Approach to Astronaut Fitness Standard Recommendations for ISS and Exploration Mission Tasks

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DISCLOSURE INFORMATION
90TH ANNUAL SCIENTIFIC MEETING
MEGHAN DOWNS, PHD

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation

PRESENTATION FLOW

Purpose

Background on fitness standards for ISS and exploration

Team of SMEs and end-users

Approach recommendation

Standard communication and implementation recommendation

BACKGROUND

- Current muscle strength and aerobic fitness standards are intended for ISS mission tasks
- Muscle standard is based on change from pre-flight strength and there is not an existing pre-flight standard
- Aerobic standard is acceptable, but only relevant to microgravity EVA
- These standards need to be updated to reflect exploration mission task performance needs

STANDARD DEVELOPMENT: OBSTACLES & CRITICAL ELEMENTS

- **Everyone wants a standard that is easy to meet and guarantees success.**

- **Obstacles to Exploration Standard Development:**
  1. Exploration mission task performance requirements are not known
  2. There are not good 1-g analogs for some tasks
  3. It is not possible to simulate post-flight multi-system deconditioning

- Given these obstacles, it is critical to define the approach for development and effective communication on how to interpret and use the standard to the end-users.

PURPOSE

- **Big Picture Goal:** To develop evidence-based standard recommendations **for aerobic fitness and muscle strength** that are specific to exploration class mission tasks that **inform requirements, provide risk-based decision making tools to future exploration programs, and protect crew health and performance on future missions.**

- **Purpose of this Presentation:** To define the approach by which fitness related standards for exploration spaceflight missions will be developed and communicated to end-users

Note: All numbers in the recommendation approach are notional and do not represent the proposed standard

STEP 1: STANDARD DEVELOPMENT TEAM

Risk Owners

- Lead, Muscle Strength and Aerobic Fitness Risk Co-owner: Meghan Downs, PhD
- Muscle Risk & EVA Operations Risk Co-owner: Rick Scheuring, DO, MS
- Aerobic Risk Co-owner: xx

Health and Medical Technical Authorities

- Health and Medical Standards: Dave Francisco
- HMTA/CMO: Terrance Taddeo, MD

Crew Representatives

- CB: Mike Misiora and Mike Rapley

Human Performance SMEs & Study PIs

- H-3PO EVA Physiologist/EVA Operation risk owner: Jason Norcross, MS
- H-3PO Technical Lead/EVA Operation risk owner: Andrew Abercromby, PhD
- ASCR: Mark Guilliams, MS
- FMT Study PIs: Jeff Ryder, PhD, Tom Barstow, PhD, Carl Ade, PhD
- Statisticians: Al Feiveson, PhD, Millennia Young, PhD

APPROACH TO DEVELOPMENT

Approach: Use the evidence base (data and SME inputs) to the fullest extent possible to develop informed and useful standard recommendations for the "bounding" exploration tasks

1. Identify critical mission "bounding tasks"
2. Identify relevant data sources, SMEs, and limitations
3. Method for standard/risk assessment tool development
4. Assess astronaut feasibility
5. Identify limitations to the standard use
6. Determine method to communicate the standard to the end user community

DEFINE BOUNDING MISSION TASKS & STANDARD METRICS

	Vehicle Egress	0-G EVA	Partial Gravity EVA
Aerobic Fitness Standard	VO_2pk	VO_2pk	VO_2pk Other candidate metrics TBD
Muscle Strength Standard	Leg press strength Bench press strength	None	Leg press strength Bench press strength Other candidate metrics TBD

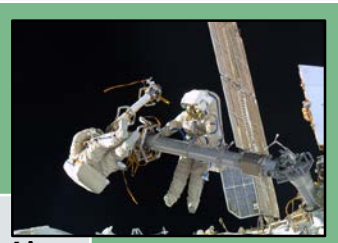
- VO_2pk can be measured pre, in, and post-spaceflight.
- The ability to assess muscle strength in-flight does not currently exist

DATA REVIEW FOR DEVELOPING STANDARD RECOMMENDATIONS"

- In-Flight Exercise Data
- Exercise hardware
- Pre, in, post-flight aerobic fitness
- Pre, in, post-flight muscle strength

0-G EVA

NBL Training



ISS EVA Metabolic Rates

Suit Characterization Studies

Capsule Egress

Functional Mission Task Study: Capsule Egress Data

ISS EVA Metabolic Rates

Suit Characterization Studies

Partial Gravity EVA

Functional Mission Task Study: Ambulation Task Data

Spacesuit Characterization Studies, walkback data

Apollo Reports

USING THE DATA TO DEVELOP THE STANDARD RECOMMENDATION

- **Ideal Scenario**: Metrics for successful task performance can be determined with a high level of confidence when there is a historical record (evidence base) of relevant data during performance of the given task
  - Most DoD field tasks can be simulated in analog environments
  - Real-time data exists for 0g EVAs

USING THE DATA TO DEVELOP THE STANDARD RECOMMENDATION

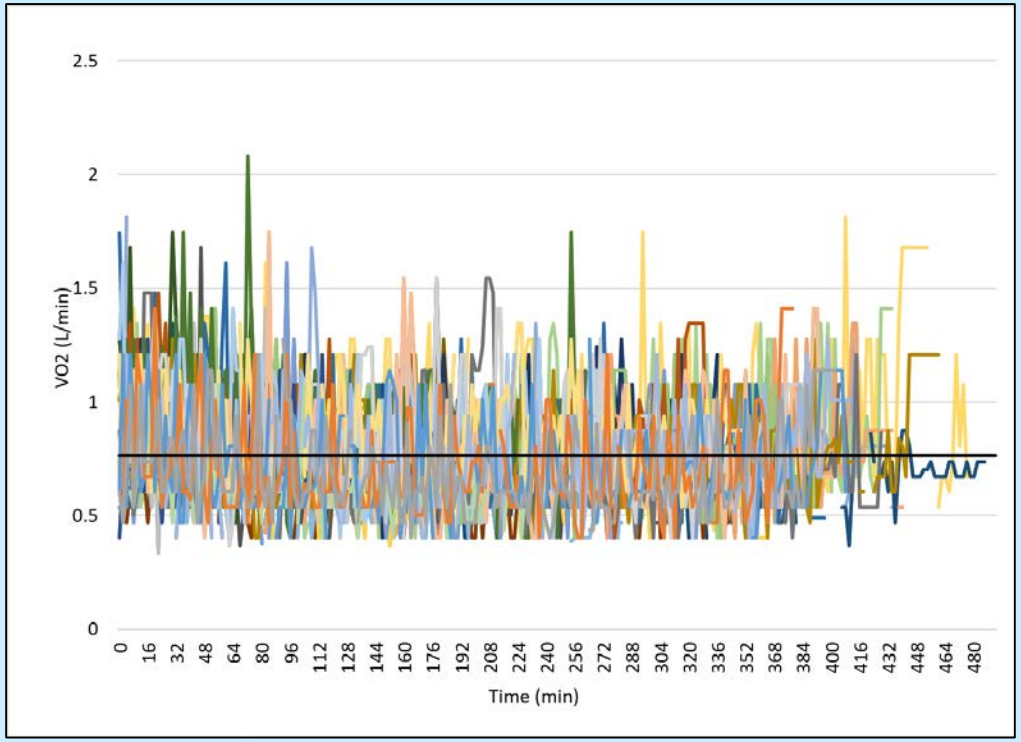
Ideal Scenario Example: Real-time data exists for 0g EVAs

Evidence base: Avg EVA VO_2 = 0.77 L/min; Avg VO_2 for highest MET rate tasks = 1.44 L/min

EVA VO_2 (0.77 L/min) should be less than 33% VO_2pk to minimize physical and potentially cognitive fatigue and reduce the risk of mistakes.

work time (hours)	%VO_2pk
4	45
8	33
10	30.5
12	28

Standard recommendation: VO_2pk = 2.33 L/min



USING THE DATA TO DEVELOP THE STANDARD RECOMMENDATION

- **<u>Exploration Mission Task Scenario</u>**: Developing standards without known task performance requirements
  - What is the critical time to egress after landing?
  - A spacesuit for partial gravity EVAs is being developed – the spacesuit will effect performance capabilities
  - We don't have design reference EVAs for the moon or Mars – how long and what tasks will be performed?

<u>SME Developed Approach:</u>

1. Identify relevant data sources, SMEs, and limitations
2. Method for standard/risk assessment tool development
3. Assess astronaut feasibility
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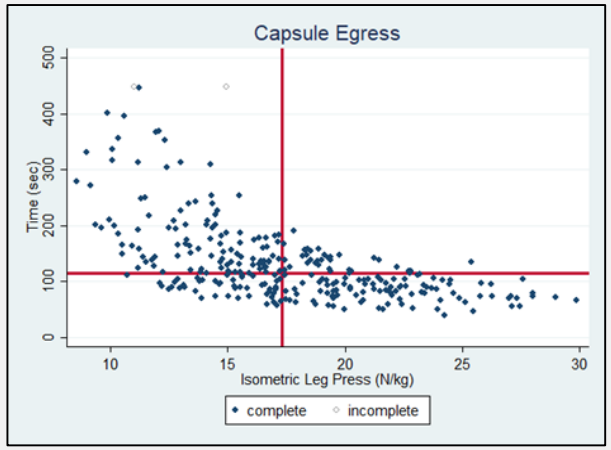
5. Determine method to communicate the standard to the end user community

EXAMPLE: USING THE DATA TO DEVELOP THE STANDARD RECOMMENDATION

- **Orion egress: There is not an absolute time for successful capsule egress. If unaided egress is required the goal is to get out as fast as possible.**



High fidelity data

- Test subject similar to the astronaut core performed capsule egress with and without added body weight (0-80%) to simulate different strength to body weight ratios (FMT study, Ryder)
- Performance time cannot be directly transferred to post-landing egress
- We can use the data to look at different percentiles of performance

Method

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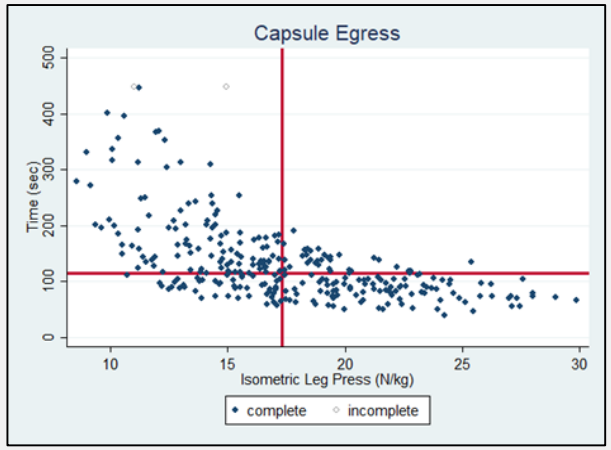

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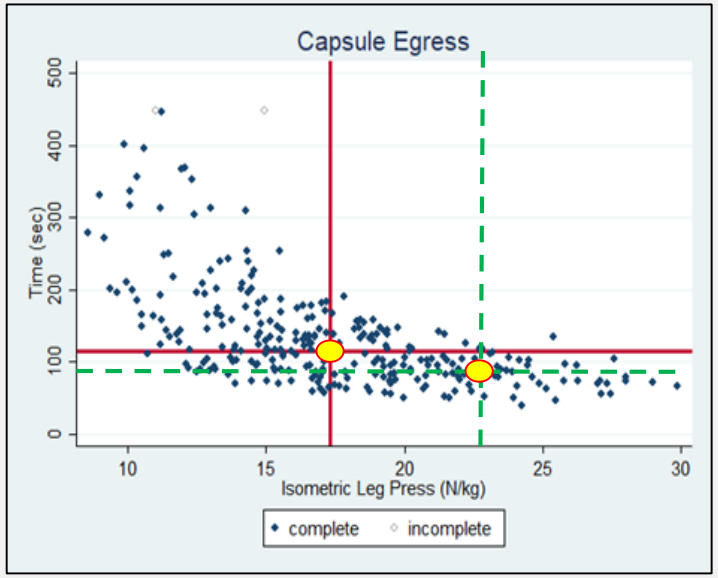

- The "breakpoints" are where gains in strength don't lead to significant gains in performance.
- Performance criteria can be set anywhere on the Y-axis and the corresponding "breakpoints" can be calculated.

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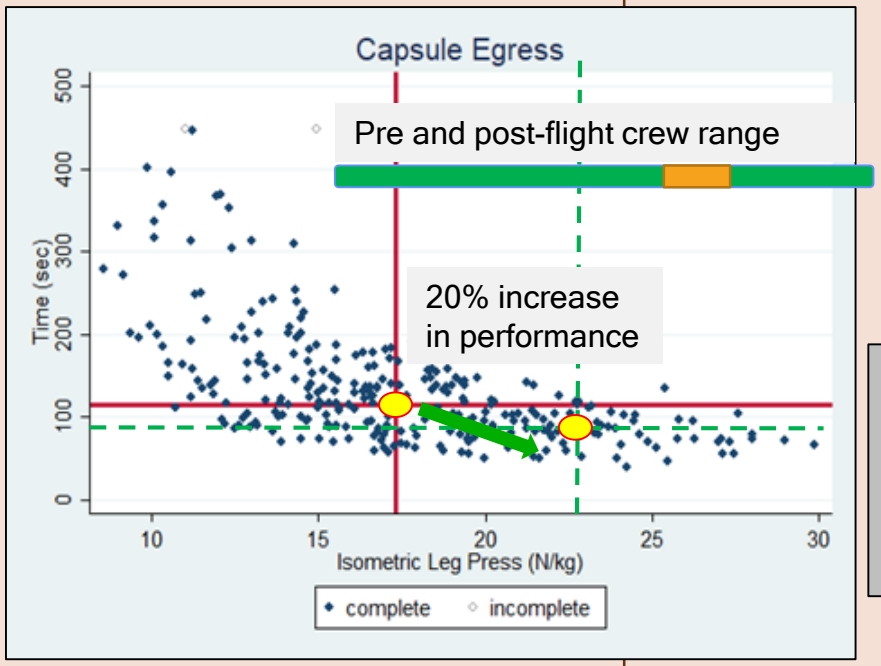
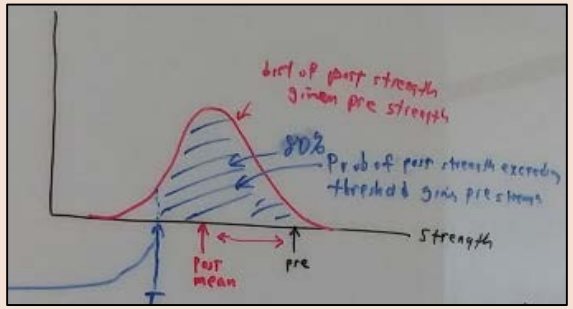
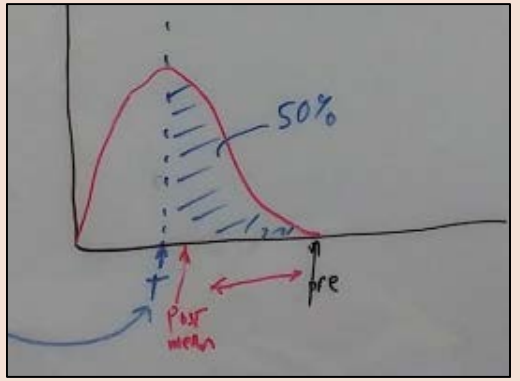




Pre-flight strength is high - 80% of astronauts with this pre-flight value would exceed the threshold post-flight.



Pre-flight strength is low - only 50% of astronauts with this lower pre-flight value would exceed the threshold post-flight.

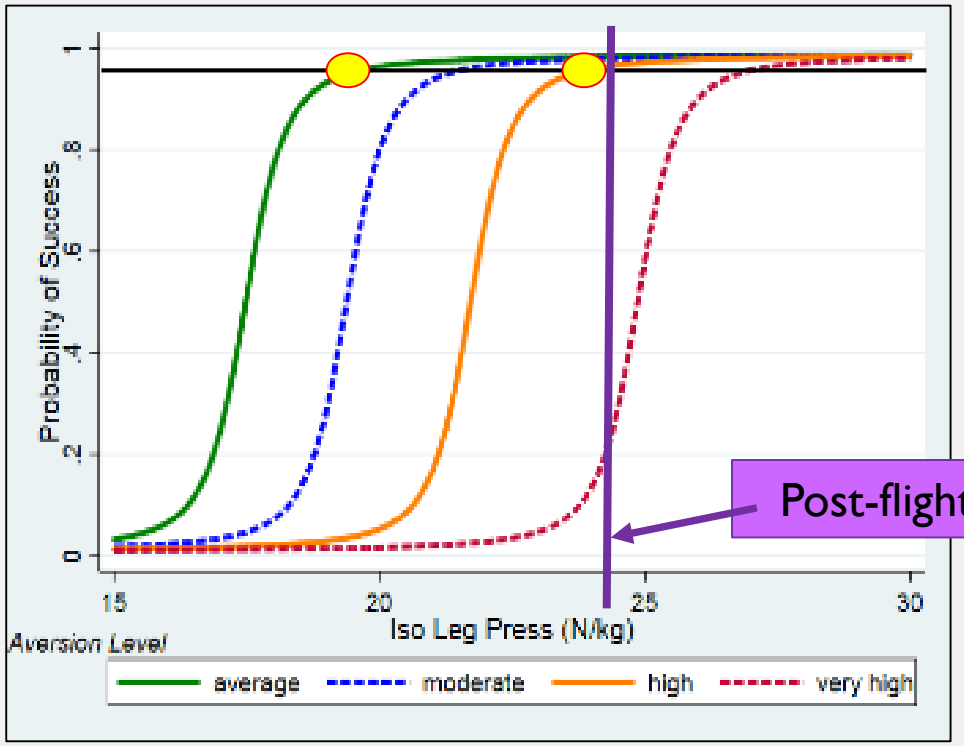
Assess astronaut feasibility

Develop Risk Based Decision Aids

To develop the decision aid tool we evaluate the probability of the post-flight strength exceeding the "breakpoint" at a given pre-flight strength in a lot of astronauts.

RISK BASED DECISION AID

- If astronauts need to egress, they need to do it well.
- A low probability of failure/high probability of success (95% confidence) should be used for the standard recommendation
- Each line color relates to the probability of completing simulated Orion egress in a given performance metric.



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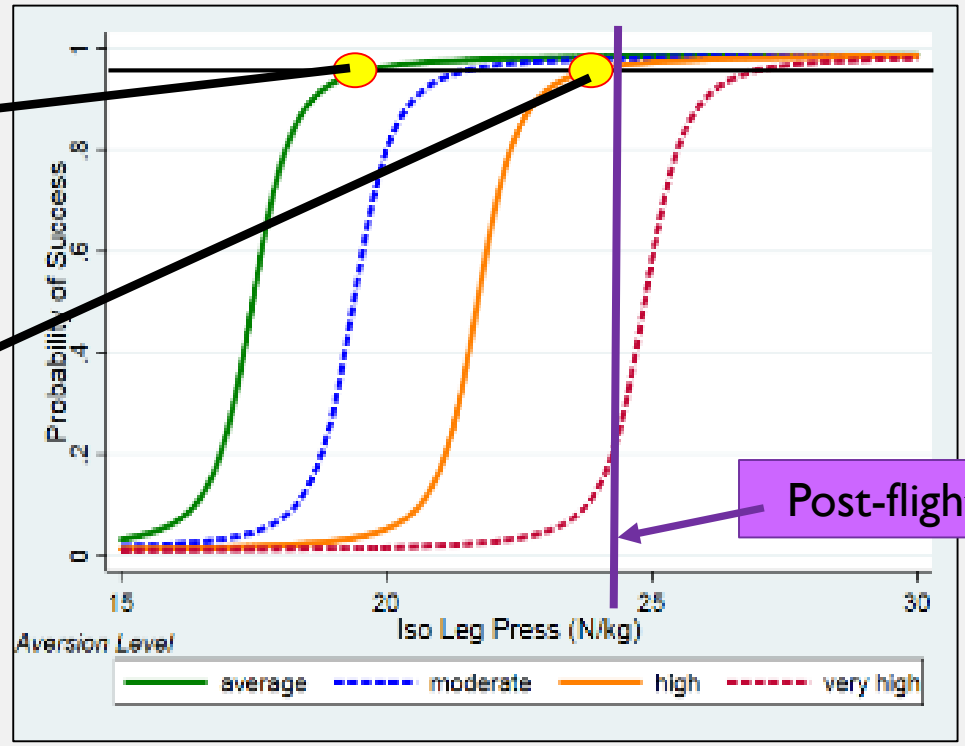
Interpretation

The yellow circle on the green line is based on the 95% probability of completing simulated Orion egress in the 50th percentile performance.

The yellow circle on the orange line is based on the 95% probability of completing simulated Orion egress in the 70th percentile performance.



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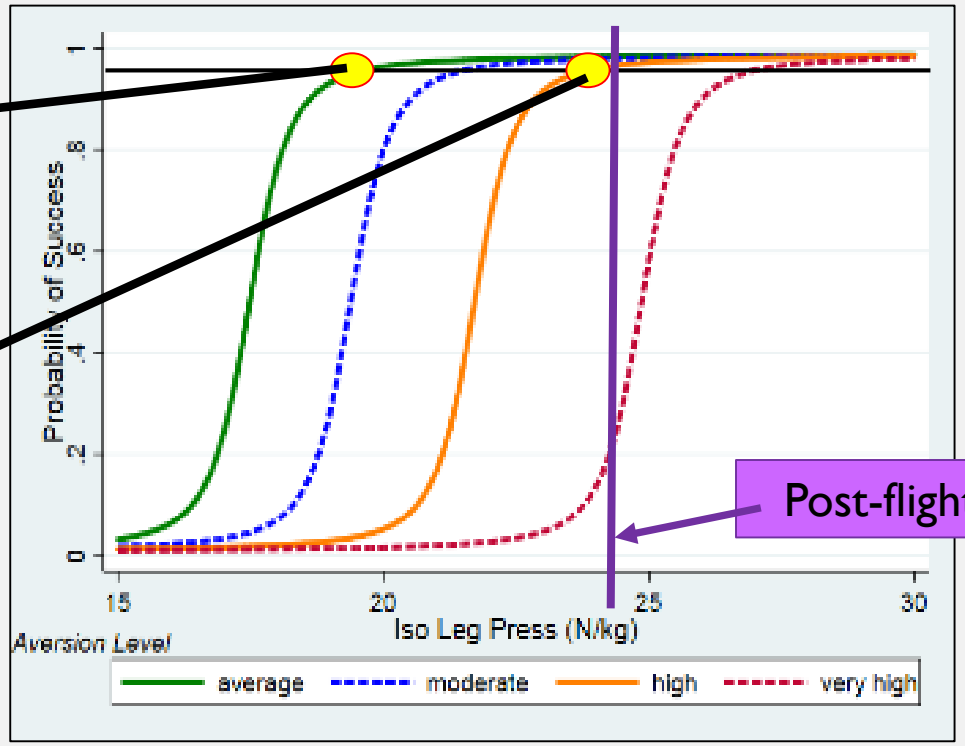
Strength gains from green to orange represents a 25% gain in performance capability



PROPOSED STANDARD LANGUAGE

Muscle Strength Standard

Muscle strength recommendations for performance of mission tasks **shall** include performance values for upper and lower body strength as recommended in Table 1. Strength values and predicted performance capabilities are provided in Figure x.

Mission Task	Isometric Leg Press Strength (N/kg body weight)	Isometric Bench Press Strength (N/kg body weight)
Capsule egress	23.0	TBD

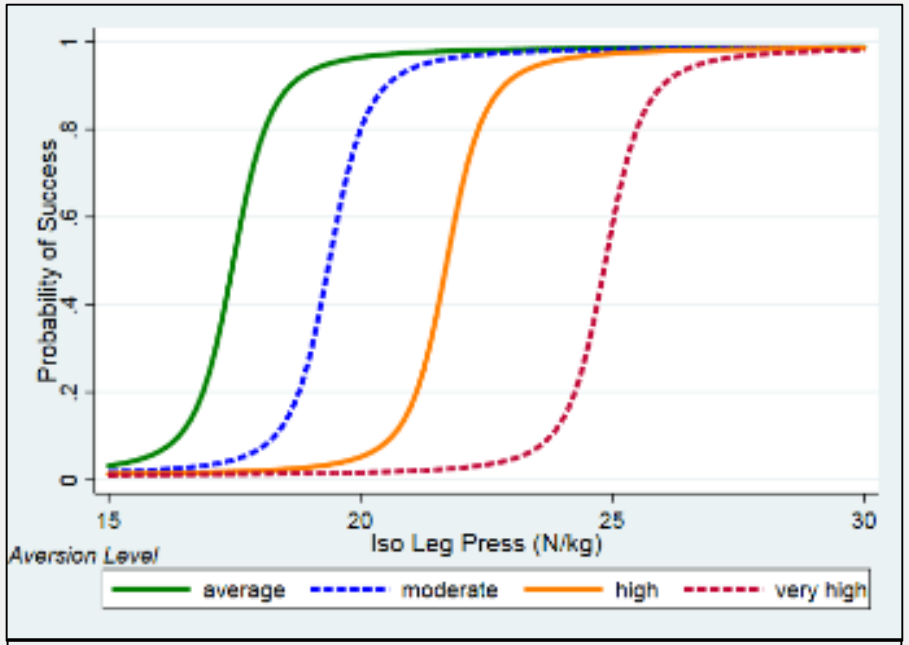


Fig X shows the probability of successfully egressing the Orion capsule in a given performance metric based on simulated Orion egress performance time.

- Muscle strength is one of many indicators for successful task performance. Other contributing factors include but are not limited to sensorimotor dysfunction, orthostatic intolerance, heat stress, human factors in vehicle design, suit fit, and practice time.
- **Accepted limitation**: The proposed standards cannot be validated or verified outside of the spaceflight experience. Consequently, the proposed standard recommendations will not be sufficient criteria to guarantee task success or failure by themselves, but are a necessary element for programs to develop risk-based requirements.

Thank You

Human Physiology, Performance, Protection, and Operations (H-3PO)

Andrew Abercromby

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Liz Goetchius

ASCR

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Rick Scheuring

Sean Roden

JSC Biostatistics

Al Feiveson

HMTA

Dave Francisco

Human Risk Community

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