Relationship of Body Composition and Physical Fitness with Injury Risks in the Military

Joseph Pierce, Ph.D.

Defense Health Agency Public Health, Injury Prevention Branch

PMO 655 Current Issues in Safety and Injury Prevention, January 2025

Disclaimer

The views expressed in this presentation are those of the author(s) and do not necessarily reflect the official policy of the Department of Defense, Defense Health Agency, or the U.S. Government.

The mention of any non-federal entity and/or its products is for informational purposes only, and is not to be construed or interpreted, in any manner, as federal endorsement of that non-federal entity or its products.

Talk Overview

- Background on body composition and physical fitness in the U.S. Military:
  - Why are these factors important to the Military/Army?
  - How does the Army assess these two factors?
- Describe trends in body composition and physical fitness (or performance) in the Military.
  - How do these two factors interact with each other?
- Describe major injury types (acute and overuse musculoskeletal injuries) observed in the Army.
- Learn about how body composition and fitness influence injury risk:
  - Independent relationships
  - Interactions between these two factors

Department of Defense Instruction (DoDI) 1308.03

DoD Instruction 1308.03

DoD Physical Fitness/Body Composition Program

Originating Component:	Office of the Under Secretary of Defense for Personnel and Readiness
Effective:	March 10, 2022
Releasability:	Cleared for public release. Available on the Directives Division Website at https://www.esd.whs.mil/DD/.
Reissues and Cancels:	DoD Instruction 1308.3, "DoD Physical Fitness and Body Fat Programs Procedures," November 5, 2002
Incorporates and Cancels:	DoD Directive 1308.1, "DoD Physical Fitness and Body Fat Program," June 30, 2004 DoD Directive 1308.2, "Joint DoD Committee on Fitness," February 4, 2005

DoDI 1308.03 Main Points

- **Establishes policy, assigns responsibilities, and prescribes procedures governing Service physical fitness/body composition standards for the Military Services.**

- The Military Services will design, implement, supervise, and **tailor physical fitness/body composition programs to suit the particular needs and mission of their respective Military Service, consistent with established scientific principles of physical training**.

- When using weight-for-height screening tables:
  - **Allowable body mass index (BMI) equivalents**: **Men: 19 – 27.5 kg/m^2; Women: 19 – 26 kg/m^2**

- When using body fat calculations:
  - **Allowable body fat**: **Men: 18 – 26%; Women: 26 – 36%**

Major Updates for DoDI 1308.03

- Body composition may be evaluated using either **body fat calculations, waist-to-height ratio, abdominal circumference, height-weight screening, or any combination thereof**.

- Service determination of **body composition relying on abdominal or waist circumference will use evidence-based reference indexes corrected for height that are not biased against short or tall Service members.**

- Scientific data may be used to **further adjust body fat standards within the DoD acceptable range, develop screening procedures, or to prescribe procedures compensating for high levels of fitness.**

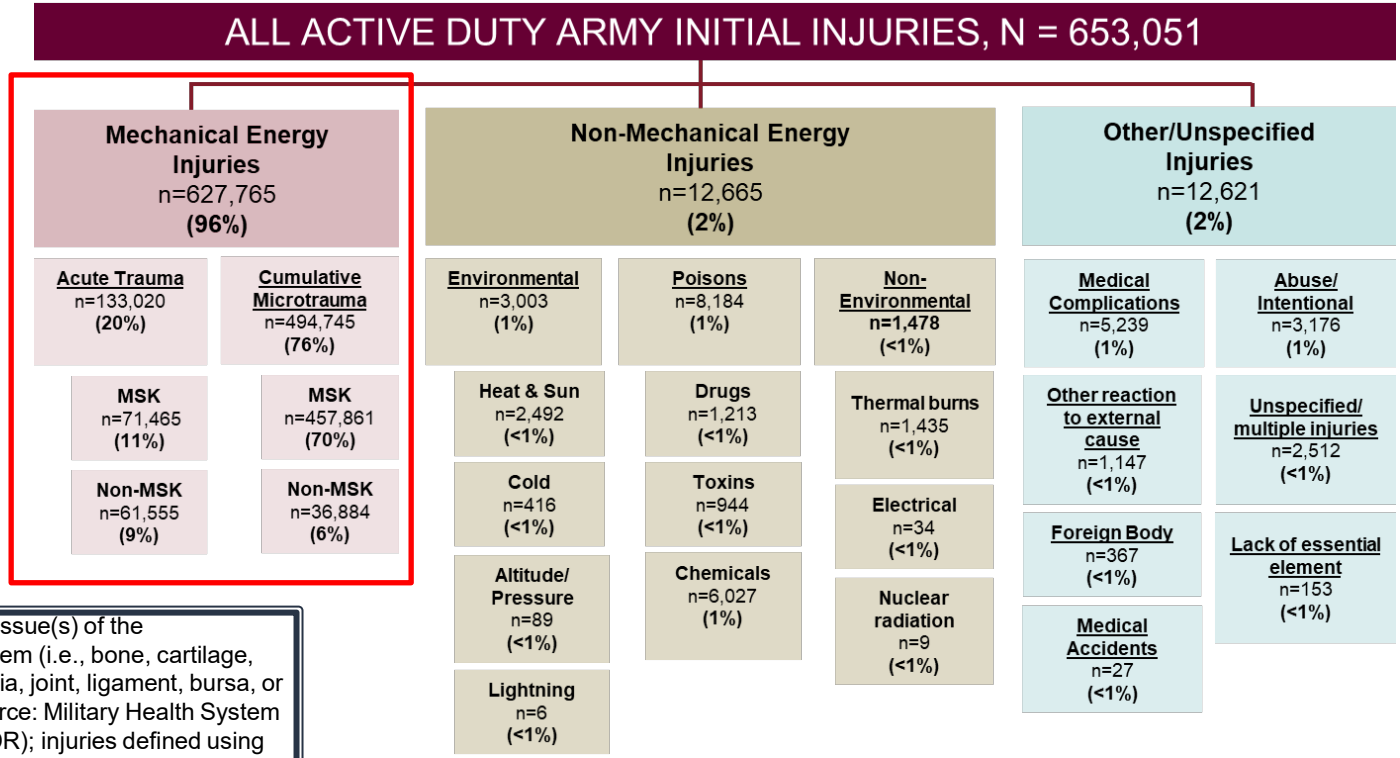
- The Military Services will **submit an "Annual Service Physical Fitness/Body Composition Report"** to the ASD(HA) and the ASD(M&RA), no later than June 1 each year.
  - Report takes into account physical fitness, body composition, and MSK injuries

Injury Definition Added to Help Guide DoDI Reporting

- **MSK injuries will be identified using current International Classification of Diseases taxonomically-defined injury diagnoses categories that separate acute traumatic injuries and cumulative microtraumatic (overuse) injuries.**

TERM	DEFINITION
injury	Damage caused by the transfer of an external mechanical, chemical, electrical, or radiological energy to the body. Most injuries are from mechanical energy transfer that results from either an abrupt high intensity force (acute traumatic injury) or a repetitive lower intensity force (cumulative microtraumatic injury, often referred to as an overuse injury). Most military injuries are to the MSK system and the majority of those are cumulative microtraumatic injuries attributed to physical training activities.

Taxonomy of U.S. Army Soldier Incident Injuries (2021)



*MSK = damage to tissue(s) of the musculoskeletal system (i.e., bone, cartilage, muscle, tendon, fascia, joint, ligament, bursa, or synovium); Data source: Military Health System Data Repository (MDR); injuries defined using the DCPH-A Taxonomy of Injuries

Annual Injury Surveillance Report 2021 Summary, TIP NO. 12-123-0123.

Military Body Composition

Body Composition Modeling and Assessment Methods

- Simplest two-compartment model:
  - Fat-free mass
  - Fat mass

- Most common assessment methods:
  - BMI (adiposity estimation only: normal weight/overweight/obese)
  - Tape testing/circumference measurements (e.g., abdominal circumference, waist:hip ratio, etc.)
  - Skinfolds
  - Bioelectrical impedance analysis (BIA)
  - Air displacement plethysmography (BodPod)
  - Underwater weighing/hydrodensitometry
  - Dual-energy x-ray absorptiometry (DEXA) (Gold standard)

Simple/inexpensive

Complex/expensive
(most accurate)

BMI Categories and Health Risk

BMI range (kg/m^2)	Weight Classification
< 18.5	Underweight
18.5–24.9	Normal weight
25.0–29.9	Overweight
≥ 30.0	Obese

All cause mortality (RR) among those who never smoked

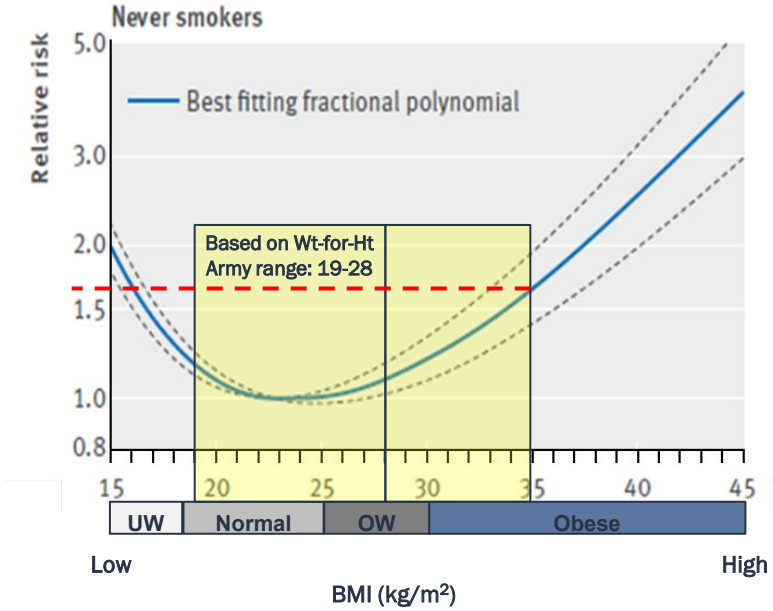
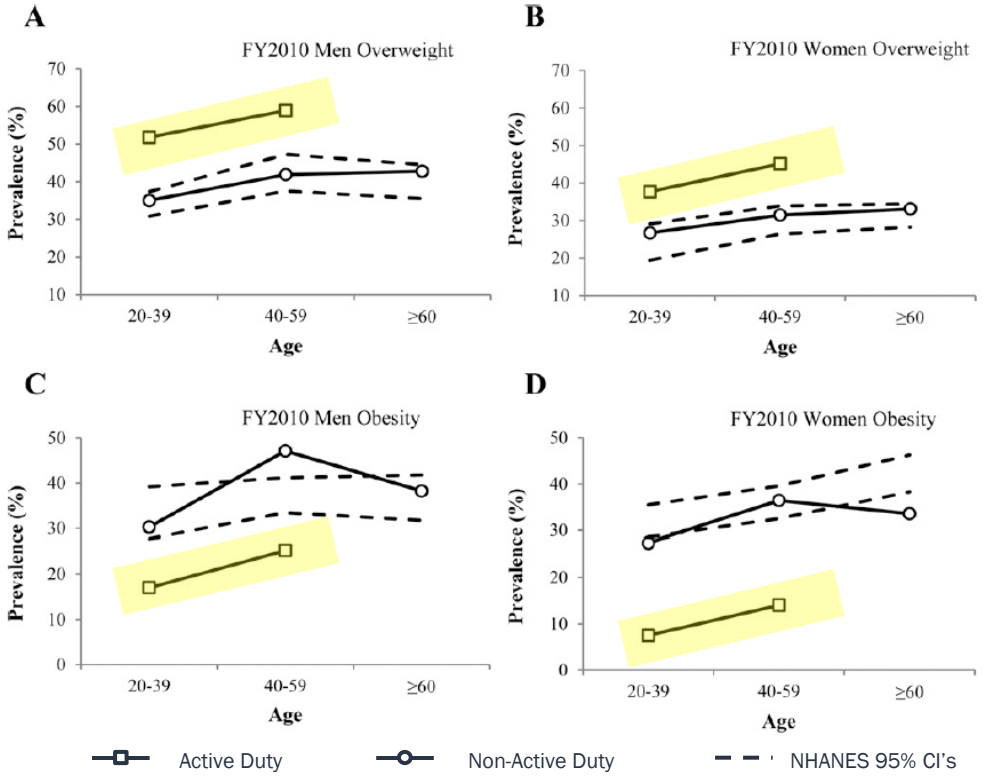


Figure adapted from: Aune, D., et al., BMJ, 353 (2156): 1-17, 2016

Military Trends in Overweight and Obesity Prevalence Against General U.S. Population (2010)



Higher Overweight prevalence in AD Men and Women vs. U.S. pop.

Lower Obesity prevalence in AD Men and Women vs. U.S. pop.

Eilerman et al. 2014. *Mil Med* 179(5):462

Body Composition Standards Vary Among Service Branches

Do we want pretty or healthy?

Military Appearance — Combat Readiness — Health

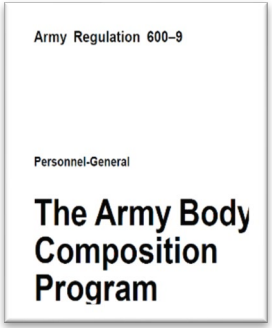
More Strict

Marine Corps Standards	Healthy Active Young Recruits	NHLBI Guideline Equivalents
<18% BF (men) <26% BF (women)	<20% BF (men) <30% BF (women)	<~26% BF (men) <~38% BF (women)

More Liberal

Friedl K. 2012. *J Strength Cond Res* 26(7):S87–S100.

Army Body Composition Program (ABCP): AR 600-9



Soldier's height and weight measured every 6 months

Meets weight-for-height (Body Mass Index (BMI)) equivalent standard
no further action

Exceeds weight-for-height standard: body fat percent determined using circumference-based tape test
Men: neck and abdomen
Women: neck, waist, and hips

**Currently considering updated assessment possibilities with fewer circ. measurements

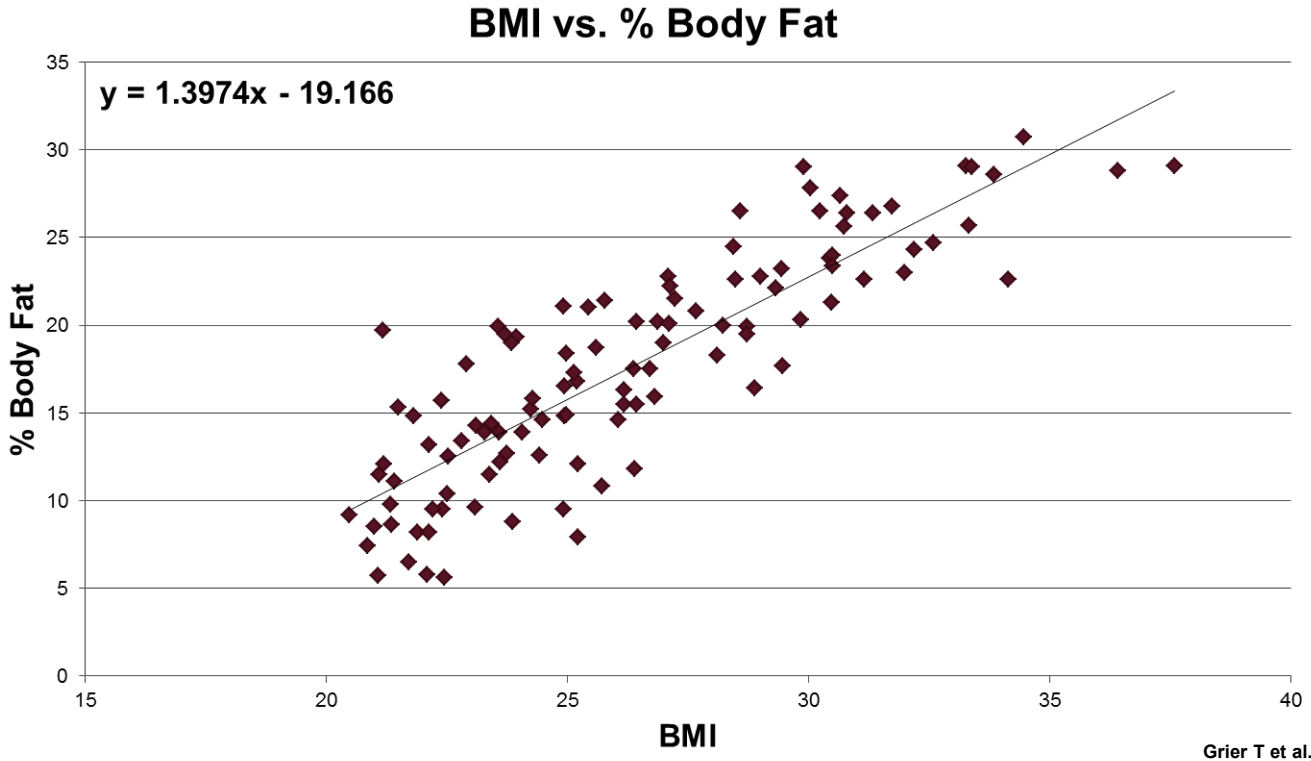
Meets body fat standards,
no further action

Exceeds body fat standards: Soldier flagged and enrolled in the unit ABCP

Department of the Army. 2019. Regulation 600-9.

Correlation Between BMI and %Body Fat (DEXA)

r=0.86
R^2=0.74



Grier T et al. 2015. *Prev Med Rep* 2:483–487.

Relationships Between BMI and Body Composition

As BMI increased (particularly ≥ 27.5 kg/m^2), Soldiers exhibited greater increases in body fat mass than lean body mass.

BMI (kg/m^2)	n	Lean Body Mass (kg)*	Difference calculated from total body weight	Fat Mass (kg)*	Difference calculated from total body weight	Body Fat (%)*
< 25	49	58.1 ± 6.2	----	9.1 ± 3.3	----	12.7 ± 4.1 %
25 – 27.49	23	63.6 ± 4.7	+5.5 kg (7%)	14.1 ± 3.7	+5 kg (6%)	17.2 ± 3.9 %
27.5 – 29.9	15	65.6 ± 4.5	+7.5 kg (9%)	19.1 ± 3.0	+10 kg (12%)	21.6 ± 3.4 %
30+	23	70.2 ± 5.6	+12.1 kg (13%)	26.1 ± 3.9	+17 kg (18%)	25.2 ± 3.5 %

***Lean body mass, fat mass, and % body fat assessed by DEXA**

Grier T et al. 2015. *Prev Med Rep* 2:483–487.

Waist Circumference Without Height Adjustment Problems

	Waist Circ. (cm)		Body fat (%)		BMI (kg/m²)	
Height Group Stratification	Men	Women	Men	Women	Men	Woman
Group 1 **Men: 162.6 – 167.6 cm (n=95)** **Women: 149.9 – 154.9 cm (n=22)**	84.3 ± 8.4[a]	78.5 ± 8.4 [a]	21.0 ± 4.3	33.2 ± 4.9	26.8 ± 3.6	25.9 ± 3.5
Group 2 **Men: 170.2 – 175.3 cm (n=280)** **Women: 157.5 – 162.6 cm (n=71)**	87.4 ± 8.9 [b]	80.0 ± 8.4 [a]	20.8 ± 4.6	32.5 ± 4.8	26.8 ± 3.6	25.3 ± 3.4
Group 3 **Men: 177.8 – 182.9 cm (n=270)** **Women: 165.1 – 170.2 cm (n=55)**	88.9 ± 8.9[b,c]	81.4 ± 9.6 [a,c]	20.6 ± 4.5	32.6 ± 5.5	26.6 ± 3.7	25.4 ± 4.1
Group 4 **Men: 185.4 – 190.5 cm (n=99)** **Women: 172.7 – 180.3 cm (n=17)**	92.7 ± 9.6 [d]	86.1 ± 9.0 [b,c]	20.8 ± 4.5	33.5 ± 4.6	26.9 ± 3.8	25.9 ± 3.7
ANOVA p-value	**0.001***	**0.043***	0.716	0.858	0.747	0.883

Waist circ. increased with increasing height, without corresponding changes in body fat (%) or BMI.

A waist circumference standard, uncorrected for height, is biased against taller individuals and should not be used as a body composition standard.

Unclassified data observations from paper in prep

Military Physical Fitness

Army Physical Fitness Test (APFT)

- Established since early 1980s
- 3-event test administered every 6 months that assessed health-based fitness attributes:
  - Muscular Endurance
    - Push-ups in 2 minutes
    - Sit-ups in 2 minutes
  - Cardiorespiratory Endurance
    - Timed 2-Mile Run
- Raw performance for each event (repetitions, time) converted into a sex- and age-adjusted (5-yr age groups) score
  - Passing: at least 60 points on each event, 180 total points
  - Each event has maximum 100 points
- Disadvantages:
  - Not specifically tied to combat-related fitness attributes
  - No basis for discriminating occupational fitness

DVIDS: 4472595

DVIDS: 170506-A-ZU930-006A

DVIDS: 5383058

Interactions Between Body Composition and Physical Fitness

- Trade-offs exist between body composition and different domains of physical fitness or performance:
  - **Moving one's own body mass through space**
    - Advantage to have lighter body mass, lower BMI/body fat
    - Ex: Distance runs, sprints, agility drills, etc.
  - **Moving an external mass through space**
    - Advantage to have more body mass and lean mass, higher BMI/body fat
    - Ex: Deadlifts, bench press, medicine ball power throw, etc.

Average APFT Points by Passing vs. Failing ABCP Screening Standards

ABCP = Army Body Composition Program

	Pass ABCP Screening Standards Men (n=183); Women (n=30)	Fail ABCP Screening Standards Men (n=92); Women (n=16)	p-value
APFT Push-ups			
Men	89.5 ± 11.5	88.0 ± 11.1	0.30
Women	93.6 ± 9.4	**85.4 ± 14.1 ***	**0.049**
APFT Sit-ups			
Men	85.9 ± 12.1	85.2 ± 12.7	0.67
Women	85.9 ± 13.3	**73.8 ± 9.8 ***	**<0.01**
APFT Two-mile Run			
Men	84.4 ± 12.5	**78.2 ± 16.2 ***	**<0.01**
Women	90.5 ± 9.8	**80.4 ± 15.1 ***	**0.03**
APFT Total Points			
Men	259.8 ± 27.8	**251.4 ± 30.8 ***	**0.03**
Women	270.0 ± 24.0	**239.6 ± 31.4 ***	**<0.01**

Data are sex- and age- adjusted APFT points (mean ± SD); *P ≤ 0.05 vs. Pass ABCP Screening Standards Group

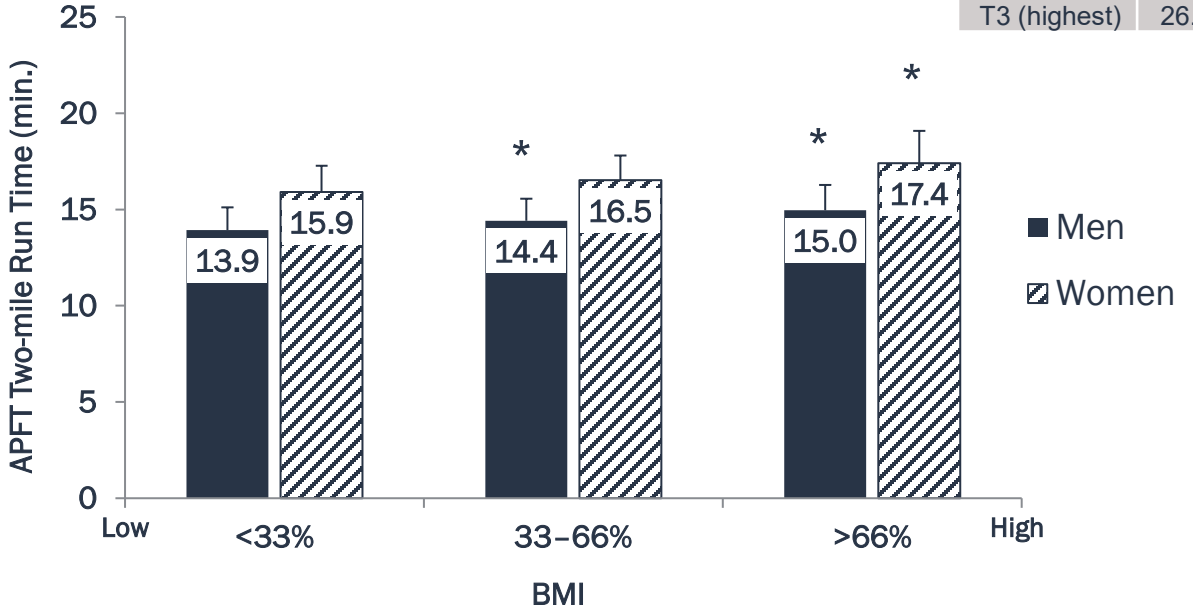
- Failing ABCP screening standards did not largely impact Soldiers' ability to pass the APFT.
  - ~6% would fail the APFT if they failed ABCP screening standards; data not shown.

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Aerobic Performance (2-mile Run Time) by BMI Tertiles

Higher BMIs associated with slower run times (lower aerobic fitness)

BMI	Men	Women
T1 (Lowest)	18.6 – 23.8	16.9 – 22.1
T2	23.9 – 26.5	22.1 – 25.4
T3 (highest)	26.6 – 34.9	25.6 – 28.6



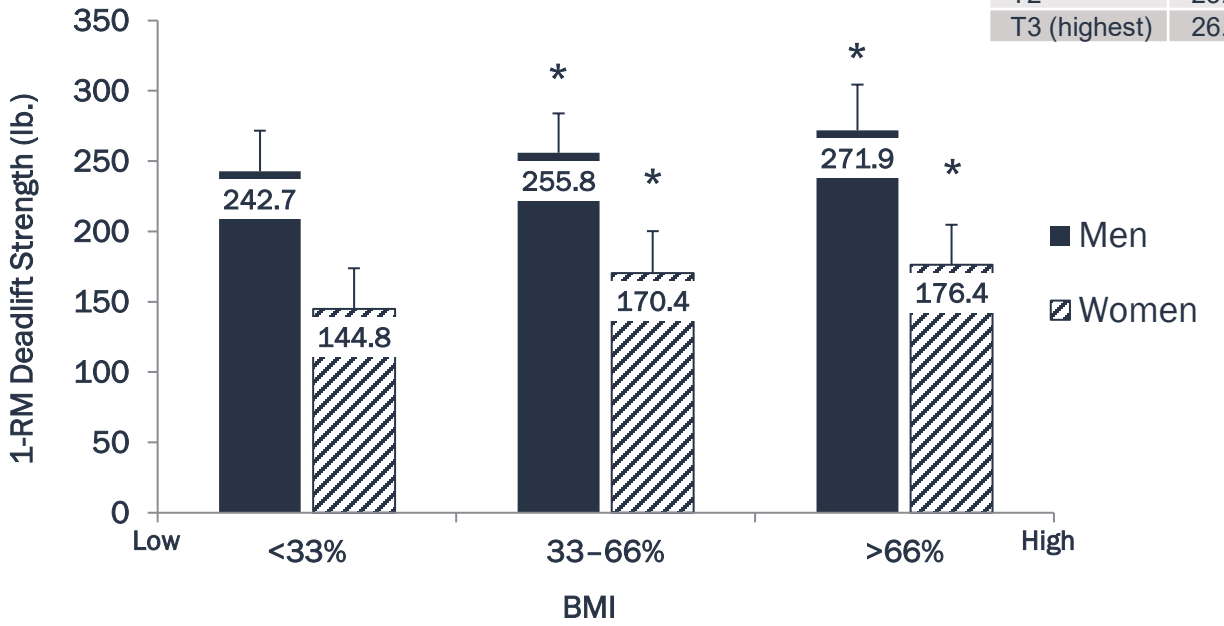
Data are mean ± SD; *P≤0.05 vs. tertile 1 (T1) (<33%)

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Muscular Strength (Lower-body) by BMI Tertiles

Higher BMIs associated with higher (lower-body) muscular strength

BMI	Men	Women
T1 (Lowest)	18.6 – 23.8	16.9 – 22.1
T2	23.9 – 26.5	22.1 – 25.4
T3 (highest)	26.6 – 34.9	25.6 – 28.6



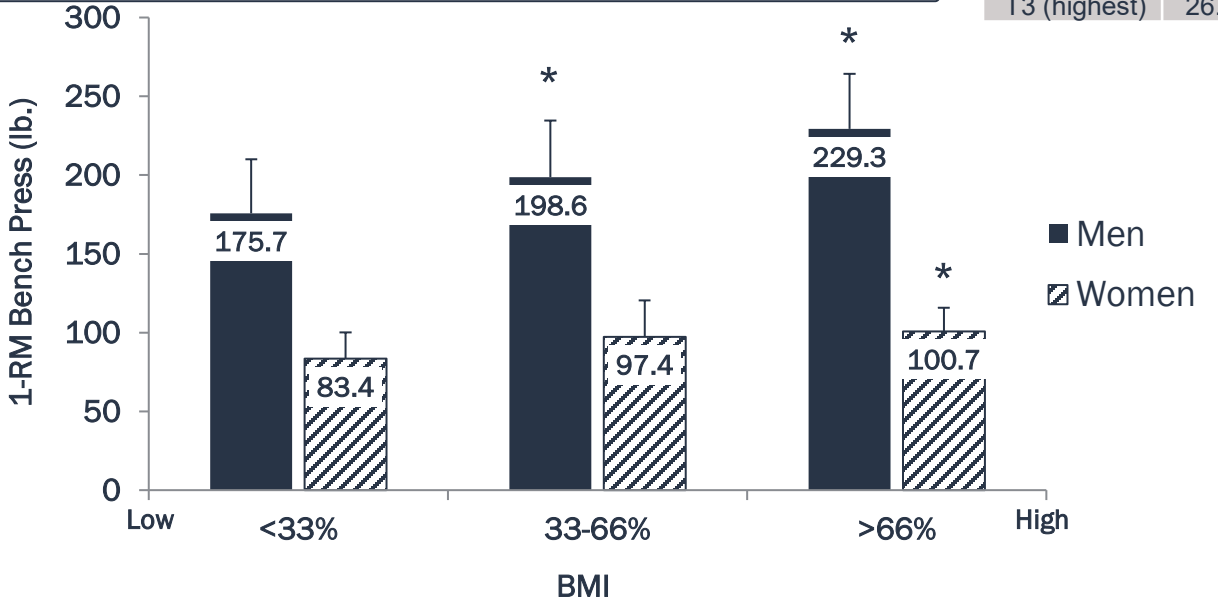
Data are mean ± SD; *P≤0.05 vs. tertile 1 (T1) (<33%)

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Muscular Strength (Upper-body) by BMI Tertiles

Higher BMIs associated with higher (upper-body) muscular strength

BMI	Men	Women
T1 (Lowest)	18.6 – 23.8	16.9 – 22.1
T2	23.9 – 26.5	22.1 – 25.4
T3 (highest)	26.6 – 34.9	25.6 – 28.6



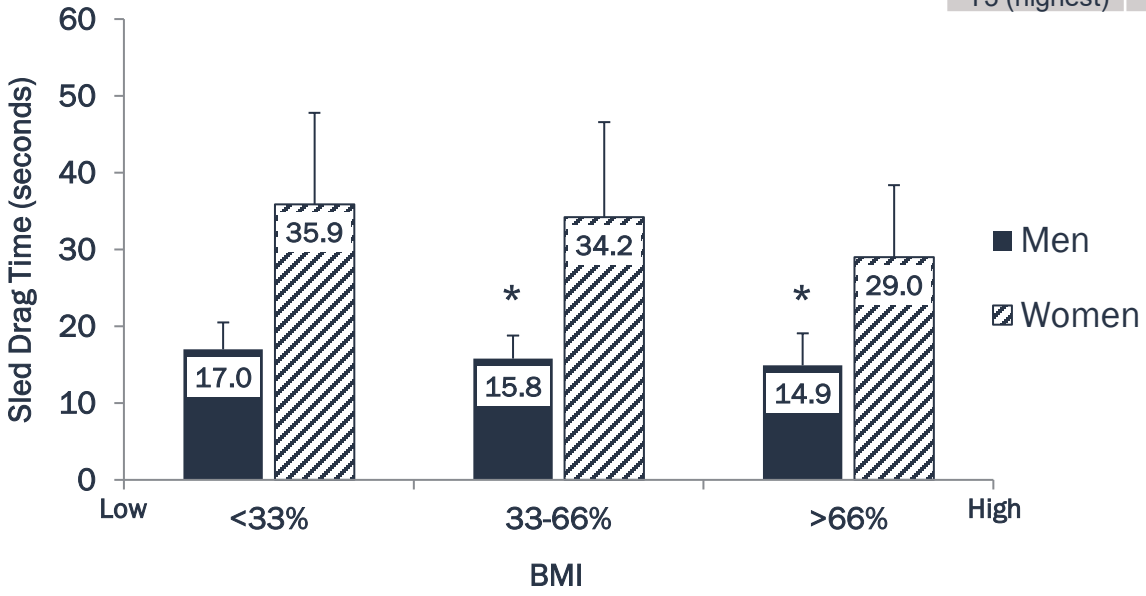
Data are mean ± SD; *P≤0.05 vs. tertile 1 (T1) (<33%)

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Muscular Power (Sled Drag) by BMI Tertiles

Higher BMIs associated with faster sled drag times (higher muscular power) – men only

BMI	Men	Women
T1 (Lowest)	18.6 – 23.8	16.9 – 22.1
T2	23.9 – 26.5	22.1 – 25.4
T3 (highest)	26.6 – 34.9	25.6 – 28.6



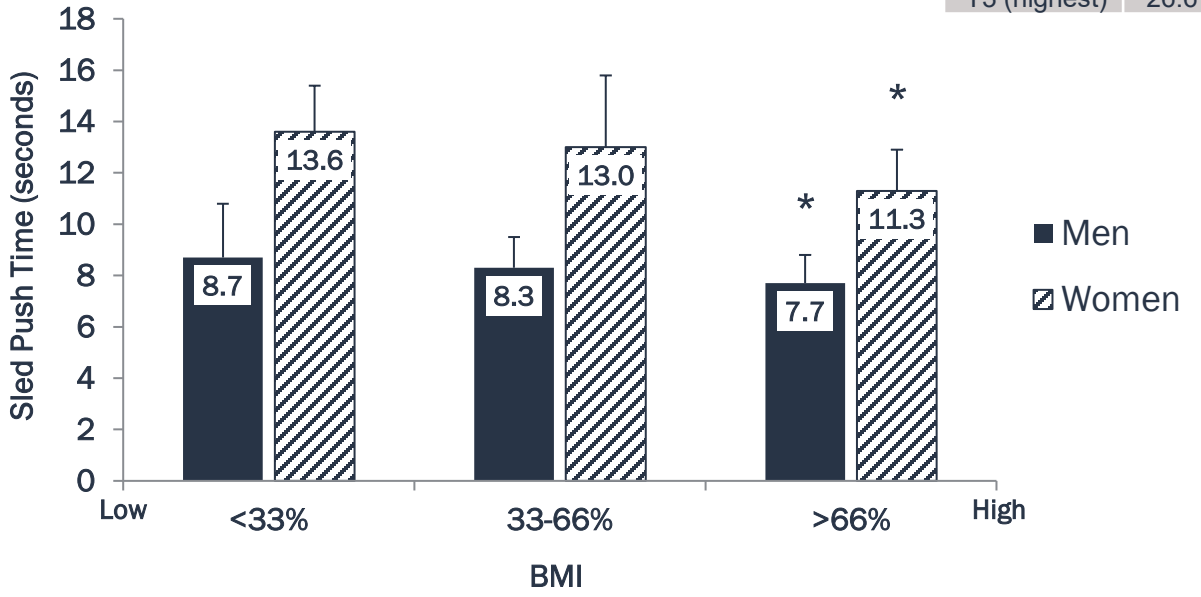
Data are mean ± SD; *P≤0.05 vs. tertile 1 (T1) (<33%)

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Muscular Power (Sled Push) by BMI Tertiles

Higher BMIs associated with faster sled push times (higher muscular power)

BMI	Men	Women
T1 (Lowest)	18.6 – 23.8	16.9 – 22.1
T2	23.9 – 26.5	22.1 – 25.4
T3 (highest)	26.6 – 34.9	25.6 – 28.6

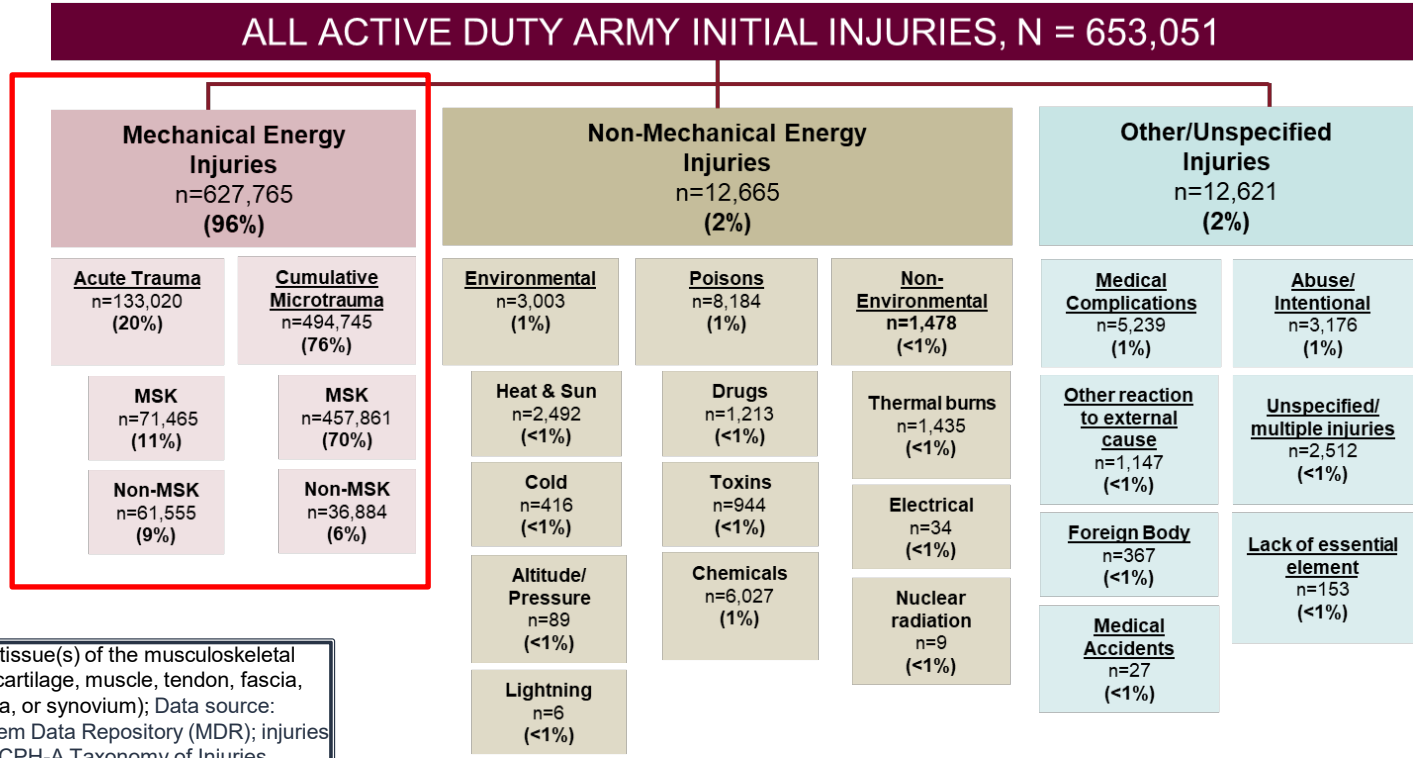


Data are mean ± SD; *P≤0.05 vs. tertile 1 (T1) (<33%)

Pierce J et al. 2017. *JSAMS* 20(Suppl 4):S79–S84.

Body Composition and Physical Fitness Influences on Injuries

Taxonomy of U.S. Army Soldier Incident Injuries (2021)



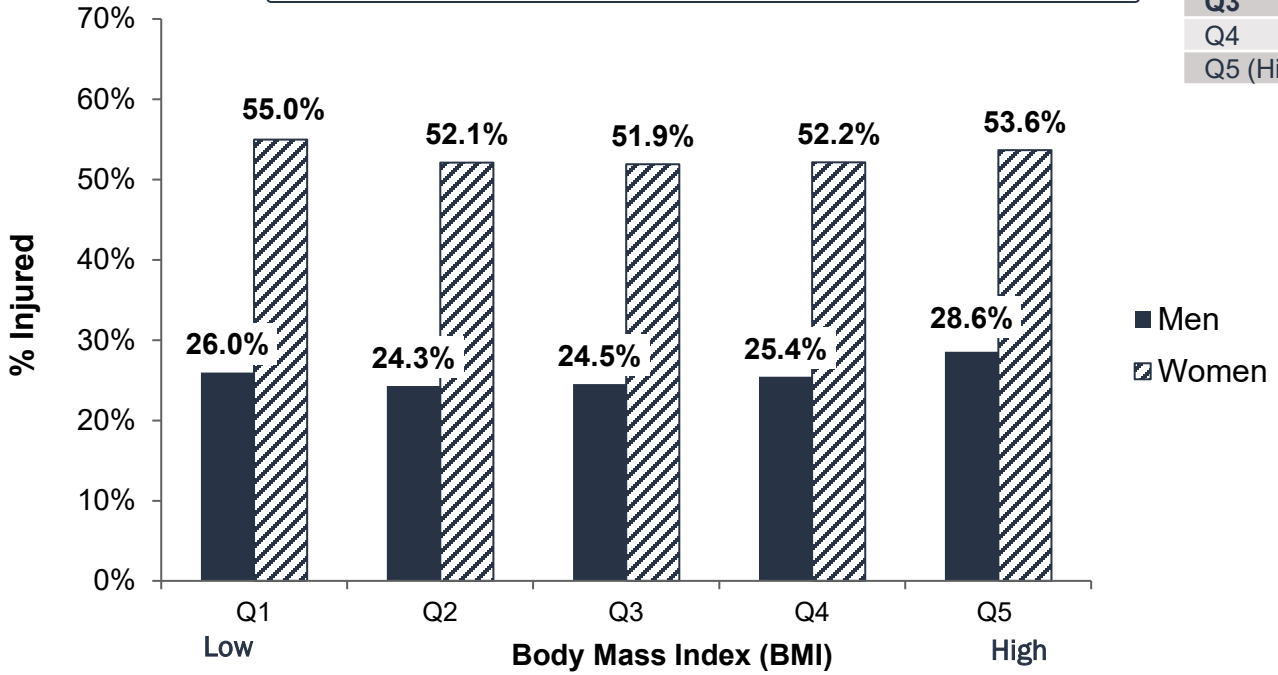
*MSK = damage to tissue(s) of the musculoskeletal system (i.e., bone, cartilage, muscle, tendon, fascia, joint, ligament, bursa, or synovium); Data source: Military Health System Data Repository (MDR); injuries defined using the DCPH-A Taxonomy of Injuries

***Annual Injury Surveillance Report 2021 Summary*; TIP No. 12-123-0123.**

BMI (Body Composition surrogate) vs. Injury Incidence in Trainees

BMI demonstrates slightly bimodal relationship with injury incidence (lowest risk in middle tiers)

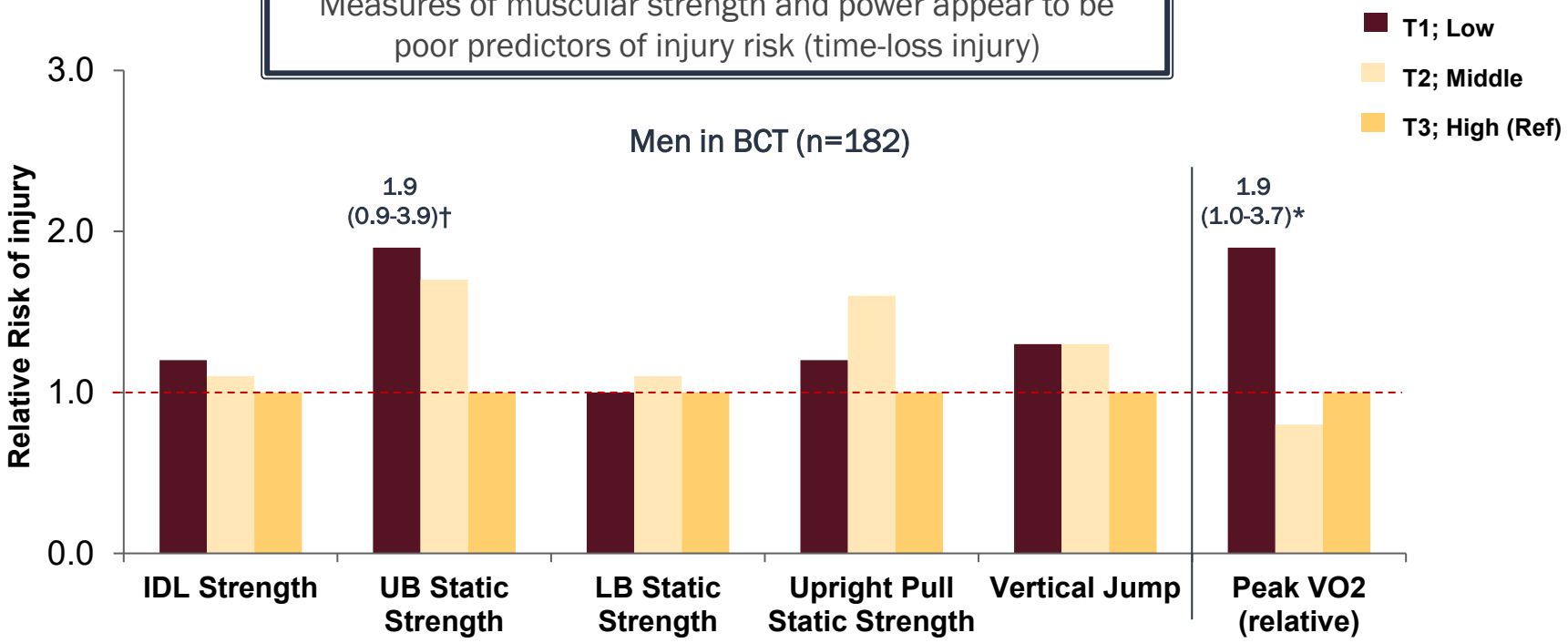
BMI	Men	Women
Q1 (Lowest)	<21.6	< 20.8
Q2	21.6–23.6	**20.8 – 22.4**
Q3	**23.7–25.7**	22.5 – 24.1
Q4	25.8–28.1	24.2 – 25.5
Q5 (Highest)	28.2+	25.6+



Unpublished data, Unclassified

Muscular Strength and Power vs. Injury in Trainees (Men)

Measures of muscular strength and power appear to be poor predictors of injury risk (time-loss injury)

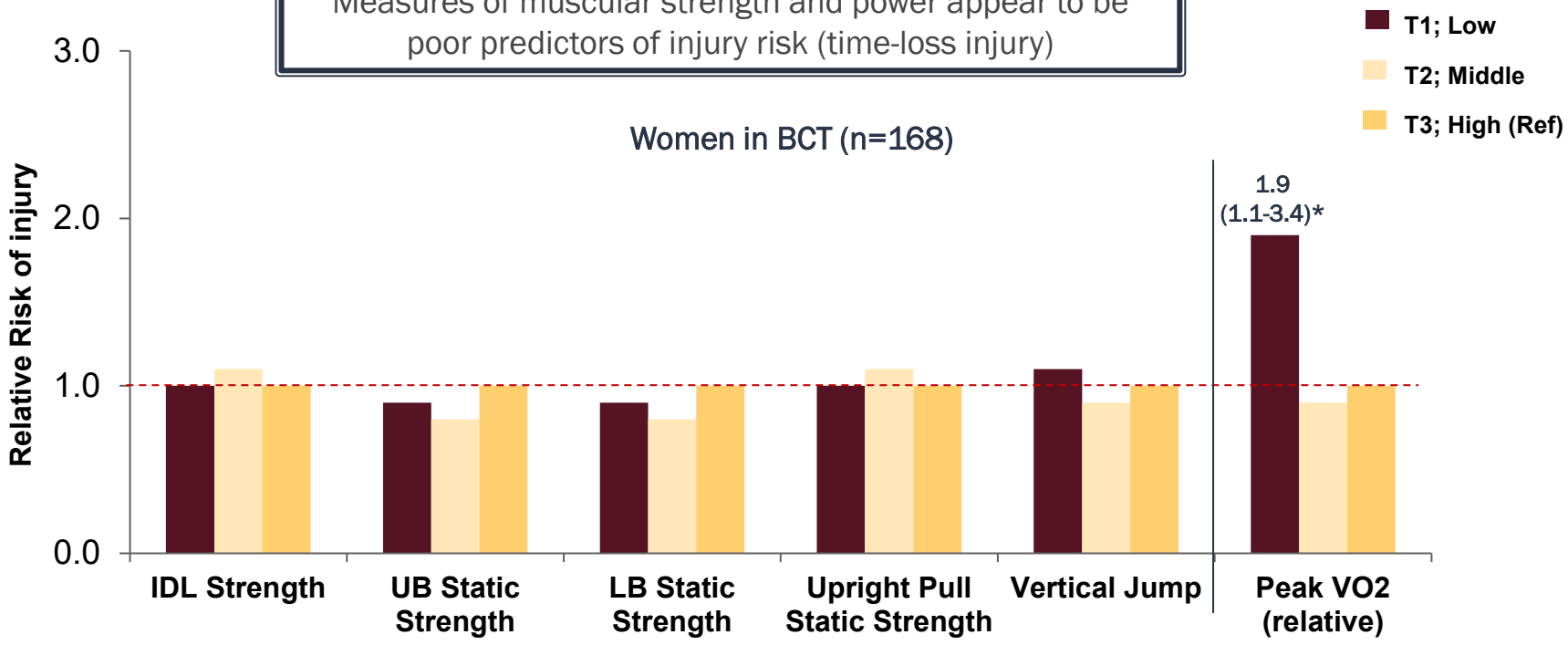


†0.08 T1 vs. T3; *P≤0.05 vs. T3

Data from Knapik J et al. 2001. *Med Sci Sports Exerc* 33(6):946–954.

Muscular Strength and Power vs. Injury in Trainees (Women)

Measures of muscular strength and power appear to be poor predictors of injury risk (time-loss injury)



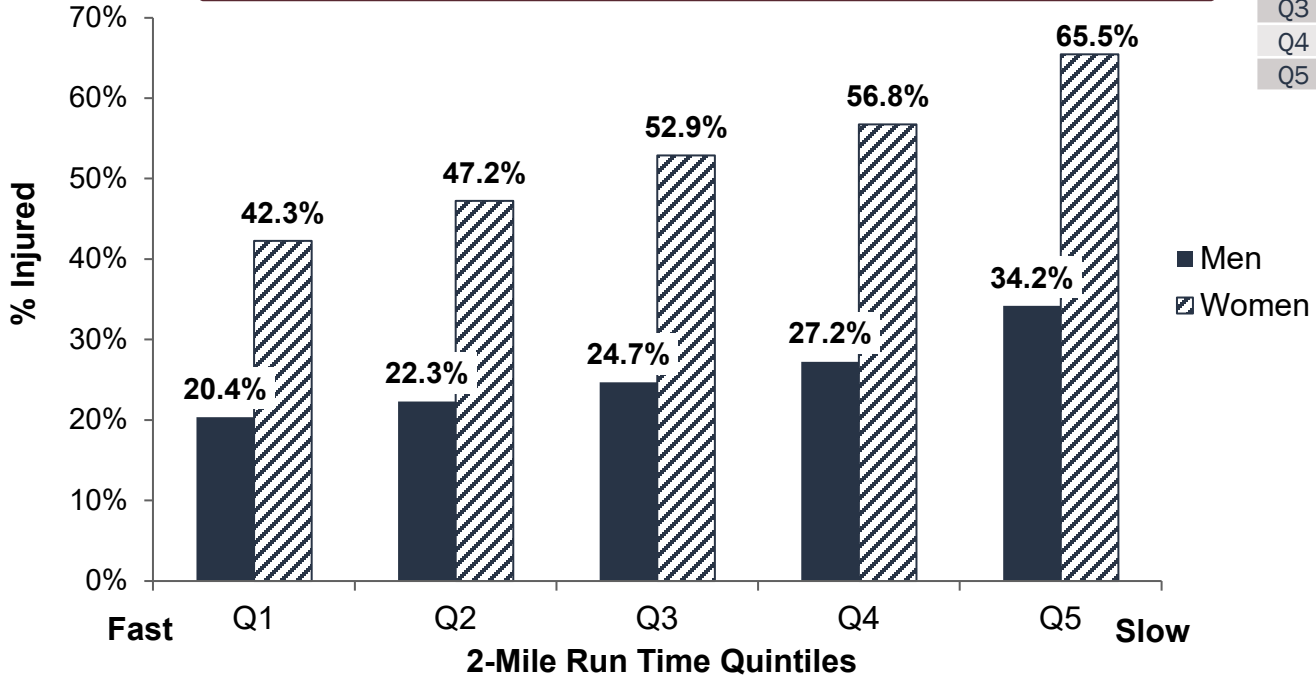
*P≤0.05 vs. T3

Data from Knapik J et al. 2001. *Med Sci Sports Exerc* 33(6):946–954.

2-Mile Run Time and Injury Incidence for Men and Women

Aerobic fitness (e.g., APFT 2-MR) is one of the most consistent predictors of injuries encountered in the military.

Runtime	Men	Women
Q1 (Fastest)	< 14.23	< 17.12
Q2	14.23 - 15.24	17.12 - 18.49
Q3	15.25 - 16.16	18.50 - 19.79
Q4	16.17 - 17.51	19.80 - 21.44
Q5 (Slowest)	17.52+	21.45+

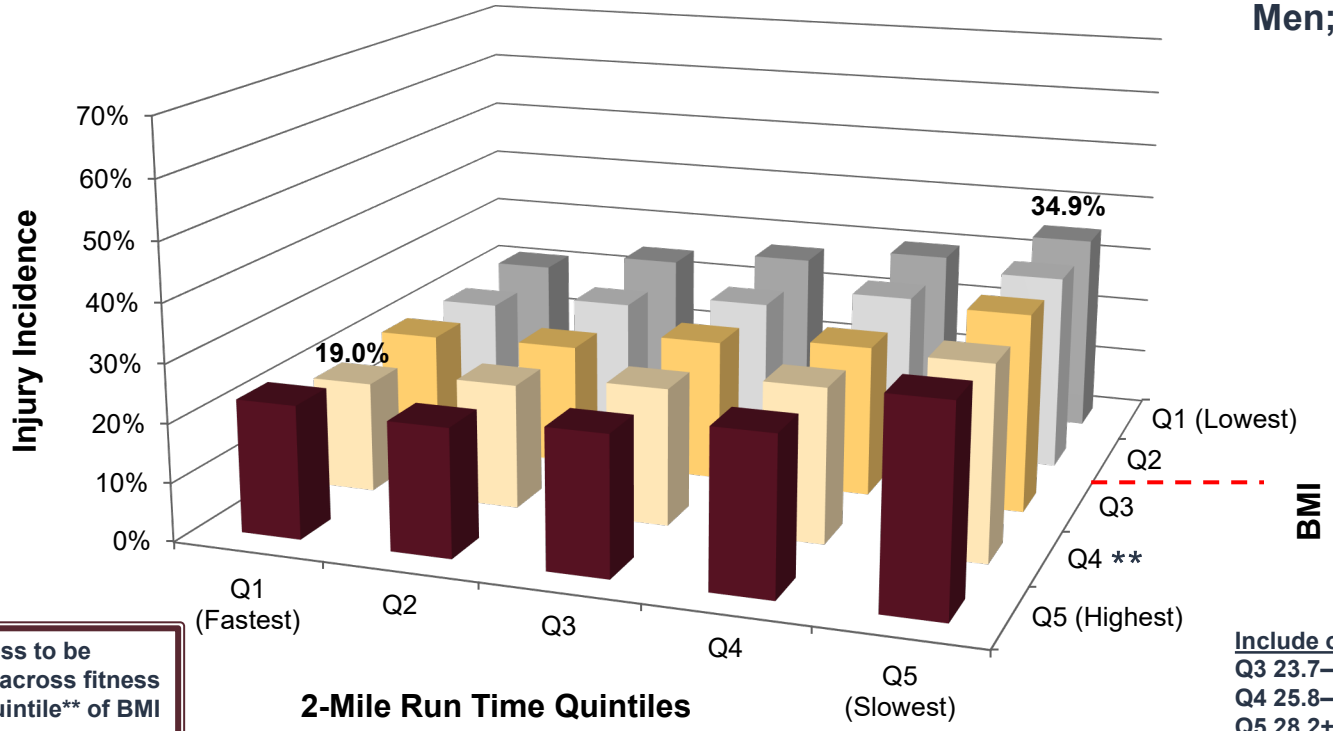


Unpublished data, Unclassified

Interactions Between Fitness and BMI on Injury Risk

Injury Incidence Stratified by 2-Mile Runtime and BMI for Men in BCT (FY 2010–13)

Men; n=136,797

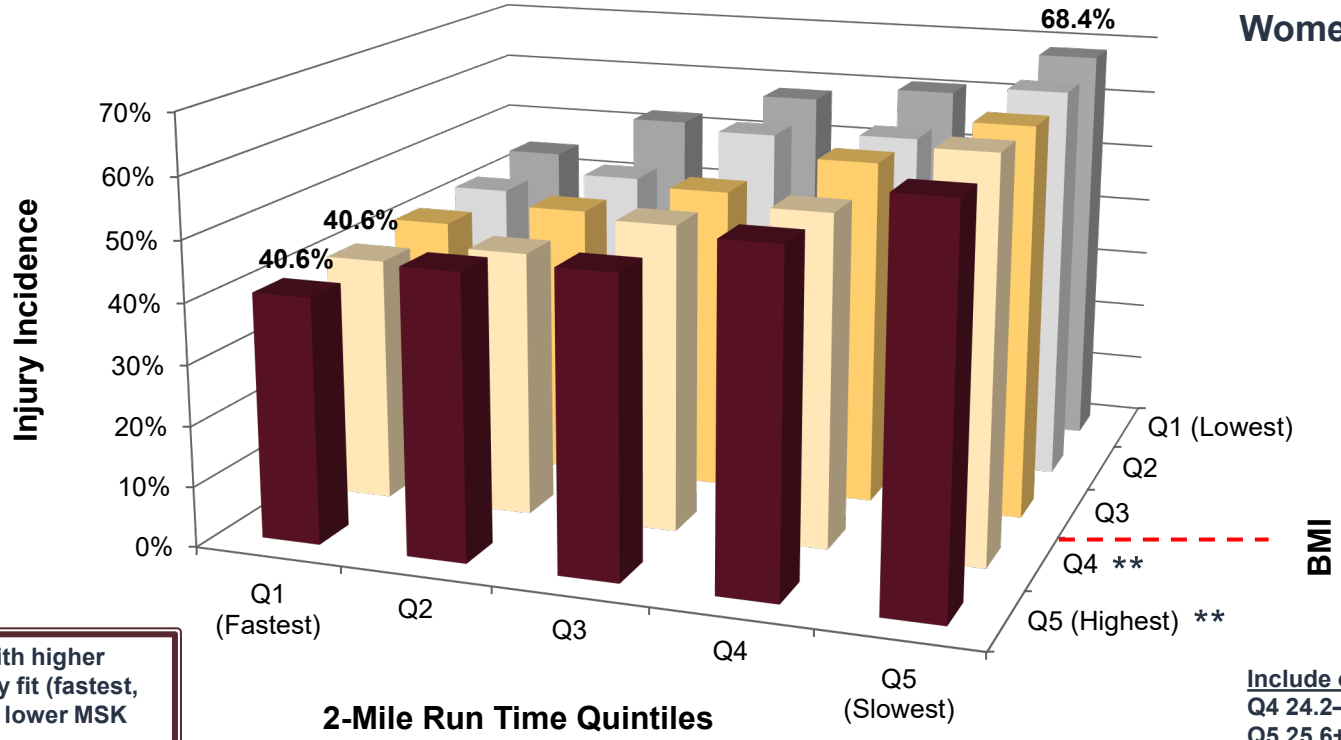


Trend exists for aerobic fitness to be associated with injuries, but across fitness levels, the second highest quintile** of BMI is at the lowest risk of injury.

Include overweight (>25):
Q3 23.7–25.7
Q4 25.8–28.1
Q5 28.2+

Unpublished data, Unclassified

Injury Incidence Stratified by 2-Mile Runtime and BMI for Women in BCT (FY 2010–13)



Data suggest that women with higher BMIs but who are aerobically fit (fastest, but heaviest) demonstrate a lower MSK injury risk.

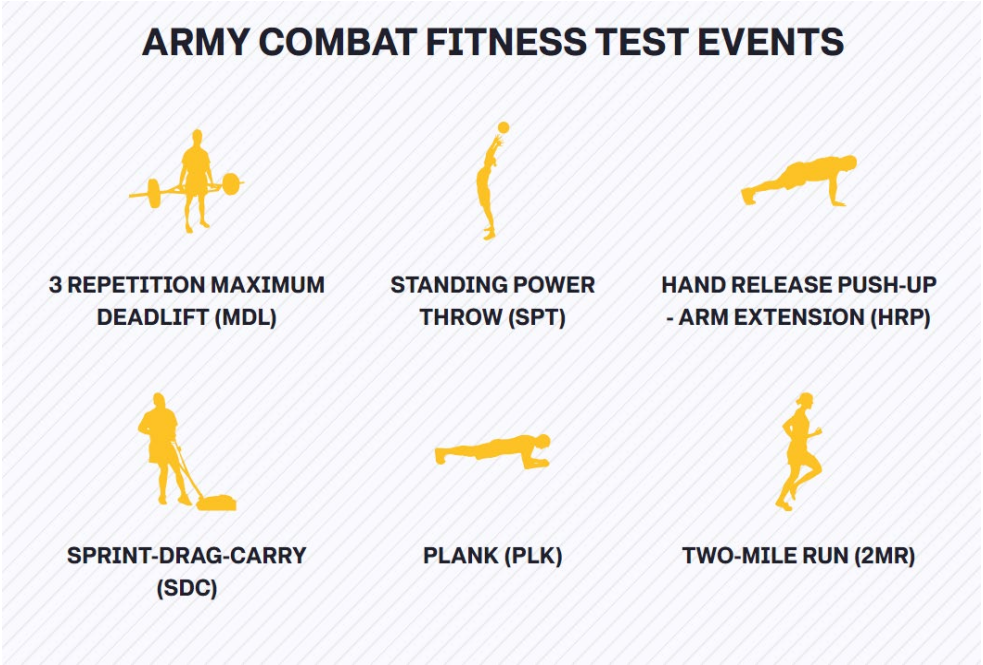
Include overweight (>25):
Q4 24.2–25.5
Q5 25.6+

Unpublished data, Unclassified

What about newer fitness assessments (e.g., ACFT)?

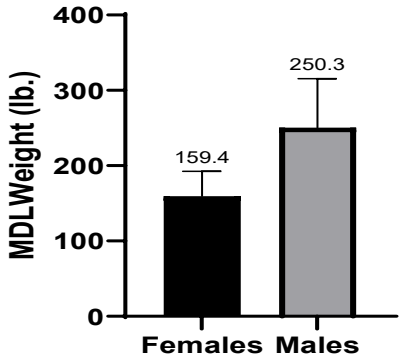
Army Combat Fitness Test (ACFT)

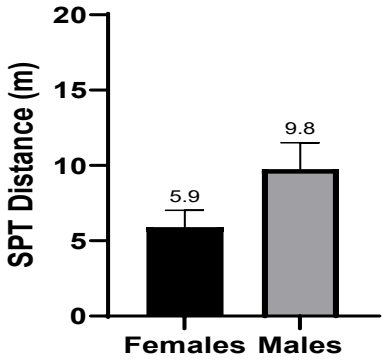
- Updated measures for Army Physical Fitness/Performance (Official test of record as of 2022)
- Broader array* of physical fitness parameters than APFT
  - Muscular strength*
  - Muscular power*
  - Muscular endurance
  - Speed/agility*
  - Anaerobic fitness/endurance*
  - Aerobic fitness/endurance
- Advantages (unlike APFT):
  - Tied to combat-related fitness attributes
  - Basis for discriminating occupational fitness

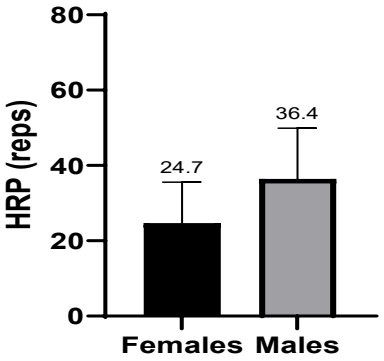


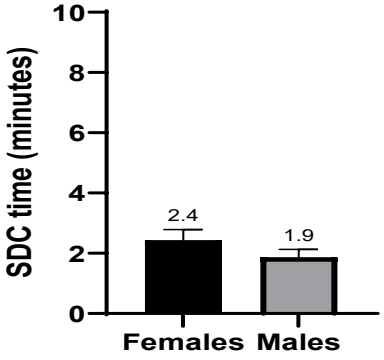
https://www.army.mil/acft/

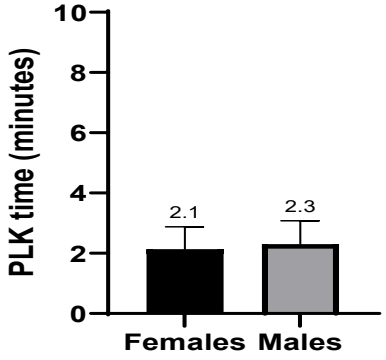
ACFT Performance by Sex

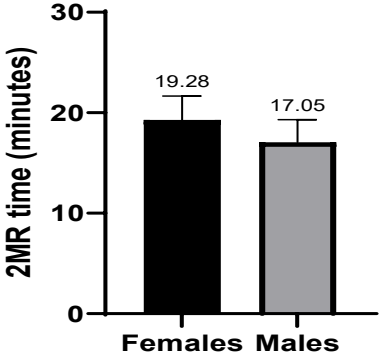












Note: Unpublished data

Univariate Logistic Regression: ACFT Performance with Future Cumulative MSKI Deadlift, Power Throw, Hand-release Push-ups

High Event Performance

Low Event Performance

ACFT Event	Females (n=3,300; injured=1,872 (57%))			Males (n=20,217; injured=9,320 (46%))		
	Bin	Injured n (%)	OR (95% CI)	Bin	Injured n (%)	OR (95% CI)
3-RM Deadlift (lb.)	200-310	353 (55.8%)	Ref	340-390	1966 (48.5%)	Ref; ‡
	160-190	463 (56%)	1.01 (0.75-1.35)	270-330	1869 (44.5%)	**0.85 (0.76-0.96)***
	148-155	176 (55.2%)	0.98 (0.67-1.42)	240-260	1936 (45.5%)	0.89 (0.79-1.00)
	140-140	497 (59.7%)	1.18 (0.88-1.57)	190-235	1709 (45.1%)	**0.87 (0.77-0.99)***
	120-130	383 (55.6%)	0.99 (0.73-1.34)	120-180	1840 (47%)	0.94 (0.83-1.07)
Standing Power Throw (m)	6.9-11.7	333 (53.4%)	Ref	11.3-19.0	1990 (50.2%)	Ref; ‡
	6.1-6.8	393 (56.8%)	1.15 (0.85-1.55)	10.1-11.2	2012 (47.1%)	**0.88 (0.78-1.00)***
	5.5-6.0	417 (56.1%)	1.12 (0.83-1.51)	9.2-10.0	1859 (45%)	**0.81 (0.72-0.92)***
	5.0-5.4	322 (55.9%)	1.11 (0.81-1.52)	8.2-9.1	1819 (44.5%)	**0.80 (0.71-0.90)***
	2.2-4.9	407 (61.2%)	1.38 (1.01-1.88)	1.0-8.1	1640 (43.6%)	**0.77 (0.68-0.87)***
Hand Release Push-ups (repetitions)	35-60	357 (52.9%)	Ref; ‡	50-100	1744 (45.6%)	Ref; ‡
	26-34	376 (54.6%)	1.07 (0.80-1.44)	41-49	1820 (44.7%)	0.96 (0.85-1.09)
	21-25	274 (55.2%)	1.10 (0.80-1.52)	33-40	1847 (45%)	0.97 (0.86-1.10)
	15-20	479 (58.9%)	1.28 (0.96-1.70)	24-32	1971 (46.2%)	1.02 (0.91-1.16)
	2-14	386 (61.6%)	**1.43 (1.05-1.94)***	1-23	1938 (49.1%)	**1.15 (1.02-1.30)***

Note: Unpublished data

3-RM = three repetition maximum; ‡ = significant *Type III* test result; Comparisons are for the specific binned group compared against the within-sex highest event performance group in each event.

Univariate Logistic Regression: ACFT Performance with Future Cumulative MSKI Sprint-Drag-Carry, Plank, Two-mile Run

	Females (n=3,300; injured=1,872 (57%))			Males (n=20,217; injured=9,320 (46%))		
ACFT Event	Bin	Injured n (%)	OR (95% CI)	Bin	Injured n (%)	OR (95% CI)
Sprint-Drag-Carry (time, min.)	0.8-2.2	347 (52.7%)	Ref , ‡	0.8-1.6	1785 (45.5%)	Ref , ‡
	2.2-2.3	373 (55.5%)	1.12 (0.83-1.51)	1.7-1.8	1629 (44.7%)	0.97 (0.85-1.10)
	2.4-2.5	396 (55.2%)	1.11 (0.82-1.49)	1.8-1.9	2096 (45.3%)	0.99 (0.88-1.12)
	2.5-2.8	429 (60.3%)	**1.37 (1.01-1.84)***	1.9-2.1	1933 (46%)	1.02 (0.90-1.15)
	2.8-6.0	327 (60.6%)	**1.38 (1.00-1.90)***	2.1-6.0	1877 (49.1%)	**1.15 (1.02-1.31)***
Plank (time, min.)	2.7-5.3	362 (52.8%)	Ref , ‡	3.2-5.5	1703 (44.2%)	Ref , ‡
	2.1-2.7	347 (55.4%)	1.11 (0.82-1.51)	2.3-3.2	1790 (44.4%)	1.01 (0.89-1.14)
	1.7-2.0	417 (57.4%)	1.20 (0.90-1.61)	2.0-2.3	2070 (46%)	1.08 (0.95-1.21)
	1.5-1.7	330 (55.2%)	1.10 (0.81-1.50)	1.6-2.0	1905 (46.5%)	1.10 (0.97-1.24)
	0.3-1.5	416 (62.7%)	**1.51 (1.11-2.04)***	0.3-1.5	1852 (49.5%)	**1.24 (1.09-1.40)***
Two-mile Run (time, min.)	11.7-17.3	348 (51.9%)	Ref , ‡	10.7-15.0	1611 (42.6%)	Ref , ‡
	17.3-18.7	357 (53%)	1.05 (0.78-1.41)	15.0-16.2	1761 (43.7%)	1.05 (0.92-1.19)
	18.7-20.0	396 (54.8%)	1.13 (0.84-1.51)	16.3-17.5	1919 (45.3%)	1.12 (0.99-1.26)
	20.0-21.7	416 (60.2%)	**1.40 (1.04-1.89)***	17.5-19.1	2071 (47.8%)	**1.23 (1.09-1.39)***
	21.7-40.0	355 (65.4%)	**1.75 (1.27-2.42)***	19.1-40.0	1958 (51.1%)	**1.41 (1.24-1.60)***

High Event Performance

Low Event Performance

Note: Unpublished data

‡ = significant *Type III* test result; Comparisons are for the specific binned group compared against the within-sex highest event performance group in each event.

Multivariate Logistic Regression: ACFT Performance with Future Cumulative MSKI Controlling for Age, %BF, and Previous Injuries

High Event Performance

Low Event Performance

ACFT Event	Females (n=3,300; n=1,872 injured (57%))			Males (n=20,217; n=9,320 injured (46%))		
	Performance Bin	Injured n (%)	Adj OR (95% CI)	Performance Bin	Injured n (%)	Adj OR (95% CI)
3-RM Deadlift (lb.)	200-310	353 (55.8%)	Ref, ‡	340-390	1966 (48.5%)	Ref
	160-190	463 (56%)	0.91 (0.66-1.27)	270-330	1869 (44.5%)	0.94 (0.82-1.07)
	148-155	176 (55.2%)	0.85 (0.55-1.30)	240-260	1936 (45.5%)	1.01 (0.87-1.17)
	140-140	497 (59.7%)	0.98 (0.68-1.42)	190-235	1709 (45.1%)	0.98 (0.83-1.15)
	120-130	383 (55.6%)	0.71 (0.47-1.07)	120-180	1840 (47%)	0.96 (0.80-1.15)
Standing Power Throw (m)	6.9-11.7	333 (53.4%)	Ref, ‡	11.3-19.0	1990 (50.2%)	Ref, ‡
	6.1-6.8	393 (56.8%)	1.21 (0.87-1.68)	10.1-11.2	2012 (47.1%)	0.91 (0.80-1.04)
	5.5-6.0	417 (56.1%)	1.19 (0.85-1.67)	9.2-10.0	1859 (45%)	**0.82 (0.72-0.94)***
	5.0-5.4	322 (55.9%)	1.16 (0.80-1.68)	8.2-9.1	1819 (44.5%)	**0.83 (0.71-0.96)***
	2.2-4.9	407 (61.2%)	**1.56 (1.06-2.28)***	1.0-8.1	1640 (43.6%)	**0.81 (0.69-0.95)***
Hand-release Push-up (repetitions)	35-60	357 (52.9%)	Ref	50-100	1744 (45.6%)	Ref
	26-34	376 (54.6%)	1.01 (0.73-1.39)	41-49	1820 (44.7%)	0.99 (0.87-1.13)
	21-25	274 (55.2%)	0.96 (0.67-1.38)	33-40	1847 (45%)	0.99 (0.86-1.14)
	15-20	479 (58.9%)	1.08 (0.76-1.53)	24-32	1971 (46.2%)	0.99 (0.85-1.15)
	2-14	386 (61.6%)	1.12 (0.76-1.67)	1-23	1938 (49.1%)	1.05 (0.89-1.25)

Note: Unpublished data

3-RM = three repetition maximum; Adjusted Odds Ratio (Adj OR) was from multiple logistic regression model, accounting for all other variables in model;
‡ = significant *Type III* test result; Comparisons are for the specific binned group compared against the within-sex highest event performance group in each event.

Multivariate Logistic Regression: ACFT Performance with Future Cumulative MSKI Controlling for Age, %BF, and Previous Injuries

High Event Performance

Low Event Performance

ACFT Event	Females (n=3,300; n=1,872 injured (57%))			Males (n=20,217; n=9,320 injured (46%))		
	Performance Bin	Injured n (%)	Adj OR (95% CI)	Performance Bin	Injured n (%)	Adj OR (95% CI)
Sprint-Drag-Carry (time, min.)	0.8-2.2	347 (52.7%)	Ref	0.8-1.6	1785 (45.5%)	Ref
	2.2-2.3	373 (55.5%)	0.99 (0.71-1.38)	1.7-1.8	1629 (44.7%)	0.94 (0.82-1.07)
	2.4-2.5	396 (55.2%)	0.93 (0.66-1.30)	1.8-1.9	2096 (45.3%)	0.94 (0.82-1.07)
	2.5-2.8	429 (60.3%)	1.07 (0.74-1.53)	1.9-2.1	1933 (46%)	0.91 (0.79-1.06)
	2.8-6.0	327 (60.6%)	0.94 (0.62-1.43)	2.1-6.0	1877 (49.1%)	0.95 (0.81-1.13)
Plank (time, min.)	2.7-5.3	362 (52.8%)	Ref	3.2-5.5	1703 (44.2%)	Ref
	2.1-2.7	347 (55.4%)	1.03 (0.74-1.42)	2.3-3.2	1790 (44.4%)	0.97 (0.85-1.11)
	1.7-2.0	417 (57.4%)	1.07 (0.77-1.48)	2.0-2.3	2070 (46%)	1.01 (0.88-1.15)
	1.5-1.7	330 (55.2%)	0.94 (0.66-1.35)	1.6-2.0	1905 (46.5%)	1.04 (0.90-1.21)
	0.3-1.5	416 (62.7%)	1.17 (0.81-1.70)	0.3-1.5	1852 (49.5%)	1.01 (0.86-1.19)
Two-mile Run (time, min.)	11.7-17.3	348 (51.9%)	Ref	10.7-15.0	1611 (42.6%)	Ref, ‡
	17.3-18.7	357 (53%)	0.94 (0.68-1.30)	15.0-16.2	1761 (43.7%)	1.03 (0.90-1.18)
	18.7-20.0	396 (54.8%)	0.95 (0.68-1.32)	16.3-17.5	1919 (45.3%)	1.08 (0.94-1.24)
	20.0-21.7	416 (60.2%)	1.13 (0.78-1.62)	17.5-19.1	2071 (47.8%)	1.14 (0.98-1.32)
	21.7-40.0	355 (65.4%)	1.30 (0.86-1.97)	19.1-40.0	1958 (51.1%)	**1.26 (1.07-1.49)***

Note: Unpublished data

Adjusted Odds Ratio (Adj OR) was from multiple logistic regression model, accounting for all other variables in model; ‡ = significant *Type III* test result; Comparisons are for the specific binned group compared against the within-sex highest event performance group in each event.

Multivariate Logistic Regression: Previous Injury with Future Cumulative MSKI Controlling for Age, %BF, and ACFT performance

Variable	Females (n=3,300; n=1,872 injured (57%))			Males (n=20,217; n=9,320 injured (46%))		
	Bin	Injured n (%)	Adj OR (95% CI)	Bin	Injured n (%)	Adj OR (95% CI)
Previous Injury (60 days prior to ACFT)	No	1461 (52.7%)	Ref, ‡	No	7623 (42.6%)	Ref, ‡
	Yes	411 (77.8%)	**2.98 (2.38-3.72)***	Yes	1697 (73.3%)	**3.49 (3.16-3.84)***

Adjusted Odds Ratio (OR) was from multiple logistic regression model, accounting for all other variables in model (Age, BF, ACFT performance);
‡ = significant *Type III* test result; Comparisons are for the specific within-sex binned group compared against the referent (no injury) group.

Note: Unpublished data

Key Lessons/Takeaways (1 of 2)

- **What does body composition tell us about an individual?**
  - Bimodal greater health risks at low and high BMIs: high BMI is the larger risk factor with J-shaped curve
  - BMI related to body fat with disproportionate increase in fat mass: >27.5 kg/m^2
- **Physical performance trade-offs with higher BMIs (and more body fat)**
  - Decreased aerobic capacity
  - Greater muscular strength and power
- **Body composition and fitness influence injury risk/occurrence independently and in concert together**
  - Low and high ends of BMI spectrum: slight bimodal relationship with injuries
  - Faster run times/higher aerobic fitness in particular: fewer injuries
  - Aerobically-fit Soldiers with high BMIs demonstrate lower injury incidence
  - Fitness event performance taking into account body composition, age, and prior injuries demonstrate sex-specific interactions and that prior injuries may be more important factor.

Key Lessons/Takeaways (2 of 2)

- **What do we do with this information/where next?**
  - Setting standards for body composition and fitness:
    - Needs to balance physical performance, health, and readiness requirements.
    - Needs to consider practicality, validity, reliability, and defensibility.
  - Less emphasis should be placed on excluding individuals based on body composition alone, especially where tradeoffs may exist:
    - Individuals with higher BMIs demonstrate enhanced physical performance on tests/tasks assessing muscular strength, power, etc.
    - Individuals with higher BMIs that also demonstrate higher levels of aerobic fitness seem to be protected from injuries.

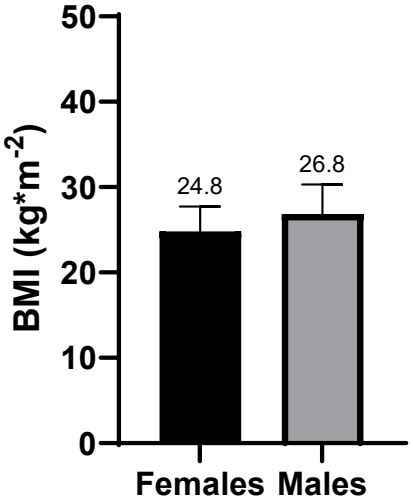
Any Questions?

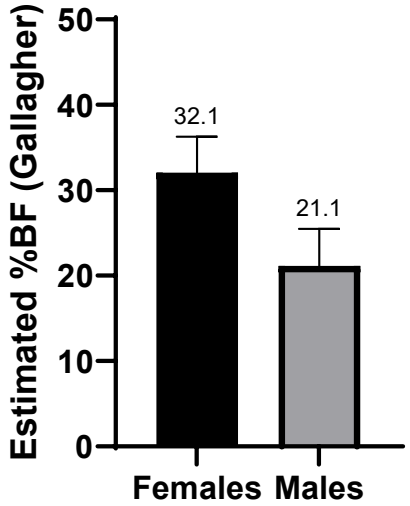
Back-up slides

Body Composition (BMI, %BF) by Sex

Female (exclusions <10%); n=3,300					
	mean	SD	range		
BMI	24.8	2.9	16.3	-	38.4
%BF (est.)	32.1	4.2	14.0	-	44.3

Male (exclusions <3%) ; n=20,217					
	mean	SD	range		
BMI	26.8	3.5	17.2	-	43.25
%BF (est.)	21.1	4.4	4.0	-	33.9





Note: Unpublished data

Prior and Future MSKIs: Females

Pre-ACFT

Table 4. Injury Encounters prior to ACFT

	N	%
Any MSK inj within 60 days	569	17.24
LE MSK inj within 60 days	291	8.82
Any MSK inj within 180 days	1,270	38.48
LE MSK inj within 180 days	761	23.06

Note: Unpublished data

Post-ACFT

Table 6b. Injury Encounter post ACFT - Any MSK

Days from ACFT to 1st Any MSK	N	%
None	1,330	40.3
less than 60 days	649	19.67
60 to 180 days	678	20.55
181 to 365 days	643	19.48

59.7%

Table 7b. Injury Encounter post ACFT – Acute MSK

Days from ACFT to 1st Acute MSK	N	%
None	2,803	84.94
less than 60 days	92	2.79
60 to 180 days	164	4.97
181 to 365 days	241	7.3

15.1%

Table 8b. Injury Encounter post ACFT - Cumulative MSK

Days from ACFT to 1st Cumulative MSK	N	%
None	1,428	43.27
less than 60 days	606	18.36
60 to 180 days	643	19.48
181 to 365 days	623	18.88

56.7%

Prior and Future MSKIs: Males

Pre-ACFT

Table 4. Injury Encounters prior to ACFT

	N	%
Any MSK inj within 60 days	2,531	12.52
LE MSK inj within 60 days	1,180	5.84
Any MSK inj within 180 days	5,801	28.69
LE MSK inj within 180 days	3,098	15.32

Note: Unpublished data

Post-ACFT

Table 6b. Injury Encounter post ACFT - Any MSK

Days from ACFT to 1st Any MSK	N	%
None	10,354	51.21
less than 60 days	3,001	14.84
60 to 180 days	3,375	16.69
181 to 365 days	3,487	17.25

48.8%

Table 7b. Injury Encounter post ACFT - Acute MSK

Days from ACFT to 1st Acute MSK	N	%
None	17,522	86.67
less than 60 days	522	2.58
60 to 180 days	855	4.23
181 to 365 days	1,318	6.52

13.3%

Table 8b. Injury Encounter post ACFT - Cumulative MSK

Days from ACFT to 1st Cumulative MSK	N	%
None	10,897	53.9
less than 60 days	2,738	13.54
60 to 180 days	3,194	15.80
181 to 365 days	3,388	16.76

46.1%

Univariate Logistic Regression: %BF and Age with Future Cumulative MSKI

	Females (n=3,300; injured=1,872 (57%))			Males (n=20,217; injured=9,320 (46%))		
Variable	Bin	Injured n (%)	OR (95% CI)	Bin	Injured n (%)	OR (95% CI)
Body Fat (%) (est.)	14.0-28.6	321 (49.7%)	Ref, ‡	4.0-17.6	1,567 (39.1%)	Ref, ‡
	28.6-31.4	396 (55.5%)	1.26 (0.94-1.70)	17.6-20.4	1,672 (42.9%)	**1.17 (1.03-1.32)***
	31.4-33.3	349 (52.5%)	1.12 (0.83-1.51)	20.4-22.5	1,853 (45.4%)	**1.29 (1.14-1.46)***
	33.3-35.8	408 (62%)	**1.65 (1.22-2.25)***	22.5-24.8	2,043 (49.3%)	**1.51 (1.34-1.71)***
	35.8-44.3	398 (64.5%)	**1.84 (1.34-2.52)***	24.8-33.9	2,185 (53.6%)	**1.80 (1.59-2.03)***
Age	17-21	366 (56.1%)	Ref	17-21	1,455 (40.8%)	Ref, ‡
	22-26	573 (53.9%)	0.91 (0.67-1.23)	22-26	2,638 (43.2%)	1.10 (0.97-1.26)
	27-31	375 (55.8%)	0.99 (0.71-1.38)	27-31	1,907 (44.1%)	1.14 (1.00-1.31)
	32-36	241 (54.2%)	0.92 (0.63-1.34)	32-36	1,440 (47.8%)	**1.33 (1.14-1.54)***
	37-41	194 (66.2%)	1.53 (0.98-2.39)	37-41	1,098 (55.7%)	**1.82 (1.53-2.16)***
	42-46	77 (65.8%)	1.50 (0.80-2.85)	42-46	515 (63.7%)	**2.55 (1.99-3.25)***
	47-51	34 (75.6%)	2.42 (0.82-7.10)	47-51	214 (63.5%)	**2.52 (1.76-3.61)***
	52+	12 (100%)	Undefined	52+	53 (52.5%)	1.60 (0.87-2.95)

‡ = significant *Type III* test result; Comparisons are for the specific within-sex binned group compared against the referent group (e.g., lowest body fat, youngest).

Note: Unpublished data

Univariate Logistic Regression: Previous Injuries with Future Cumulative MSKI

	Females (n=3,300; injured=1,872 (57%))			Males (n=20,217; injured=9,320 (46%))		
Variable	Bin	Injured n (%)	OR (95% CI)	Bin	Injured n (%)	OR (95% CI)
Previous Injury (60 days prior to ACFT)	No	1,461 (52.7%)	Ref, ‡	No	7,623 (42.6%)	Ref, ‡
	Yes	411 (77.8%)	**3.15 (2.53-3.92)***	Yes	1,697 (73.3%)	**3.70 (3.36-4.08)***
Previous Injury (180 days prior to ACFT)	No	975 (46.6%)	Ref, ‡	No	5,768 (38.9%)	Ref, ‡
	Yes	897 (74.3%)	**3.30 (2.83-3.86)***	Yes	3,552 (65.8%)	**3.01 (2.82-3.21)***

‡ = significant *Type III* test result; Comparisons are for the specific within-sex binned group compared against the referent group (e.g., no injury).

Note: Unpublished data

Multivariate Logistic Regression: %BF and Age with Future Cumulative MSKI

Variable	Females (n=3,300; n=1,872 injured (57%))			Males (n=20,217; n=9,320 injured (46%))		
	Bin	Injured n (%)	Adj OR (95% CI)	Bin	Injured n (%)	Adj OR (95% CI)
Body Fat (%) (est.)	14.0-28.6	321 (49.7%)	Ref, ‡	4.0-17.6	1,567 (39.1%)	Ref, ‡
	28.6-31.4	396 (55.5%)	1.21 (0.89-1.65)	17.6-20.4	1,672 (42.9%)	1.08 (0.95-1.24)
	31.4-33.3	349 (52.5%)	1.06 (0.77-1.45)	20.4-22.5	1,853 (45.4%)	1.11 (0.97-1.27)
	33.3-35.8	408 (62%)	1.37 (0.97-1.93)	22.5-24.8	2,043 (49.3%)	**1.16 (1.01-1.34)***
	35.8-44.3	398 (64.5%)	**1.50 (1.03-2.18)***	24.8-33.9	2,185 (53.6%)	**1.26 (1.07-1.47)***
Age (y)	17-21	366 (56.1%)	Ref	17-21	1,455 (40.8%)	Ref, ‡
	22-26	573 (53.9%)	0.93 (0.67-1.28)	22-26	2,638 (43.2%)	1.03 (0.90-1.18)
	27-31	375 (55.8%)	0.98 (0.68-1.41)	27-31	1,907 (44.1%)	1.02 (0.88-1.19)
	32-36	241 (54.2%)	0.87 (0.58-1.30)	32-36	1,440 (47.8%)	1.14 (0.97-1.35)
	37-41	194 (66.2%)	1.33 (0.83-2.15)	37-41	1,098 (55.7%)	**1.56 (1.29-1.89)***
	42-46	77 (65.8%)	1.27 (0.64-2.51)	42-46	515 (63.7%)	**2.08 (1.60-2.72)***
	47-51	34 (75.6%)	1.77 (0.57-5.47)	47-51	214 (63.5%)	**2.06 (1.41-3.02)***
	52+	12 (100%)	Undefined	52+	53 (52.5%)	1.29 (0.68-2.46)

Adjusted Odds Ratio (Adj OR) was from multiple logistic regression model, accounting for all other variables in model; ‡ = significant *Type III* test result; Comparisons are for the specific within-sex binned group compared against the referent group (e.g., lowest body fat, youngest).

Note: Unpublished data