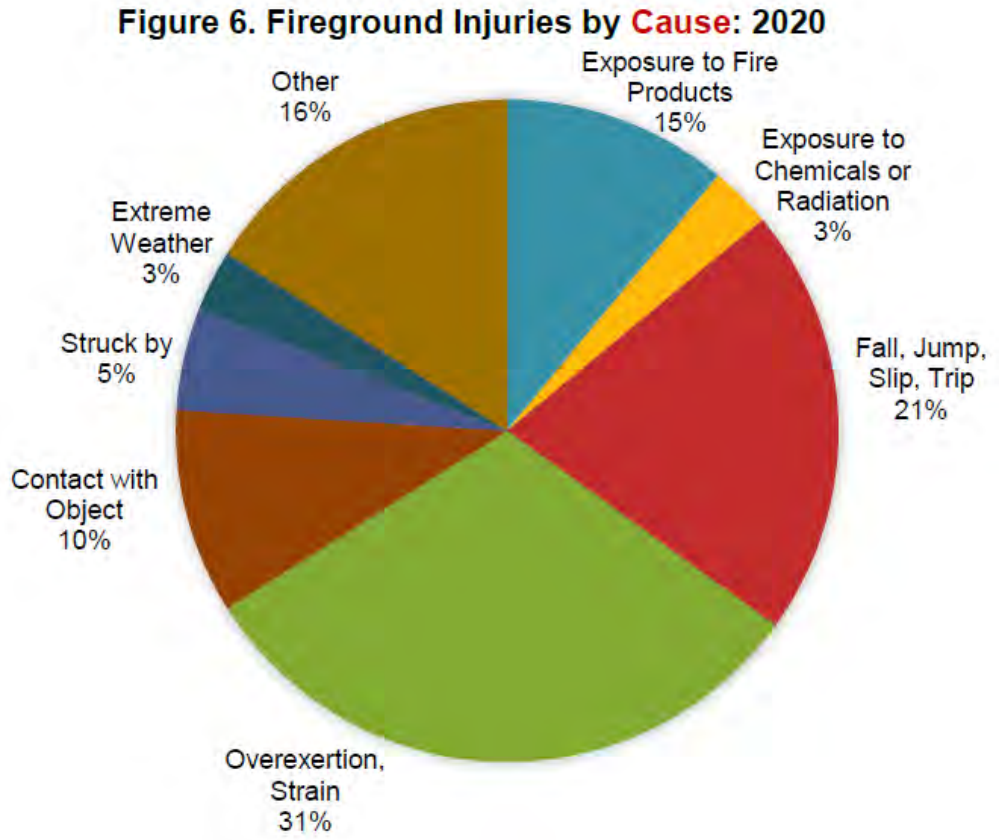
Primary Body Part Injured	Percent
Lower extremities	20%
Knee	8%
Ankle	6%
Lower leg	3%
Upper extremities	18%
Hand and fingers	11%
Wrist	2%
Elbow	2%
Lower arm	2%
Internal	17%
Trachea and lungs	14%
Neck and shoulders	13%
Shoulder	8%
Neck	4%
Head	11%
Unclassified head	5%
Ear	3%
Eye	2%
Thorax	7%
Back, except spine	5%
Chest	2%
Multiple parts	7%
Spine	3%
Abdominal area	3%

INJURY STATISTICS

Firefighter Injury Causes

- **1 out of 3** are due to **overexertion or strain**
- **1 out of 5** are due to **falls, slips, & trips**

31% + 21% = 52%!



Campbell R, Evarts B. *National Fire Protection Association*. 2021.

FIREFIGHTER MSKI RISK

Firefighter MSKI Mechanisms

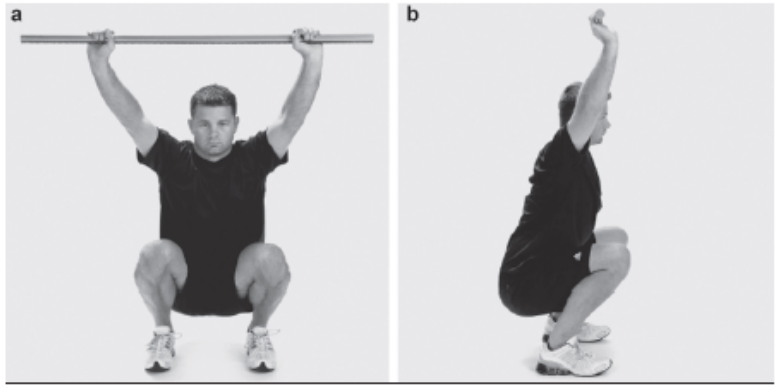
- Practitioners may also be uniquely positioned to help impact potentially **HALF** of fireground injuries
  - Especially since previous research suggests that **↓ functional movement quality is associated with ↑ MSKI risk**
    (Chimera & Warren, 2016; Teyhen et al., 2014)
  - Recent research also suggests that **↓ 2-leg overhead squat** movement quality is associated with ↑ MSKI risk as well (Eckard et al., 2018)

How is functional movement quality quantified again?

MOVEMENT QUALITY ASSESSMENT

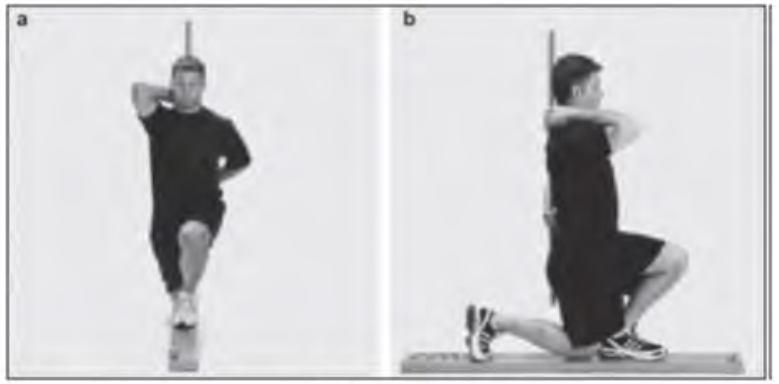
Cook G, et al. *Int J Sports Phys Ther*. 2014;9(3):396-409.
Cook G, et al. *Int J Sports Phys Ther*. 2014;9(4):549-563.

Functional Movement Screen (FMS) (Functional Movement Systems, Chatham, VA)



Deep Squat

Hurdle Step



In-Line Lunge


Shoulder Mobility


Active Straight-Leg Raise

Trunk Stability Push-Up

Rotary Stability Test

MOVEMENT QUALITY ASSESSMENT

Functional Movement Screen (FMS) (Functional Movement Systems, Chatham, VA)

FMS SCORING

3 = Performed pattern as directed

2 = Performed pattern with compensation or imperfection

1 = Unable to perform pattern as directed

0 = Pain reported (regardless of quality)

7 sub-scores are summed to form
a Composite FMS score (0-21)

TEST		RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT				
HURDLE STEP	L			
	R			
INLINE LUNGE	L			
	R			
SHOULDER MOBILITY	L			
	R			
IMPINGEMENT CLEARING TEST	L			
	R			
ACTIVE STRAIGHT-LEG RAISE	L			
	R			
TRUNK STABILITY PUSHUP				
PRESS-UP CLEARING TEST				
ROTARY STABILITY	L			
	R			
POSTERIOR ROCKING CLEARING TEST				
TOTAL				

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

Cook G. *Movement: Functional Movement Systems – Screening, Assessment and Corrective Strategies*. On Target Publications; 2010.

FIREFIGHTER MSKI RISK

Movement Quality

- ***Is ↓ functional movement quality is associated with ↑ MSKI risk among firefighters though?***

Work 46 (2013) 11–17
DOI 10.3233/WOR-121545
IOS Press

Modifiable risk factors predict injuries in firefighters during training academies

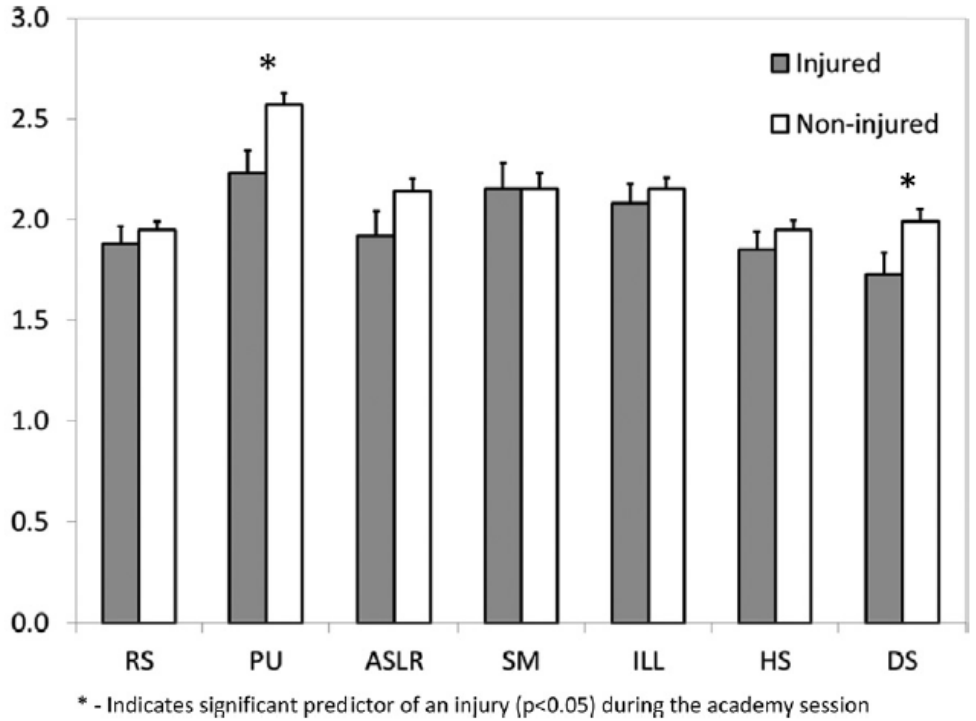
Robert J. Butler[a,*], Michael Contreras[b], Lee C. Burton[c], Phillip J. Plisky[d], Adam Goode[a] and Kyle Kiesel[d]
[a]*Doctor Division of Physical Therapy, Duke University, Durham, NC, USA*
[b]*Orange County Fire Authority, Irvine, CA, USA*
[c]*Department of Physical Education, Averett University, Danville, VA, USA*
[d]*Department of Physical Therapy, University of Evansville, Evansville, IN, USA*

Butler RJ, et al. *Work*. 2013;46(1):11-17.

FIREFIGHTER MSKI RISK

Movement Quality

- **Movement Quality:**
  - **Deep Squat** associated with MSKI
    (OR: 1.21 [95% CI: 1.01 – 1.42])
  - **Trunk Stability Push-Up Test** associated with MSKI
    (OR: 1.30 [95% CI: 1.07 – 1.53])



Butler RJ, et al. *Work*. 2013;46(1):11-17.

FIREFIGHTER MSKI RISK

Movement Quality

- **Movement Quality:**
  - **Optimal Composite FMS score cut-off: ≤14**
    (OR: 8.31 [95% CI: 3.2 – 21.6])
    - Consistent with previous literature at the time
      (Chimera & Warren, 2016; Teyhen et al., 2014)

Table 1
Specificity and sensitivity for composite FMS score across different cut points

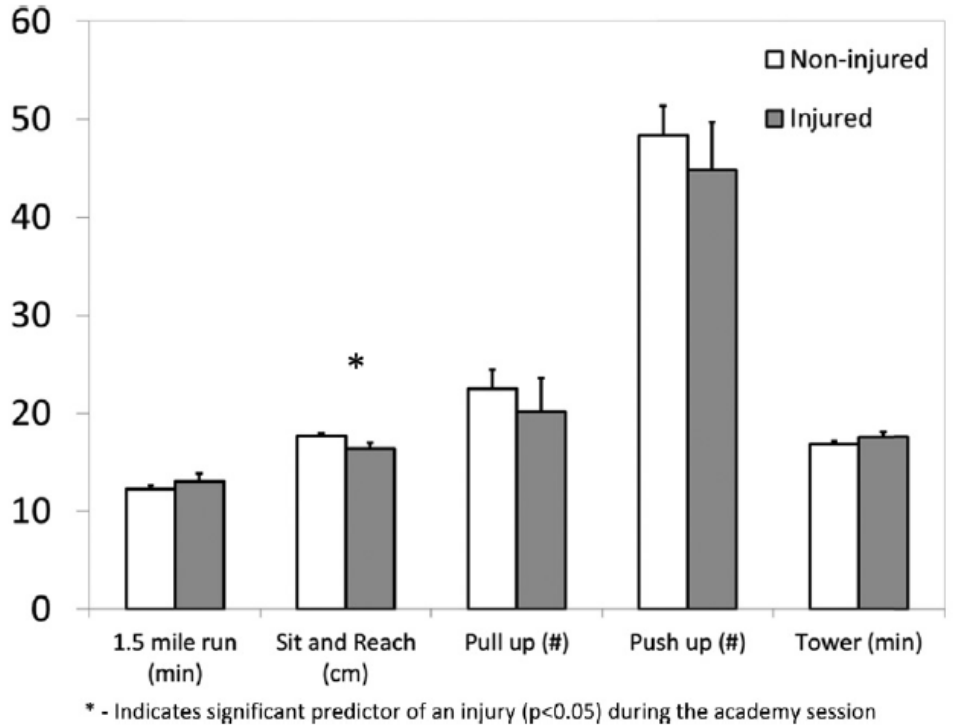
Cut off	Sensitivity	Specificity	Correctly classified	LR +	LR −
= 12	97.5	17.2	75.9	1.18	0.15
= 13	92.4	34.5	76.9	1.41	0.22
= 14	83.5	62.1	77.8	2.20	0.26
= 15	63.3	75.9	66.7	2.62	0.48
= 16	39.2	82.8	60.9	2.27	0.73
= 17	25.3	89.7	42.6	2.44	0.83

Butler RJ, et al. *Work*. 2013;46(1):11-17.

FIREFIGHTER MSKI RISK

Movement Quality

- **Fitness / Performance:**
  - Only **Sit & Reach** associated with MSKI
    (OR: 1.24 [95% CI: 1.06 – 1.42])



However, others have found different results…

Butler RJ, et al. *Work*. 2013;46(1):11-17.

FIREFIGHTER MSKI RISK

Movement Quality

- **Movement Quality:**
  - Injured recruits demonstrated lower Composite FMS scores than uninjured recruits ($P = 0.012$)
  - Composite FMS scores ≤14 predicted MSKI:
    - Sensitivity: 87%
    - Specificity: 56%
    - +LR: 1.97
    - –LR: 0.23

Manton C, et al. *J Orthop Sports Phys Ther*. 2016;46(1):A188.

FIREFIGHTER MSKI RISK

Movement Quality

- However, injured recruits also demonstrated:
  - ↑ Resting Heart Rate ($P = 0.012$)
  - ↑ 1.5-mile Run ($P = 0.017$)
  - ↑ Body Mass ($P = 0.003$)
  - ↑ Body Fat Percentage ($P = 0.024$)
  - ↑ BMI ($P = 0.043$)

So is it all about movement, or more about body composition and cardiorespiratory fitness??

Manton C, et al. *J Orthop Sports Phys Ther*. 2016;46(1):A188.

MOVEMENT QUALITY ASSESSMENT

Movement Quality

- ↑ Obesity is associated with ↓ Composite FMS Scores in other populations (Duncan & Stanely, 2012; Duncan et al., 2013; Farrell et al., 2021; Perry & Koehle, 2013)
  - However, it was unknown within the firefighter population?

Influence of body mass index on movement efficiency among firefighter recruits

David J. Cornell[a,*], Stacy L. Gnacinski[a], Aaron Zamzow[b], Jason Mims[c] and Kyle T. Ebersole[a]
[a]*Integrative Health Care & Performance Unit, Department of Kinesiology, University of Wisconsin–Milwaukee, Milwaukee, WI, USA*
[b]*City of Madison Fire Department, Madison, WI, USA*
[c]*City of Milwaukee Fire Department, Milwaukee, WI, USA*

Cornell DJ, et al. *Work*. 2016;54(3):679-687.

Measures of health, fitness, and functional movement among firefighter recruits

David J. Cornell[a*], Stacy L. Gnacinski[a], Aaron Zamzow[b], Jason Mims[c] and Kyle T. Ebersole[a]
[a]*University of Wisconsin-Milwaukee, USA;* [b]*City of Madison Fire Department, USA;* [c]*City of Milwaukee Fire Department, USA*

Cornell DJ, et al. *Int J Occup Saf Ergon*. 2017;23(2):198-204.

MOVEMENT QUALITY ASSESSMENT

Movement Quality

- Significant Indirect Relationships Between Composite FMS Scores and:
  (Cornell et al., 2016)
  - **BMI** (*r* = -0.235, *P* = 0.045)
- No Significant Relationships Between Composite FMS Scores and:
  (Cornell et al., 2017)
  - Est. VO_2max (*r* = 0.163, *P* = 0.153)

Measures of Functional Movement Quality Among Firefighters

David J. Cornell, PT, DPT, PhD, CSCS, TSAC-F; Kyle T. Ebersole, PhD, LAT, ATC, PES; Razia Azen, PhD; Kathryn R. Zalewski, PT, PhD, MPA; Jennifer E. Earl-Boehm, PhD, LAT, ATC; Carlynn A. Alt, PT, PhD

If Obesity is impacting the assessment of movement quality, can we assess it another way??

Cornell DJ, et al. *Athl Train Sports Health Care*. 2021;13(5):e262-270.

MOVEMENT QUALITY ASSESSMENT

Movement Efficiency Test

(Fusionetics, Milton, GA)

- 7 Sub-Tests:
  - 2-Leg Squat
  - 2-Leg Squat with Heel Lift
  - 1-Leg Squat
  - Push-Up
  - 4 Shoulder Movements
  - 2 Trunk Movements
  - 2 Cervical Movements

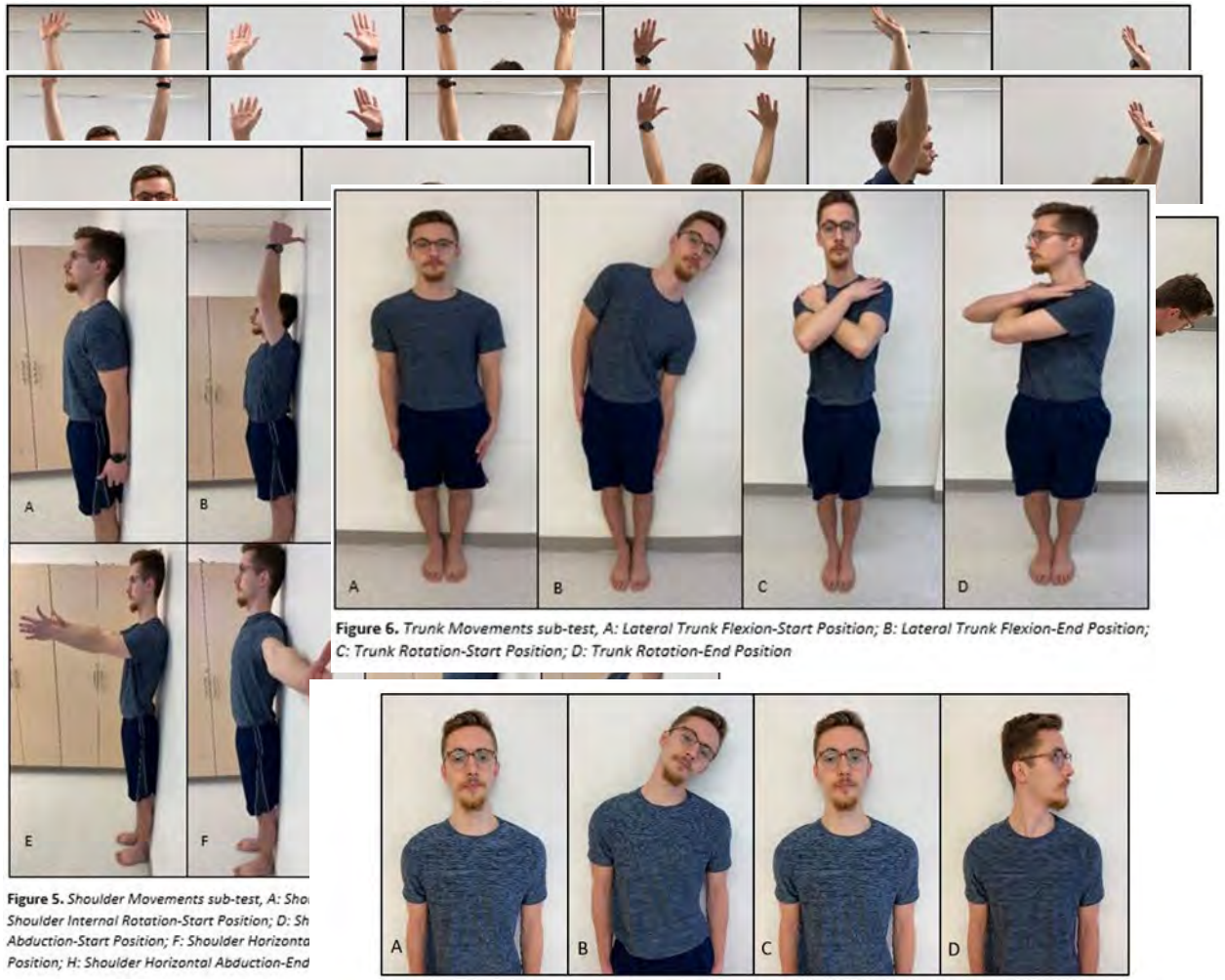


Figure 5. *Shoulder Movements sub-test, A: Sho... Shoulder Internal Rotation-Start Position; D: Sh... Abduction-Start Position; F: Shoulder Horizonta... Position; H: Shoulder Horizontal Abduction-End*

Figure 6. *Trunk Movements sub-test, A: Lateral Trunk Flexion-Start Position; B: Lateral Trunk Flexion-End Position; C: Trunk Rotation-Start Position; D: Trunk Rotation-End Position*

Figure 7. *Cervical Movements sub-test, A: Cervical Lateral Flexion-Start Position; B: Cervical Lateral Flexion-End Position; C: Cervical Rotation-Start Position; D: Cervical Rotation-End Position*

Cornell DJ, et al. *Athl Train Sports Health Care*. 2021;13(5):e262-270.

MOVEMENT QUALITY ASSESSMENT

Movement Efficiency Test (Fusionetics, Milton, GA)

- 7 Sub-Tests:
  - **Binary (yes/no)** scoring based on 60 different commonly observed movement compensations
  - An Overall ME Test Score is calculated
    - **0 – 100 (worst – best)**

1-LEG SQUAT

CHECKPOINT	COMPENSATION	RIGHT	LEFT
VIEW: FRONT			
Foot/Ankle	Foot Flattens		
Knee	Knee Moves In (Valgus)		
	Knee Moves Out (Varus)		
L-P-H-C	Uncontrolled Trunk: Flexion, Rotation, and/or Hip Shift		
	Loss of Balance		

Cornell DJ, et al. *Athl Train Sports Health Care*. 2021;13(5):e262-270.

MOVEMENT QUALITY ASSESSMENT

Movement Quality

- Associations between Overall ME Test Scores and:
  - NOT associated with BMI (r = -0.146, P = 0.315)
  - NOT associated with Age (r = -0.203, P = 0.161)
    - Important because previous research suggests that Age influences FMS Scores as well (Perry et al., 2013; Loudon et al., 2014; Teyhen et al., 2014)
    - Including in this study (r = -0.528, P < 0.001)
  - Composite FMS Scores (r = 0.612, P < 0.001)
    - Further, after controlling for the influence of Age and BMI, Overall ME Test Scores only account for 25.3% of the variance in Composite FMS Scores (r_{sp} = 0.503, P < 0.001, R^2 = 0.253)

Cornell DJ, et al. *Athl Train Sports Health Care*. 2021;13(5):e262-270.

MOVEMENT QUALITY ASSESSMENT

Movement Quality

- Although both the FMS and ME Test attempt to quantify the overall movement quality of an individual and are measuring directly related constructs, **the FMS and ME Test may quantify the functional movement quality of firefighters differently**
- However, Age and BMI weren't associated with Overall ME Test scores…
  - Thus, the ME Test may represent a method of quantifying movement quality without the influences of BMI (and Age)??

But back to the FMS real quick…

Cornell DJ, et al. *Athl Train Sports Health Care*. 2021;13(5):e262-270.

FIREFIGHTER MSKI RISK

Movement Quality

- ***Finally, is ↓ functional movement quality is associated with ↑ MSKI risk among active-duty firefighters though?***

Functional Movement Screen as a Predictor of Occupational Injury Among Denver Firefighters

Erin Shore [1,*], Miranda Dally [1,2], Shawn Brooks [3], Danielle Ostendorf [4], Madeline Newman [5], Lee Newman [1,2,6]

[1] *Center for Health, Work & Environment, Colorado School of Public Health, University of Colorado, Anschutz Medical Campus, 13001 E. 17th Pl., 3rd Floor, Mail Stop B1119 HSC, Aurora, CO, 80045, USA*
[2] *Department of Environmental and Occupational Health, Colorado School of Public Health, University of Colorado, Anschutz Medical Campus, 13001 E. 17th Pl., 3rd Floor, Mail Stop B1119 HSC, Aurora, CO, 80045, USA*
[3] *Denver Fire Department, 501 Knox Ct, Denver, CO, 80204, USA*
[4] *Division of Endocrinology, Metabolism, and Diabetes, Department of Medicine, University of Colorado Anschutz Medical Campus, 12631 E. 17th Ave. Campus Box B178, Aurora, CO, 80045, USA*
[5] *Springbuk®, 525 S Meridian Street #1b, Indianapolis, IN, 46225, USA*
[6] *Department of Epidemiology, Colorado School of Public Health and Department of Medicine, School of Medicine, University of Colorado, Anschutz Medical Campus, 13001 E. 17th Pl., 3rd Floor, Mail Stop B1119 HSC, Aurora, CO, 80045, USA*

Shore E, et al. *Saf Health Work*. 2020;11(3):301-306.

FIREFIGHTER MSKI RISK

Movement Quality

- No differences in Composite FMS scores or FMS Sub-Test scores
- Composite FMS ≤14 **NOT associated** with:
  - Any Claim
    (OR: 1.27 [95% CI: 0.88 – 1.83])
  - Overexertion Claim
    (OR: 1.33 [95% CI: 0.81 – 2.21])

Shore E, et al. *Saf Health Work*. 2020;11(3):301-306.

Table 2
FMS scores and subscores by claim status

Claim vs. No claim			
FMS score	Overall N = 581	Claim N = 188	No claim N = 393
	Mean (SD)	Mean (SD)	Mean (SD)
Composite Score	14.9 (2.3)	14.8 (2.3)	14.9 (2.2)
Deep squat	2.0 (0.6)	2.0 (0.6)	2.1 (0.6)
Hurdle step	2.0 (0.3)	2.0 (0.3)	2.0 (0.3)
In-line lunge	2.0 (0.7)	2.0 (0.6)	2.0 (0.7)
Shoulder mobility	2.1 (0.7)	2.1 (0.8)	2.1 (0.7)
Active leg raise	2.2 (0.6)	2.3 (0.6)	2.2 (0.6)
Trunk stability push-up	2.7 (0.6)	2.6 (0.6)	2.7 (0.6)
Rotary stability	1.8 (0.4)	1.9 (0.4)	1.8 (0.4)

Overexertion claim vs. No claim/other claim			
	Overall N = 581	Overexertion Claim N = 72	No claim, other caim N = 509
	Mean (SD)	Mean (SD)	Mean (SD)
Composite Score	14.9 (2.3)	14.7 (2.2)	14.9 (2.3)
Deep squat	2.0 (0.6)	2.0 (0.5)	2.1 (0.6)
Hurdle step	2.0 (0.3)	2.0 (0.3)	2.0 (0.3)
In-line lunge	2.0 (0.7)	1.9 (0.7)	2.0 (0.7)
Shoulder mobility	2.1 (0.7)	2.0 (0.7)	2.1 (0.7)
Active leg raise	2.2 (0.6)	2.3 (0.6)	2.2 (0.6)
Trunk stability push-up	2.7 (0.6)	2.7 (0.6)	2.7 (0.7)
Rotary stability	1.8 (0.4)	1.9 (0.4)	1.8 (0.4)

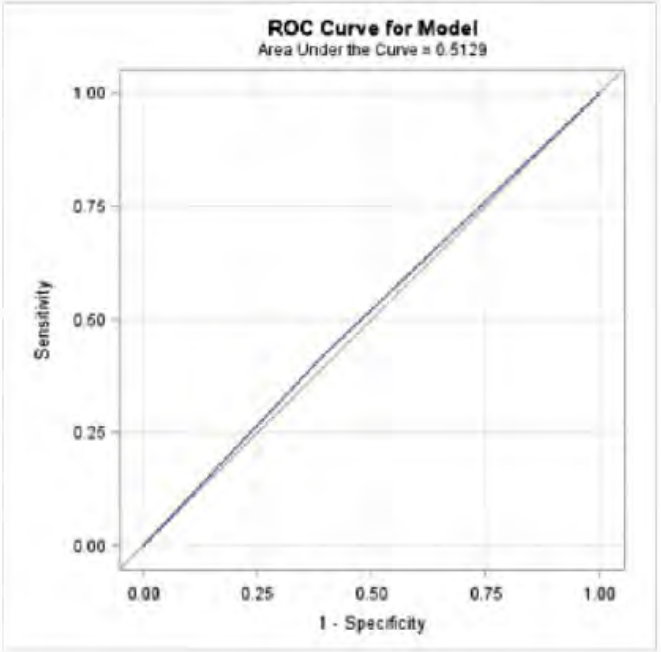
FMS, Functional Movement Screen.

FIREFIGHTER MSKI RISK

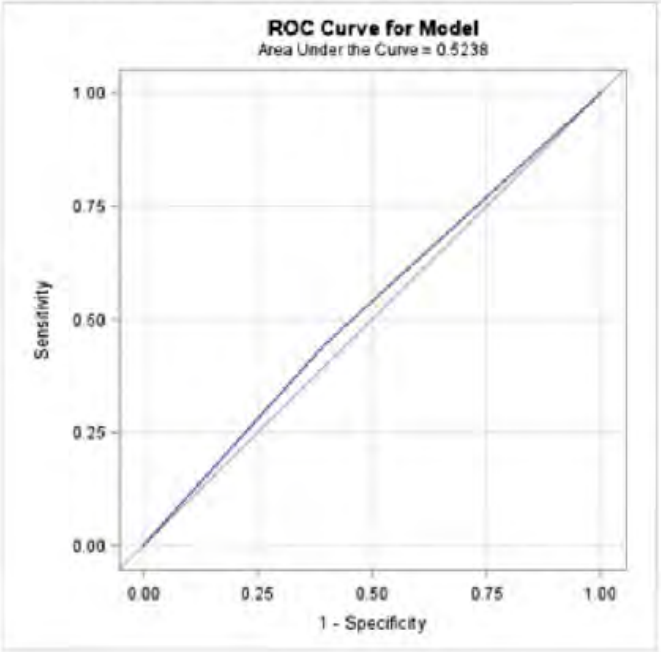
Movement Quality

- Composite FMS scores NOT able to clinically predict Workers Compensation Claims at any cut-off

Claim vs. No Claim



Over-exertion Claim vs. No Claim, Other Claim



Shore E, et al. *Saf Health Work*. 2020;11(3):301-306.

FIREFIGHTER MSKI RISK

Movement Quality

- Although movement quality may be an important factor to consider, it's not necessarily a sole predictor of MSKI among firefighters…
  - Need to appreciate how obesity influences movement!
- This lack of predictive validity is consistent with other tactical athlete populations as well
  (Kollock et al., 2019)
  - And potentially explains some of the controversy in the FMS literature in general (Dorrel et al., 2015; Moran et al., 2017; Warren et al., 2018)

So what IS related to MSKI among firefighters?

FIREFIGHTER MSKI RISK

Cardiorespiratory Fitness (CRF)

- Compared to firefighters with a VO_2max > 48 ml/kg/min:
  - Firefighters with a VO_2max 43 – 48 ml/kg/min were **1.61 times** more likely to experience a MSKI
  - Firefighters with a VO_2max < 43 ml/kg/min were **2.63 times** more likely to experience a MSKI

Table 5. Hazard Ratios[a] for Injuries by Levels Aerobic Fitness in Repeated Measures Modeling, Tucson, Arizona, 2005–2009

Vo_{2max} Level[b]	All Injuries (n = 716)		Exercise Injuries (n = 718)		Sprains and Strains (n = 718)	
	HR	95% CI	HR	95% CI	HR	95% CI
I		Referent		Referent		Referent
II	1.38	1.06, 1.78	1.20	0.81, 1.77	1.61	1.21, 2.13
III	2.22	1.72, 2.88	2.53	1.76, 3.64	2.63	1.98, 3.50

Abbreviations: CI, confidence interval; HR, hazard ratio, Vo_{2max}, relative aerobic capacity.

[a] All models were adjusted for sex and age.

[b] The relativeaerobic capacity for each level was as follows: I, >48 mL/kg/minute; II, 43–48 mL/kg/minute; and III, <43 mL/kg/minute.

Poplin GS, et al. *Am J Epidemiol*. 2014;179(2):149-155.

FIREFIGHTER MSKI RISK

Cardiorespiratory Fitness (CRF)

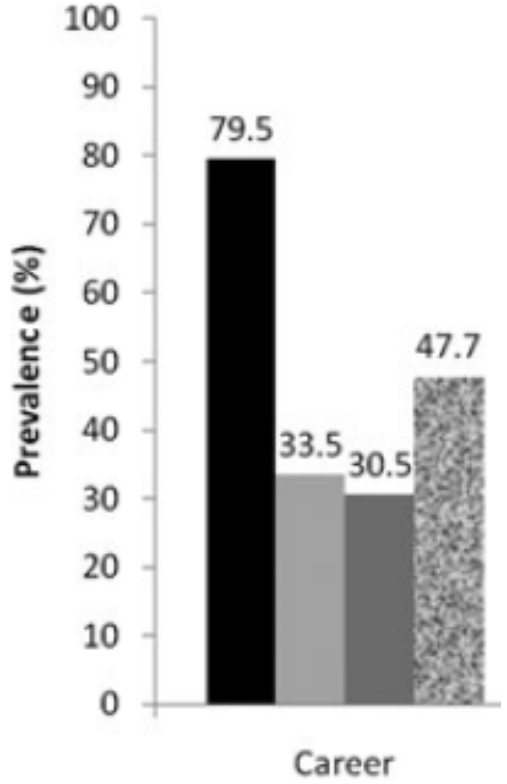
- However, the average VO_2max reported in the firefighter literature is **36 ml/kg/min (10.3 METS)** (Storer et al., 2014)
  - Note: This is below the NFPA recommended VO_2max of **42 ml/kg/min (12 METS)** (*NFPA 1582: Standard on Comprehensive Occupational Medical Program for Fire Departments*; 2018)

What else is related to MSKI among firefighters?

FIREFIGHTER MSKI RISK

Obesity

- Similar to the general population, the prevalence of obesity among U.S. firefighters is high as well (Soteriades et al., 2011)
- Research suggests that:
  - 46% of career firefighters are overweight
  - 33% of career firefighters are obese



Poston WSC, et al. *J Occup Environ Med*. 2011;53(3):266-273.

FIREFIGHTER MSKI RISK

Obesity

- Obese firefighters are more likely to experience a MSKI than normal weight firefighters
  - BMI ≥30 kg/m^2:
    5.2 times more likely
  - Waist Circumference ≥ 40 in:
    2.8 times more likely

TABLE 2 Longitudinal predictors of any injury and MS injury

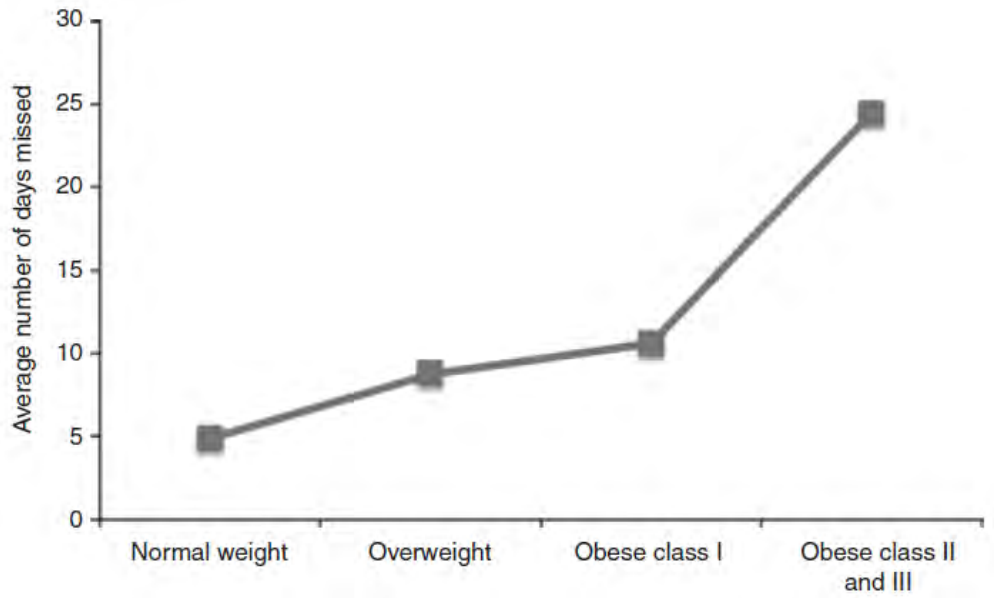
	Incident injury	Incident MS injury
Body composition		
Obesity, BMI defined (%)		
Normal weight	–	–[a]
Overweight	1.9 (0.7-5.2)	1.8 (0.4-8.6)
Obese	2.6 (0.9-7.4)	5.2 (1.1-24.5)
Obesity, waist circumference (%)		
under 40 inches	–	–[a]
over 40 inches	1.9 (1.0-3.6)	2.8 (1.2-6.4)
Obesity, body fat defined (%)		
Not obese <25%	–	–[a]
Obese	1.3 (0.7-2.5)	1.8 (0.8-4.0)

Jahnke SA, et al. *Obesity*. 2013;21(8):1505-1508.

FIREFIGHTER MSKI RISK

Obesity

- Class II/III Obese Firefighters experience ↑ injury-related missed workdays:
  - Normal Weight Firefighters: **4.89 times**
  - Overweight Firefighters: **2.55 times**
  - Class I Obese Firefighters: **2.71 times**

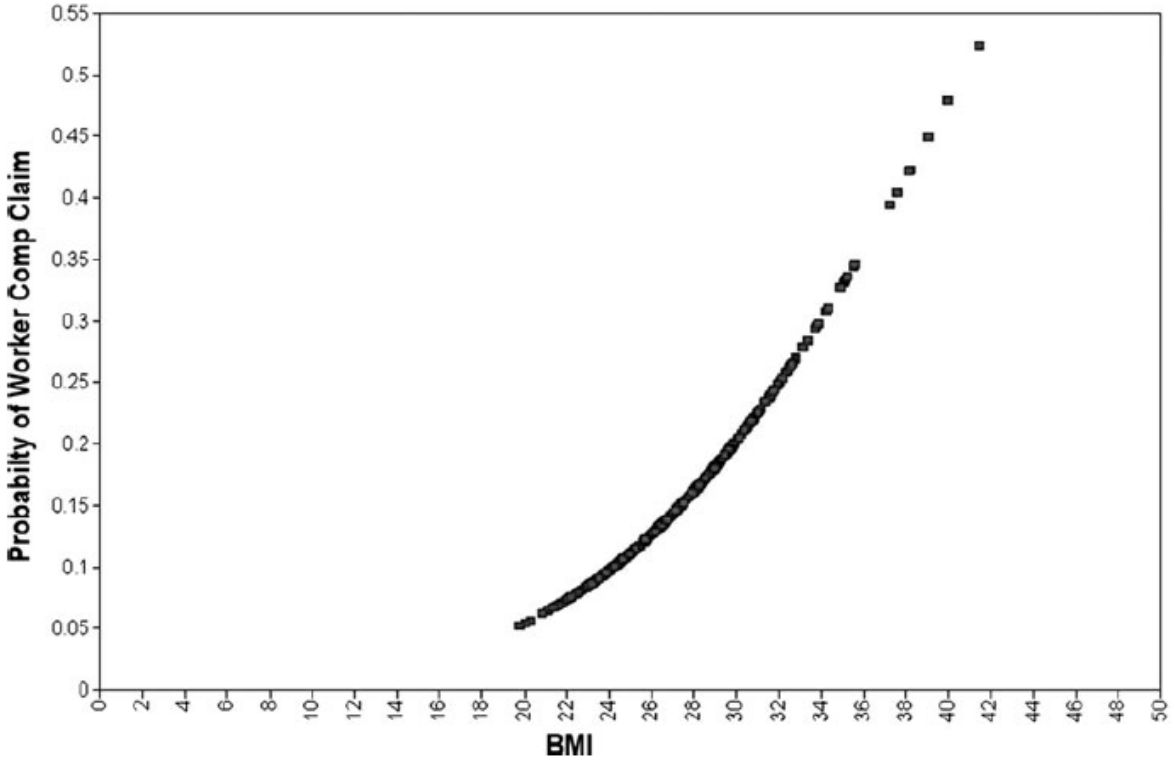


Poston WSC, et al. *Obesity*. 2011;19(10):2076-2081.

FIREFIGHTER MSKI RISK

Obesity

- Odds of filing a workers compensation claim are **almost 3 times higher** among obese firefighters than normal weight firefighters (OR: 2.89 [95% CI: 1.17 – 3.30])



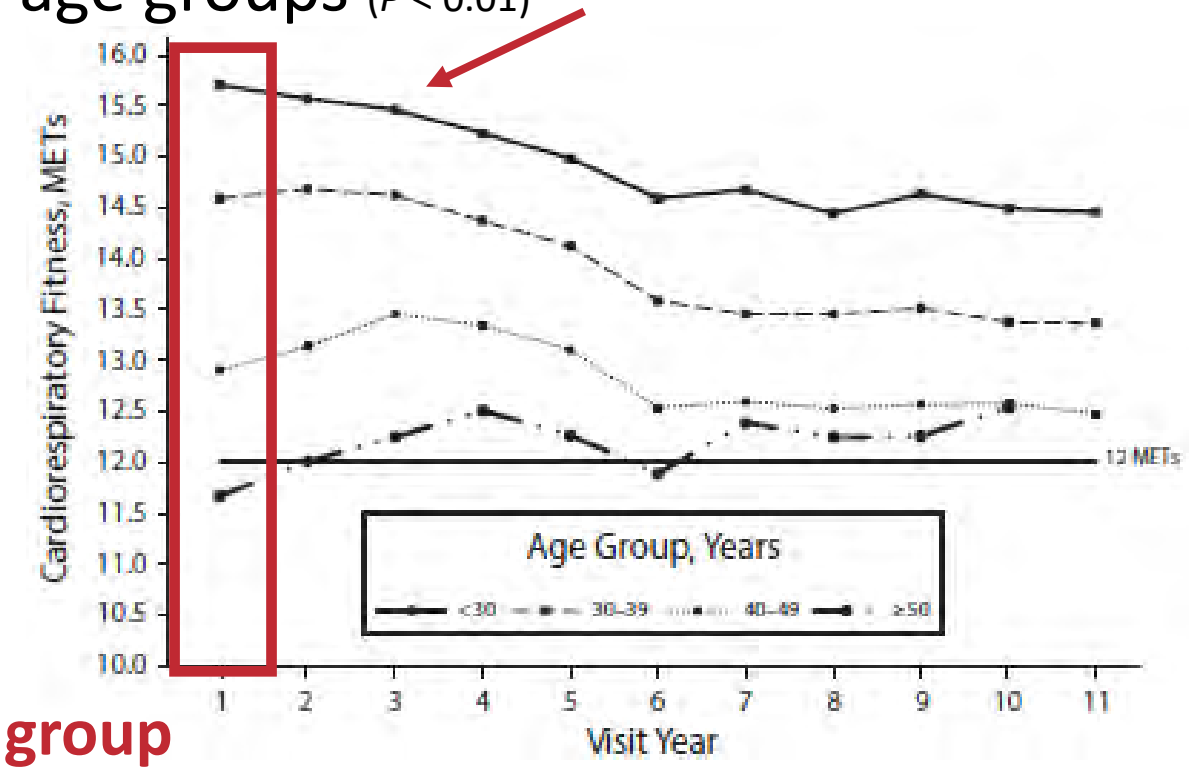
So how do measures of CRF and Obesity longitudinally change over time?

Kuehl KS, et al. *J Occup Environ Med*. 2012;54(5):579-582.

FIREFIGHTER HEALTH AND FITNESS

Cardiorespiratory Fitness (CRF)

- Cross-sectional differences across age groups ($P < 0.01$)
  - Age <30 yrs: 15.7 METS
    - **1.9%** did not meet ≥12 MET NFPA guideline
  - Age ≥50 yrs: 11.7 METS
    - **56.1%** did not meet ≥12 MET NFPA guideline
- Longitudinal changes:
  - **Fastest decline in CRF in <30 yrs group**

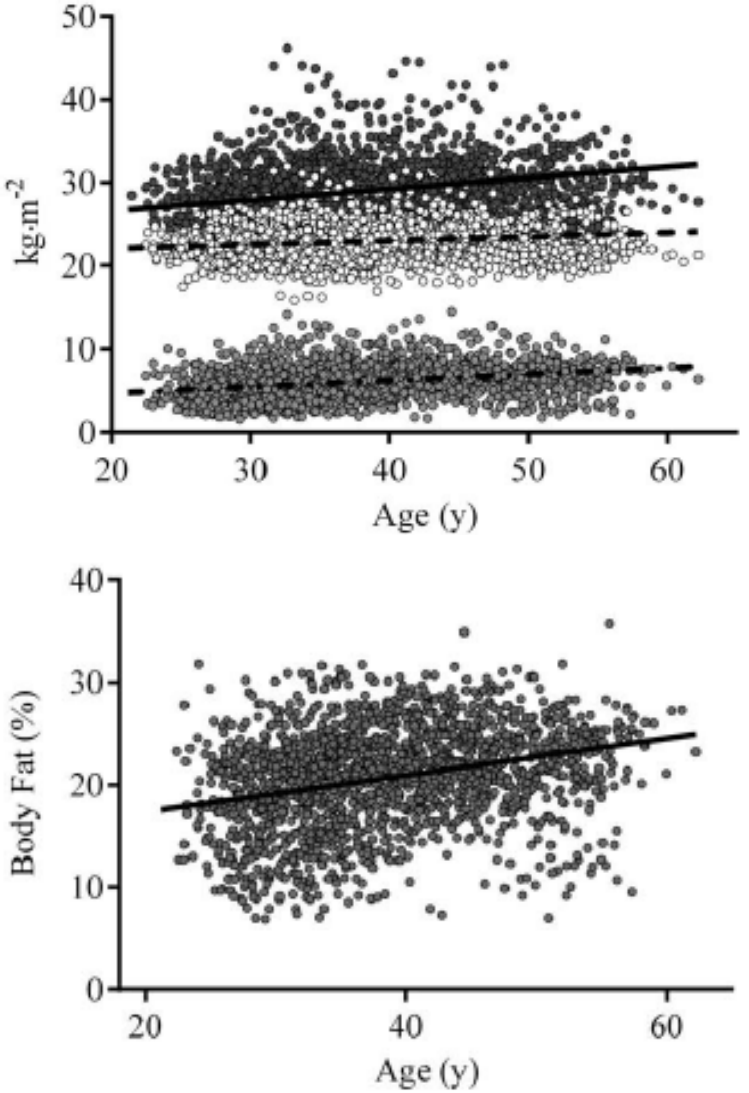


Cameron NA, et al. *Am J Public Health*. 2018;108(10):1388-1393.

FIREFIGHTER HEALTH AND FITNESS

Obesity

- Retrospective Analyses:
  - With each 1-year increase in age, the following significantly increased:
    - Body Mass (+0.42 kg, $P < 0.001$)
    - BMI (+0.13 kg/m^2, $P < 0.001$)
    - Body Fat Percentage (+0.18%, $P < 0.001$)
    - Fat Mass (+0.25 kg, $P < 0.001$)

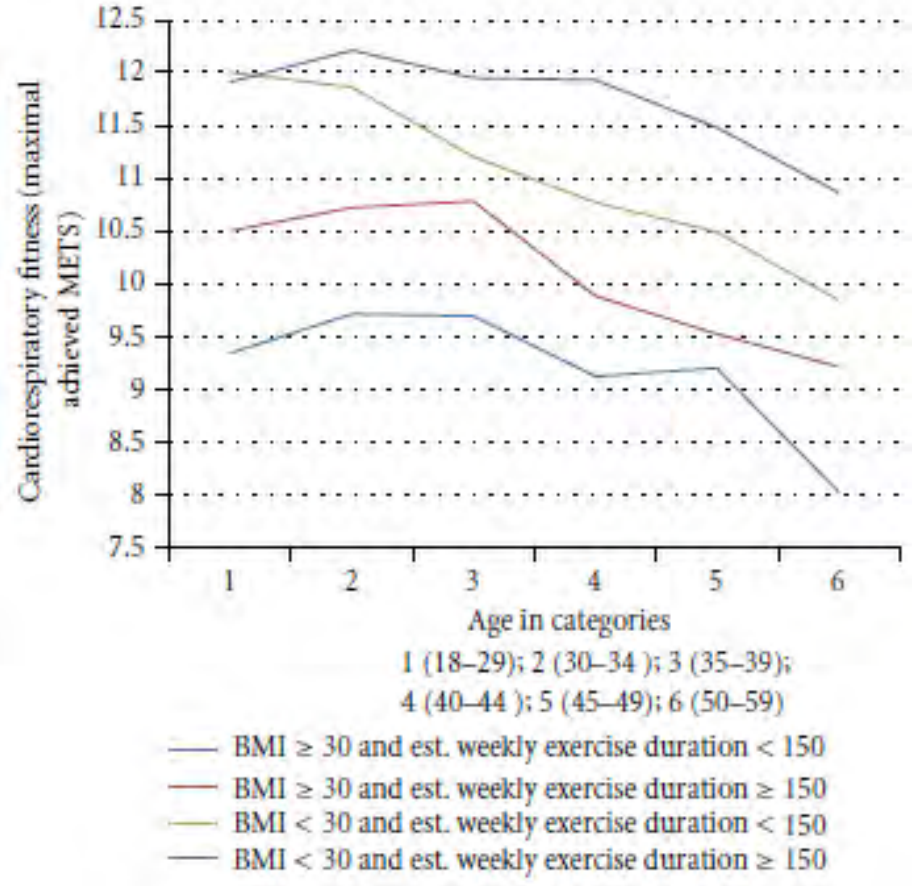


Bond CW, et al. *J Occup Environ Med*. 2022;64(2):123-130.

FIREFIGHTER HEALTH AND FITNESS

CRF and Obesity

- Cross-Sectional Analyses:
  - CRF declines with advancing age, BUT the decline is greatly attenuated among **less obese firefighters** AND more **physically active firefighters**



However, these changes don't even take years to occur…

Baur DM, et al. *J Obesity*. 2012;2012:710903.

FIREFIGHTER HEALTH AND FITNESS

CRF and Obesity

- Examined longitudinal changes in CRF and body composition among firefighter recruits:
  - W1 = beginning of their firefighter recruit training academy
  - W14 = end of their firefighter recruit training academy
  - W38 = end of their probationary period

Changes in Health and Fitness in Firefighter Recruits: An Observational Cohort Study

DAVID J. CORNELL[1], STACY L. GNACINSKI[1,2,3], BARBARA B. MEYER[2], and KYLE T. EBERSOLE[1]

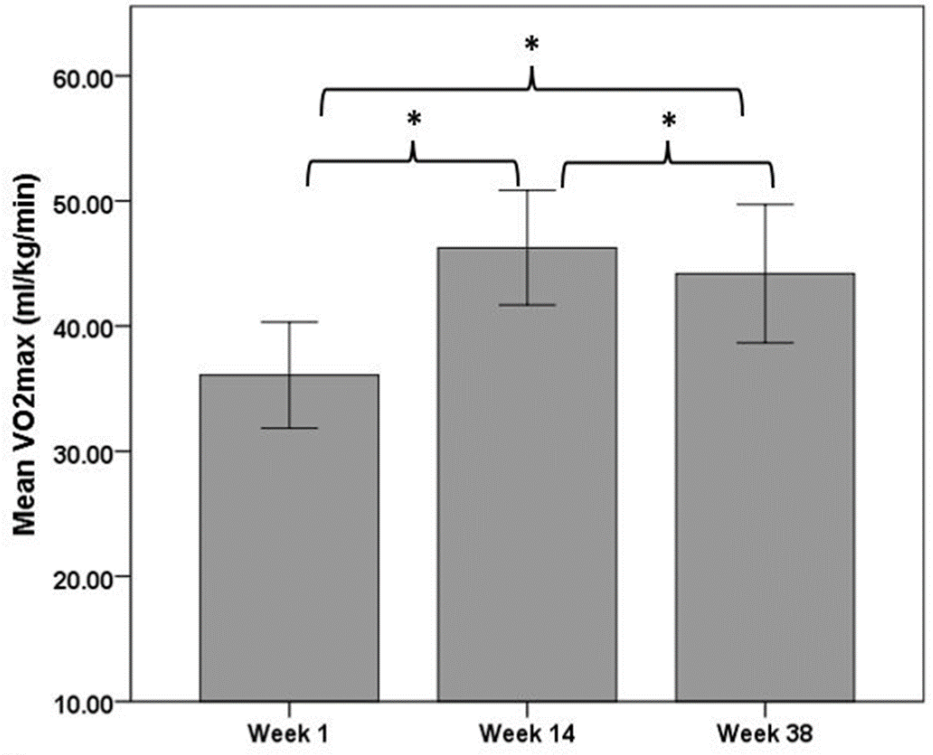
[1]Human Performance and Sport Physiology Laboratory, Integrative Health Care and Performance Unit, Department of Kinesiology, University of Wisconsin-Milwaukee, Milwaukee, WI; [2]Laboratory for Sport Psychology and Performance Excellence, Integrative Health Care and Performance Unit, Department of Kinesiology, University of Wisconsin-Milwaukee, Milwaukee, WI; and [3]Department of Health Sciences, College of Pharmacy and Health Sciences, Drake University, Des Moines, IA

Cornell DJ, et al. *Med Sci Sports Exerc*. 2017;49(11):2223-2233.

FIREFIGHTER HEALTH AND FITNESS

Cardiorespiratory Fitness (CRF)

- Significant changes in Aerobic Fitness over time
  ($F_{6,21}$ = 55.111, Λ = 0.060, P < 0.001)
  - Est. Rel. VO_2max (ml/kg/min)
    ($F_{2,52}$ = 105.325, P < 0.001)



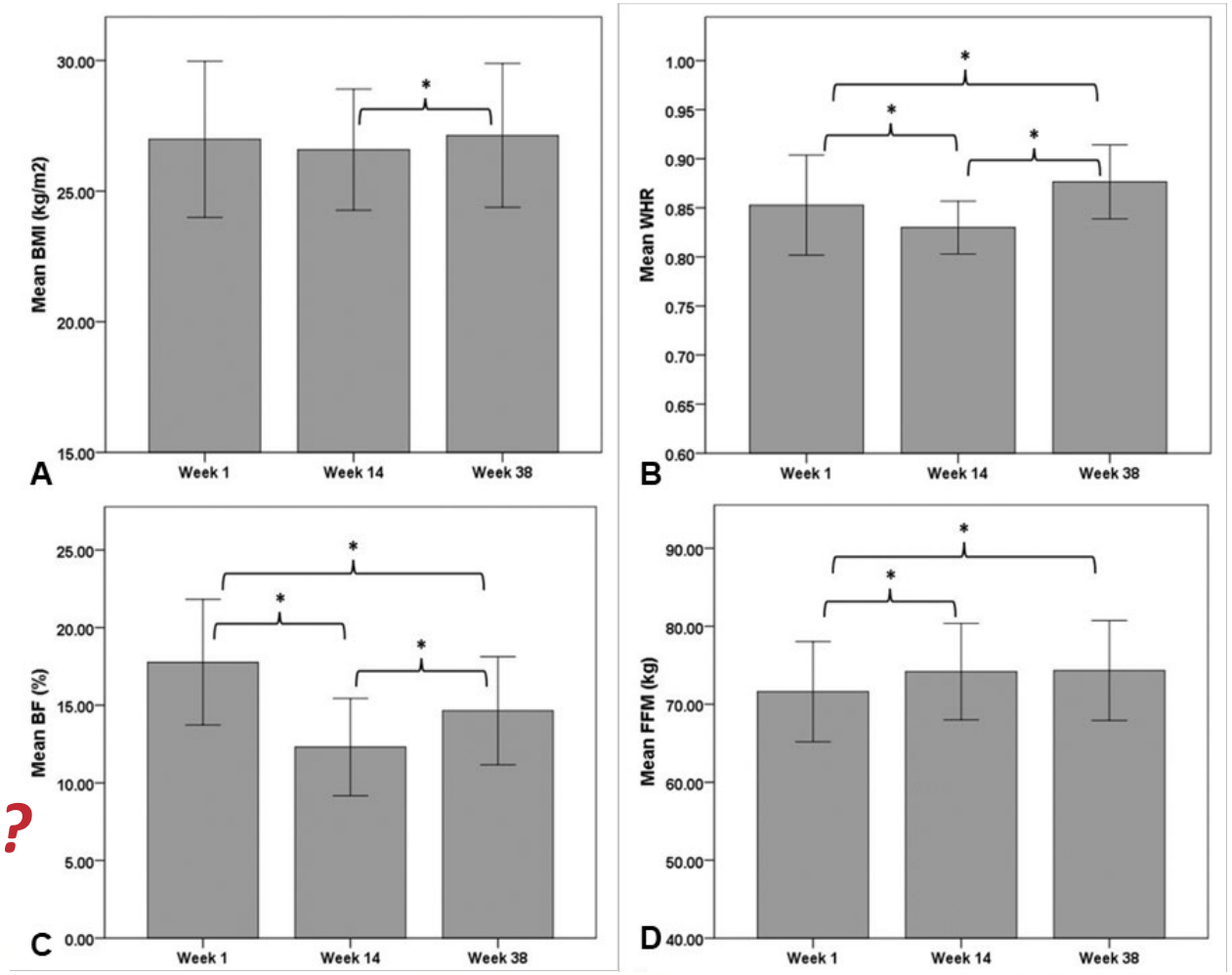
Adapted From:
Cornell DJ, et al. *Med Sci Sports Exerc*. 2017;49(11):2223-2233.

FIREFIGHTER HEALTH AND FITNESS

Obesity

- Significant changes in Body Composition over time
  ($F_{10,17}$ = 30.390, Λ = 0.053, P < 0.001)
  - A. BMI (kg/m^2)
    ($F_{2,52}$ = 4.906, P = 0.011)
  - B. WHR
    ($F_{2,52}$ = 19.012, P < 0.001)
  - C. Est. BF (%)
    ($F_{2,52}$ = 103.104, P < 0.001)
  - D. Est. Fat-Free Mass (kg)
    ($F_{2,52}$ = 24.276, P < 0.001)

What about changes in FMS scores??



Adapted From:
Cornell DJ, et al. *Med Sci Sports Exerc*. 2017;49(11):2223-2233.

FIREFIGHTER HEALTH AND FITNESS

Movement Quality

- Examined longitudinal changes in functional movement quality among firefighter recruits:
  - W1 = beginning of their firefighter recruit training academy
  - W14 = end of their firefighter recruit training academy
  - W38 = end of their probationary period

Article

Functional Movement Quality of Firefighter Recruits: Longitudinal Changes from the Academy to Active-Duty Status

David J. Cornell [1,2,3,*], Stacy L. Gnacinski [4] and Kyle T. Ebersole [5,6]

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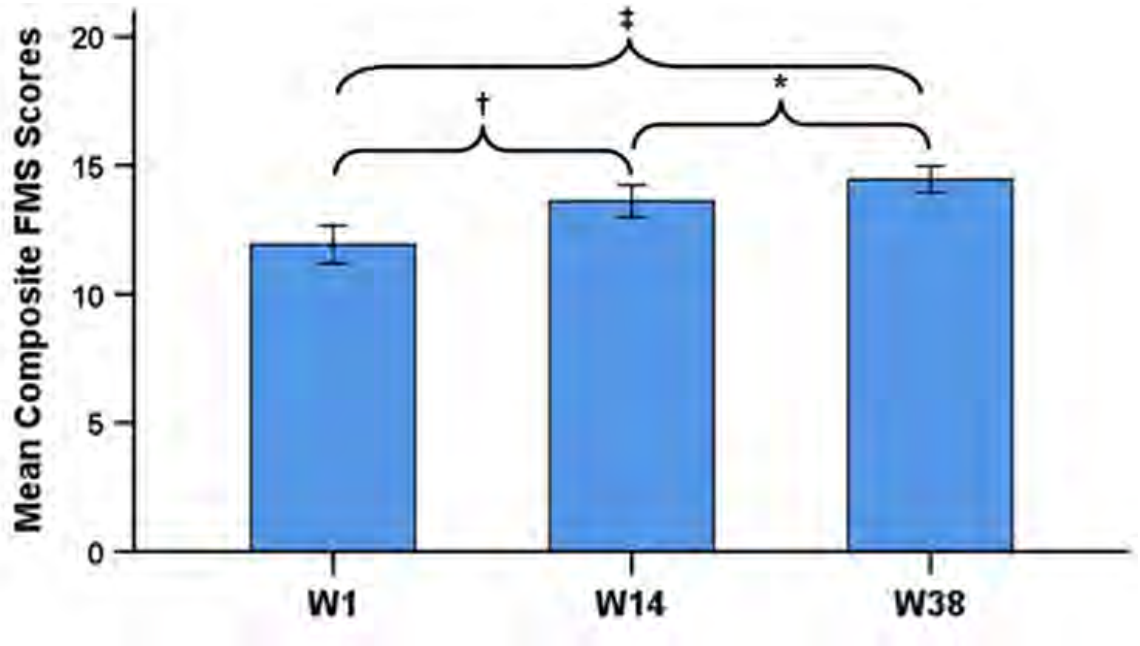
Cornell DJ, et al. *Int J Environ Res Public Health*. 2021;18(7):3656.

FIREFIGHTER HEALTH AND FITNESS

Movement Quality

- After adjusting for changes in BMI across time:
  - Significant INCREASES in Composite FMS scores were identified across time – **including AFTER completion of the training academy!**
    ($F_{1,25}$ = 54.09, P < 0.001)
    - W1: 11.92 ± 1.83*
    - W14: 13.62 ± 1.55†
    - W38: 14.46 ± 1.27‡
    - Overall Change: **+2.54**



Cornell DJ, et al. *Int J Environ Res Public Health*. 2021;18(7):3656.

FIREFIGHTER HEALTH AND FITNESS

Movement Quality

- Changes appear to be driven by improvements in:
  - Hurdle Step
  - In-Line Lunge
  - Trunk Stability Push-Up
  - Rotary Stability

Table 2. Changes in FMS sub-test scores across time, mean (SD).

FMS Sub-Test	W1	W14	W38
Deep Squat	1.28 (0.59)	1.59 (0.58)	1.25 (0.49)
Hurdle Step	1.38 (0.50)	1.46 (0.58)	2.0 (0.00) *, ‡
In-Line Lunge	1.50 (0.58)	1.62 (0.57)	1.96 (0.45) *, ‡
Shoulder Mobility	1.92 (0.86)	2.12 (0.71)	2.13 (0.68)
Active Straight Leg Raise	2.23 (0.59)	2.19 (0.49)	2.38 (0.58)
Trunk Stability Push-Up	2.42 (0.76)	2.73 (0.45)	2.88 (0.33) ‡
Rotary Stability	1.08 (0.27)	2.00 (0.00) †	1.73 (0.45) *, §

FMS, Functional Movement Screen; W1, beginning of the training academy; W14, end of the training academy; W38, end of the probationary period. † W1 < W14; * W14 < W38; § W14 > W38; ‡ W1 < W38, respectively ($p < 0.05$).

- The combined physical training associated with the training academy and active-duty work was capable of improving movement quality
  - Possible that improvements movement competency during single-leg tasks, as well as core strength and stability, facilitated these increased FMS scores??

Cornell DJ, et al. *Int J Environ Res Public Health*. 2021;18(7):3656.

FIREFIGHTER MSKI RISK

Summary

- **Movement Quality:**
  - Movement quality might not be a great predictor of MSKI risk, nor a stable measure of movement quality, among firefighters
    - At least if using the FMS…
- **CRF and Obesity:**
  - 1 MET of improvement in aerobic capacity (or 3.5 ml/kg/min) may be able to reduce risk of MSKI by 14% among firefighters (Poplin et al., 2014)
    - But only 36% of firefighters achieve recommended amount of aerobic exercise & resistance exercise (Storer et al., 2014)
  - 1 unit ↑ in BMI resulted 9% ↑ in injury-related missed workdays (Poston et al., 2011)
  - Both measures change in a negative fashion over the career of firefighters
    - **AND THIS CHANGE HAPPENS QUICKLY!**

FIREFIGHTER MSKI RISK

Summary

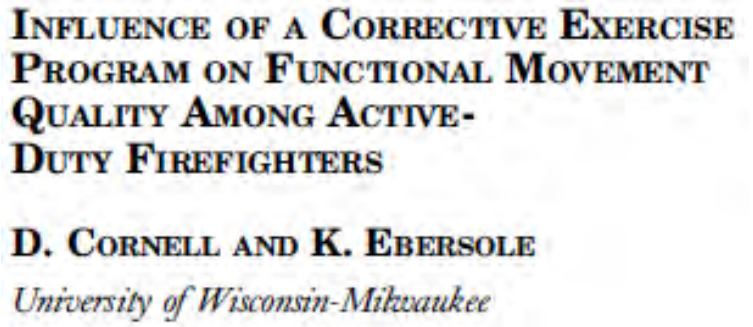
- However, to meet the essential occupational demands, firefighters must still safely and effectively perform numerous functional movements, ***including a squat***
  (*NFPA 1582: Standard on Comprehensive Occupational Medical Program for Fire Departments*; 2018)
  - There's also some evidence FMS scores *may* be related to occupational performance among other tactical athletes?
    (Bock et al., 2016; Glass & Ross, 2015; Glass et al., 2017)
- Further, conducting movement screening may still help identify specific musculoskeletal and/or neuromuscular coordination deficiencies that require attention (Cook, 2010)

So what are some interventions that have improved the movement quality of firefighters??

CORRECTIVE EXERCISE PROGRAMMING

Program #1: General

- If we know what some of the common injuries and movement impairments are among firefighters, can't we just prescribe a general corrective exercise program for firefighters to complete??
  - Think like the *Throwers' 10 Program* for overhead athletes…
    (Wilk et al., 2004; 2011)
  - To test this hypothesis, we created *The Firefighter-10*:
    - 10 Mobility Exercises
    - 10 Activation Exercises
    - 1 Integration Exercise


INFLUENCE OF A CORRECTIVE EXERCISE PROGRAM ON FUNCTIONAL MOVEMENT QUALITY AMONG ACTIVE-DUTY FIREFIGHTERS

D. CORNELL AND K. EBERSOLE

University of Wisconsin-Milwaukee

Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

MOBILITY EXERCISES

1. Donkey Kickbacks & Fire Hydrant

2. Thread the Needle

3. Cat / Cow

4. Spiderman

5. High-Handle / Door Stretch

6. Chest Doorway Stretch

7. Triceps Reach Backs

8. Forearm Flexor / Extensor Stretch

9. Neck / Upper Trapezius Stretch

10. Gastrocnemius / Soleus Stretch

Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

1. Supine Bridge

2. Bird Dog

6. Lat Pull Downs

ACTIVATION EXERCISES

3. Clam Shells

4. Standing Rows

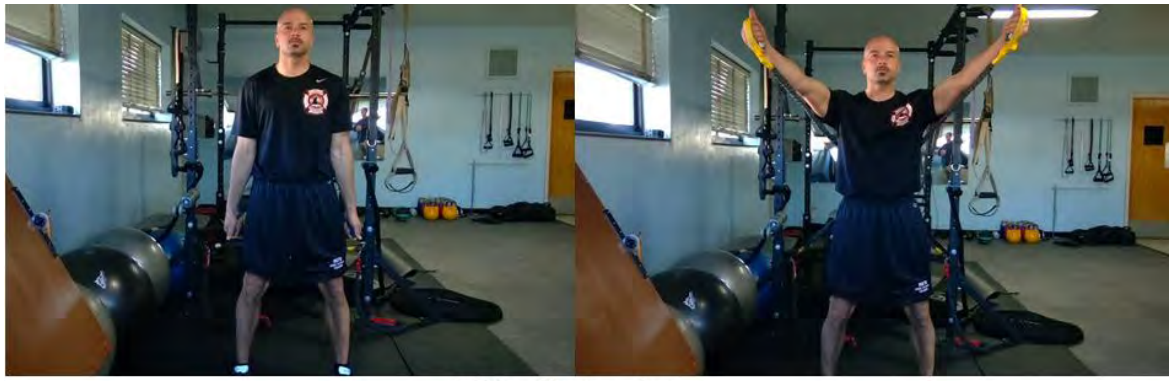
5. Reverse Flys

7. 90/90

Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

ACTIVATION EXERCISES (cont)



8. Shoulder Scaption

9. Shoulder Incline Press-Plus

10. Shoulder Flexion "Victory"

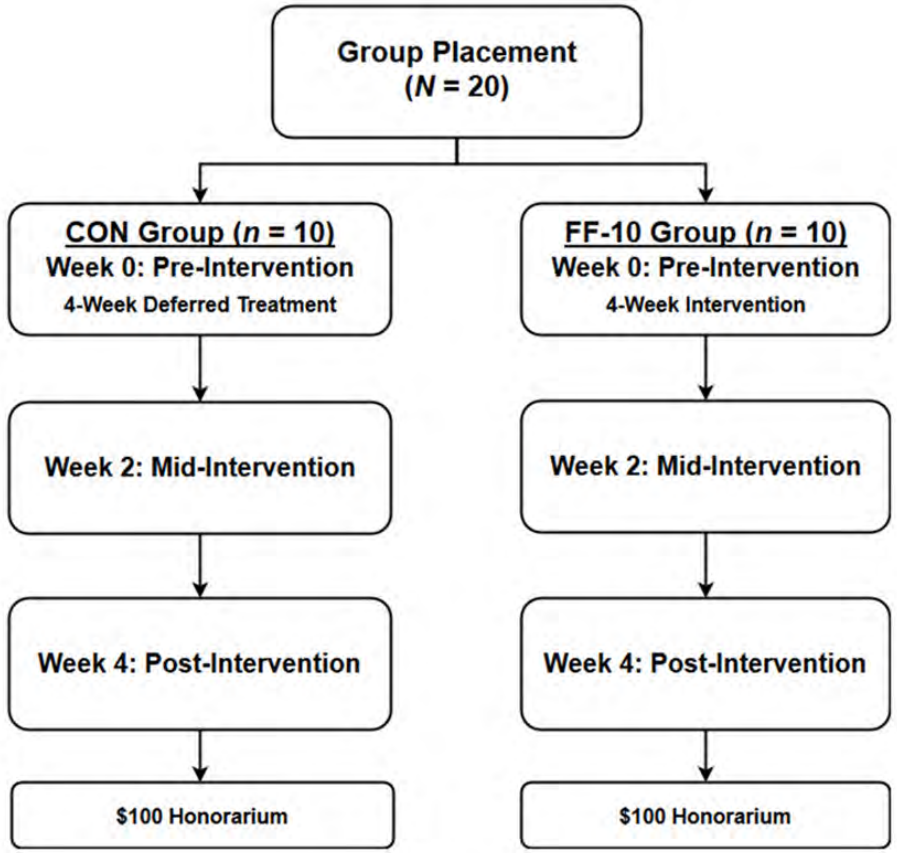
11. Single Leg Squat & Row

Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

Program #1: General

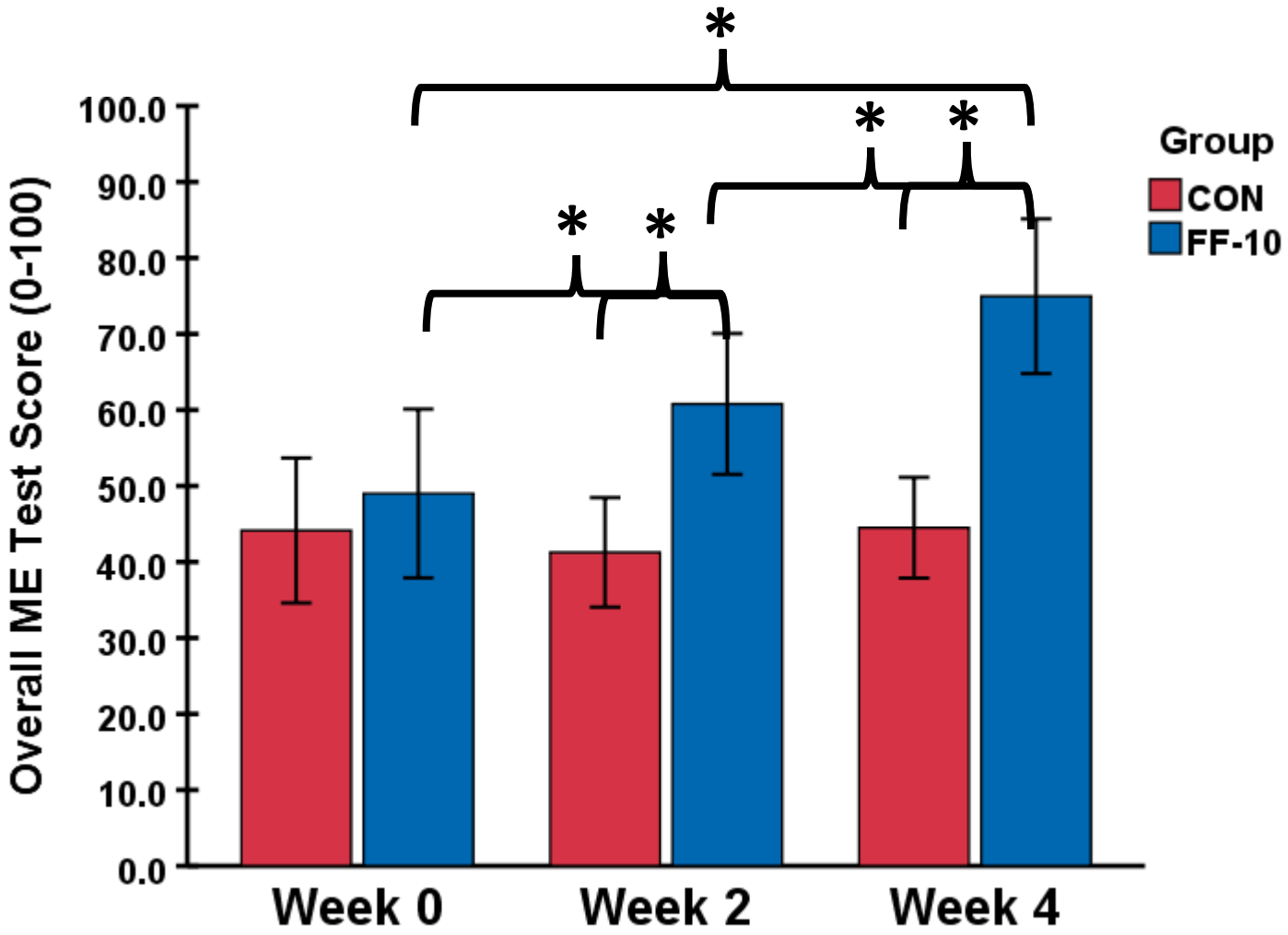
- Quasi-Experimental Design
  - Control (CON) Group: completed other exercise programming as usual
  - Experimental (FF-10) Group: completed *The Firefighter-10* programming 3-4 days per week
    - An ATC provided instruction for first session and answered questions thereafter
- Movement Quality at Weeks 0, 2, and 4
  - Overall ME Test Scores (0 – 100)



Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

- Significant Group × Time Interaction
  ($F_{2,36}$ = 32.630, P < 0.001)
- No Significant Changes in CON Group
  ($F_{2,18}$ = 1.062, P = 0.367)
- Significant Increases in FF-10 Group
  ($F_{2,18}$ = 81.626, P < 0.001)
  - Week 2
    (P < 0.001, g = 2.25)
    (+11.78; P < 0.001)
  - Week 4
    (P < 0.001, g = 3.40)
    (+14.17; P < 0.001)
  - Week 0 to 4
    (**+25.95**; P < 0.001)



Cornell D, Ebersole K. *J Strength Cond Res*. 2017;31(Suppl 1):S90-S91.

CORRECTIVE EXERCISE PROGRAMMING

Program #1: General

- Significant improvements in functional movement quality among active-duty firefighter can be elicited via *The Firefighter-10* program
- These improvements also represent a true "real change" in functional movement quality as they exceed the $MDC_{95\%}$
  (Cornell & Ebersole, 2018)
  - **+25.95 > 12.68**
- However, not all fire departments will have access to an ATC to provide instruction
- In addition, *The Firefighter-10* is a generic program, and isn't tailored to the specific needs or movement compensations that a firefighter is presenting with…

CORRECTIVE EXERCISE PROGRAMMING

Program #2: Specific

- Corrective exercise programming can be generated by the FMS Pro software based on their FMS sub-test scores to address:
  - Mobility
  - Static Motor Control
  - Dynamic Motor Control
  - Strength

Table 2
Example corrective exercises based on FMS scores

Client A		Client B	
Corrective Exercise	Sets/Reps or Duration	Corrective Exercises	Sets/Reps or Duration
Single leg lowering 2	2 sets/10 reps	Hamstring foam roller	1 set, 60 sec
Chop from half-kneeling with cable bar	2 sets/10 reps	Calf muscle foam roller	1 set, 60 sec
Brettzel	1 min, 20 sec	Quadriceps foam roller	1 set, 60 sec
Plank diagonals	2 sets, 2 min, 20 sec	Single leg lowering 1	3 sets, 30 sec each
D1 Extension from half-kneeling	2 sets, 12 reps	Hip flexor stretch from half kneeling with dowel	2 sets, 3 reps, 7 sec/rep
		Latissimus dorsi foam roller	1 set, 60 sec
		Mid-back foam roller	1 set, 60 sec
		T-spine rotation with rib grab	2 sets, 3 reps, 5 sec/rep
		Mountain climber from incline	3 sets, 15 reps
		T-spine rotation with reach	3 sets, 1 rep, 5 sec/rep

Stanek JM, et al. *Work*. 2017;56(2):213-220.

CORRECTIVE EXERCISE PROGRAMMING

Program #2: Specific

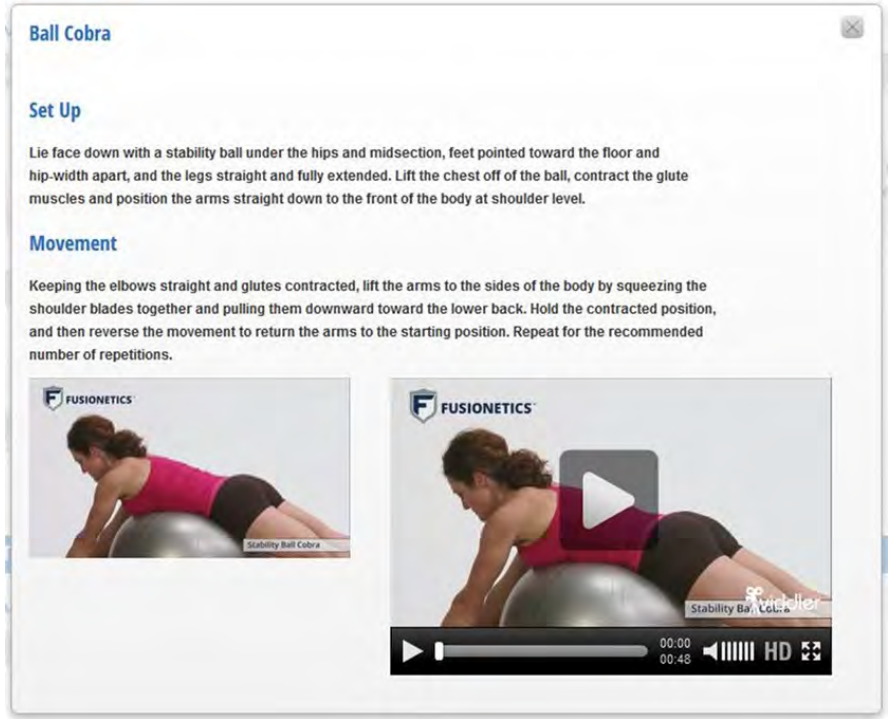
- All firefighters completed 8-week intervention
  - **NO CONTROL GROUP**
  - No guidance from a practitioner (e.g., S&C coach, ATC, etc.)
- Significant improvements in Pre- to Post-Composite FMS Scores:
  (U = 984.5, z = –3.43, P = 0.001)
  - Pre: 12.09 ± 2.75 vs. Post: 13.66 ± 2.28
    - However, researchers did not control for Age or Obesity-level
    - And this +1.57 improvement may not be practically meaningful, as it did not exceed the 2.50 $MDC_{95\%}$ previously reported in tactical athlete populations
      (Teyhen et al., 2012)

Stanek JM, et al. *Work*. 2017;56(2):213-220.

CORRECTIVE EXERCISE PROGRAMMING

Program #3: Specific

- Corrective exercise programming can also be generated by the Fusionetics™ Human Performance System based on individual movement compensations
  - Inhibit & Lengthen
    - Foam Rolling, Stretching, and Mobility
  - Activate
    - Isolated Strengthening
  - Integrate
    - Dynamic Exercise



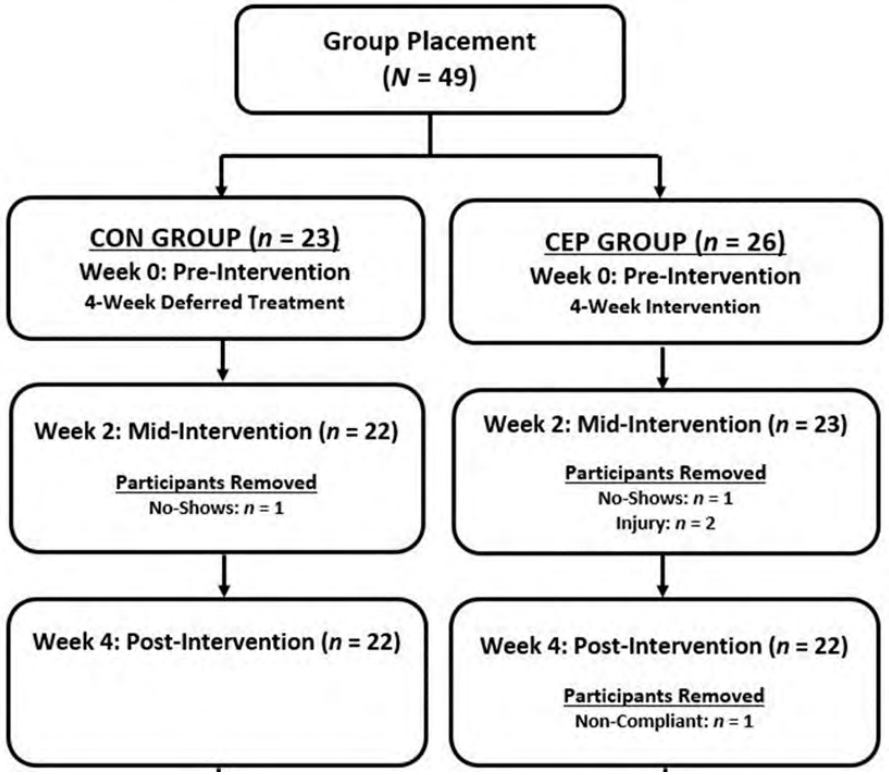
Cornell DJ, et al. *J Strength Con Res*. 2021;35(4):e92.

Supported By: NSCA Foundation

CORRECTIVE EXERCISE PROGRAMMING

Program #3: Specific

- Quasi-Experimental Design
  - Counterbalanced into groups based on Week 0 Overall ME Test scores
  - Control (CON) Group: completed other exercise programming as usual
  - Experimental (CEP) Group: completed Fusionetics programming 3-4 days per week
    - No additional instruction was provided
- Movement Quality at Weeks 0, 2, and 4
  - Overall ME Test Scores (0 – 100)

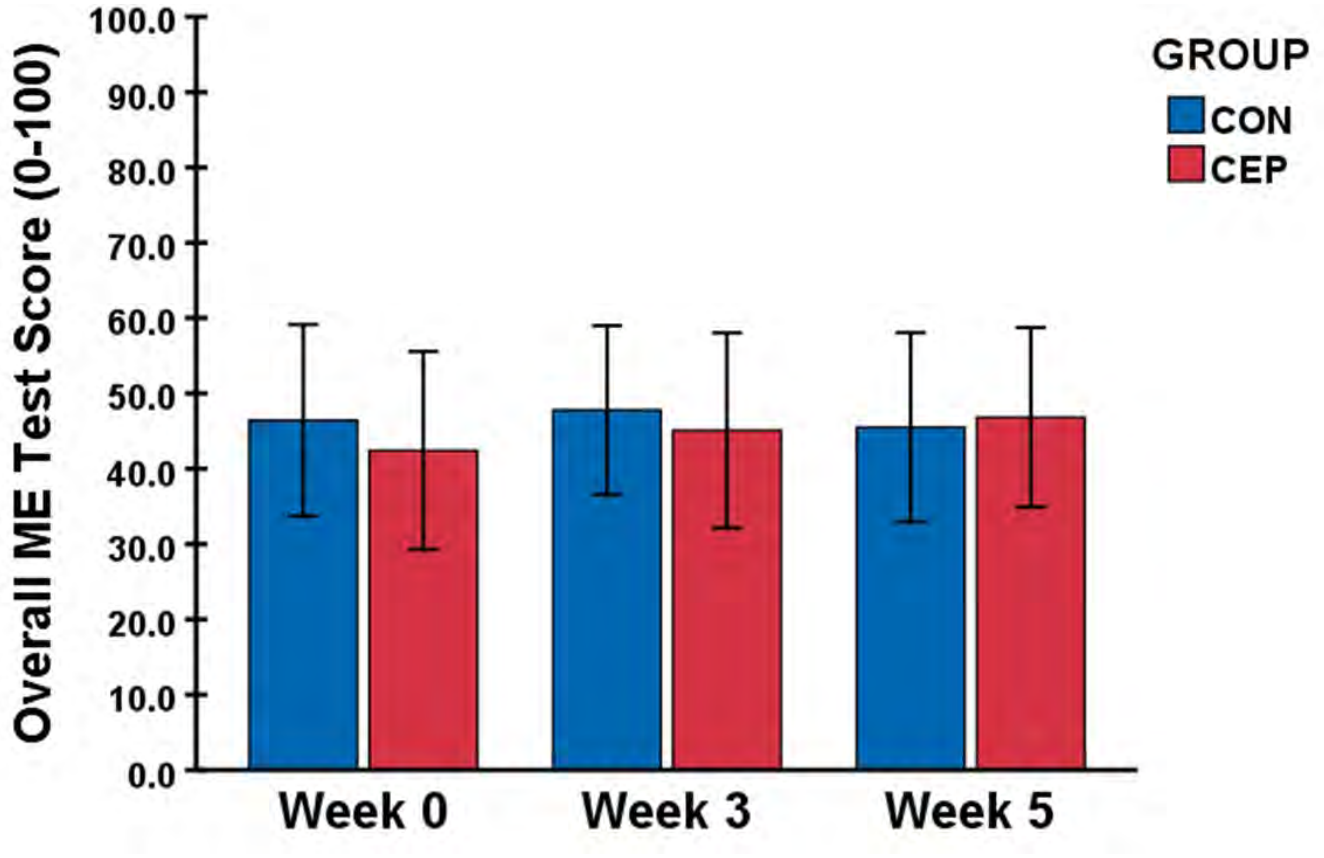


Supported By: NSCA Foundation

Cornell DJ, et al. *J Strength Cond Res*. 2021;35(4):e92.

CORRECTIVE EXERCISE PROGRAMMING

- No Significant Group × Time Interaction
  ($F_{2,84}$ = 1.550, P = 0.218)
- No Significant Main Effect of Time
  ($F_{2,84}$ = 0.982, P = 0.379)
  - Including within each Group:
    - CON ($F_{2,42}$ = 0.449, P = 0.641)
    - CEP ($F_{2,42}$ = 2.416, P = 0.102)



Supported By: NSCA Foundation

Cornell DJ, et al. *J Strength Cond Res*. 2021;35(4):e92.

CORRECTIVE EXERCISE PROGRAMMING

Summary

- Taken together, significant improvements in functional movement quality among active-duty firefighters can be elicited in a short timeframe (2–4 weeks)
  - *Theoretically* placing these individuals at a lower risk for future MSKI
- However, the delivery of self-guided interventions through online programming may not create the desired significant improvements
  - ***Thus, the utilization of initial hands-on instruction by a qualified practitioner appears to be vital to program success***
  - ***In other words, PTs, ATCs, S&C Coaches, etc. need to be involved!!***

ACKNOWLEDGEMENTS

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- Health Assessment Laboratory (UMass Lowell)

Fire Department Affiliations / Collaborators

- Milwaukee Fire Department
- North Shore Fire Department
- Greenfield Fire Department
- Denver Fire Department
- Lowell Fire Department

THANK YOU

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Musculoskeletal Injury Risk Among Firefighters: Movement Quality Isn't the Only Factor

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