

How Can we Evacuate Individuals with Disabilities from High Rise Buildings Safely and Efficiently?

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Evacuation Needs



<http://www.foxnews.com/story/0,2933,579922,00.html>



<http://highriseoperations.com/2012/04/truck-company-operations-at-high-rise-fires/>

EMS – An occupation with Significant MSD Risks

- Maguire, B.J., Hunting, K.L., Guidotti, T.L., & Smith, G.S. (2005). Occupational injuries among emergency medical services personnel. Prehospital Emergency Care, 9, 405-411.
 - Relative risk: 5.8 relative to health services
- Gershon RR, Vlahov D, Kelen G, Conrad B, Murphy L. (1995) Review of accidents/injuries among emergency medical services workers in Baltimore, Maryland. Prehosp Disaster Med., 10:14-18.
 - 43% Strains/Spains, 20% of injuries to the back
- Hogle PT, Ellis L. (1990). Evaluation of the injury profile of personnel in a busy urban EMS system. Am J Emerg Med. 8:308-11.
 - Back strain accounted for 78% of lost days.

EMS – An occupation with Significant MSD Risks

- Haynes, H.J.G., Molis, J.L., 2017. United States Firefighter Injuries – 2016, National Fire Protection Association, NFPA No. FFI10.
 - Sprains, strains, and muscular pain account for **60% of the injuries suffered by firefighters while performing non-fire emergency tasks**, such as EMS and other rescue operations
- Furber, S., Moore, H., Williamson, M., Barry, J. (1997). Injuries to ambulance officers caused by patient handling tasks. J. Occup Health Safety, 13, 259-265.
 - Most common location – private residence where **stairs and heavy patients** are contributing factors.
 - 63% of injuries were back injuries

Study Objective

- To evaluate different types of **stair descent devices** that can be used to evacuate individuals with motor disabilities from high-rise buildings.
 - Biomechanical Demands
 - Physiologic Demands
 - Efficiency

Prior Work

- Adams and Galea (2010)
 - Decreased task performance times when using a track-type device vs:
 - manually carried stair-chair,
 - an ambulance cot,
 - or a drag mattress
- The physical demands on the responders were not quantified.

Track-Chair Comparison Study

- Fredricks et al., 2006
 - Compared two track chairs
 - Modeled with the 3DSSPP
 - Substantial differences between two track-type chairs
 - Spine Compression
 - Spine Shear
 - Used two operators (leader/follower)
 - Load sharing

Study Aims

1. To quantify the differences among types of existing evacuation devices with regards to the physical demands placed on firefighters.
2. To quantify the variation in evacuation times, including occupant preparation for transport and the stair descent process, across different evacuation devices.

Study Aims (Continued)

3. To determine the impact of environmental factors including:
 - the width of the stairs,
 - the sense of urgency,

4. To assess usability issues with each of the evaluated devices through video analysis and a structured interview process.

Study Aims (Continued)

5. To understand the consumer's perspective.

Approach

- Evaluate physical demands experienced by seasoned FF as they roll/slide stair descent devices down flights of stairs.
- Physical Demands are measured using:
 - Electromyography (EMG)
 - Heart Rate
 - Self Report

Task

- Secure occupant in device
- Transport the occupant down three flights of stairs.
 - Through two landings



Experimental Design

- Factors considered
 - Device Design
 - Staircase Width
 - Urgency

Device Type

- 3 Main Categories
 - Hand-carried devices
 - Devices with stair descent tracks
 - Sled type devices





Extended Handle Stairchair



Basic Stairchair



Manual Carry



Fabric Seat

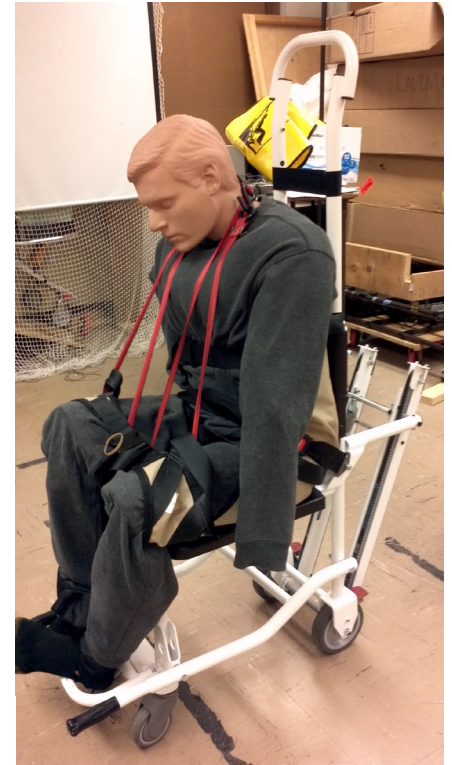
Track-Type Devices



Long Track
(Garaventa)



Rear Facing
(Glider)



Narrow
(AOK)



2-Wheeled
(Evac+Chair)



Standard
(Ferno EZ-Glide)

Sled-Type Devices



Hurricane Sandy Hits NYC



Staircase Width

- Based on NFPA 101-2009 describing staircase widths based on occupant load:

Category	Width (inches)	Capacity (persons)	Code
Narrow	36	< 50	7.2.2.2.1.2 (A)
Medium	44	< 2000	7.2.2.2.1.2 (B)
Wide	56 (52)	>= 2000	7.2.2.2.1.2 (B)

Staircase Width



Staircase Width



Urgency

- Controlled via instructions given to the subject prior to each run.
 - non-urgent - “you can take as much time as you need during this descent”
 - urgent - “the situation requires you leave the building as quickly as possible.”
 - Repeating recorded message “This is an urgent condition”

Participants-

- Recruited from a population of firefighters
- Twelve subjects/study- male
 - Height: 183 cm (175 – 196 cm)
 - Weight: 88 kg (71 – 111 kg)
 - Age: 36 yrs (24 – 61 years)
 - Experience: 9 yrs (1.5 – 23 years)
- Signed IRB approved consent documents

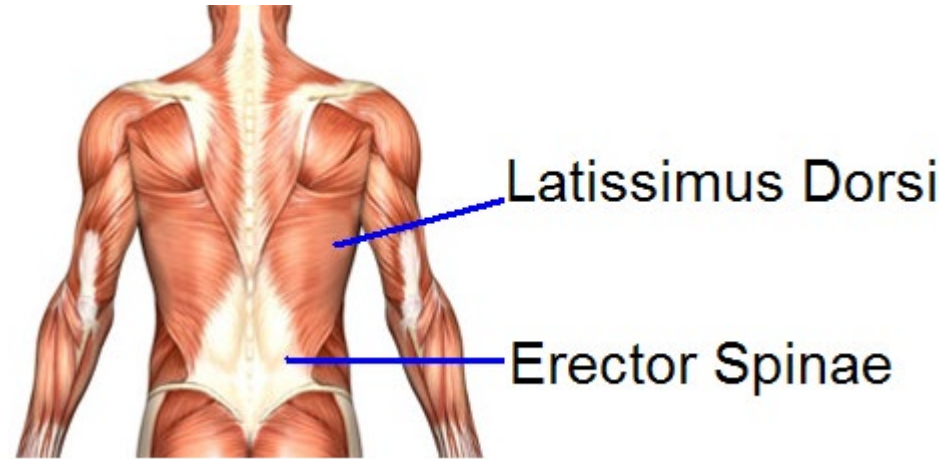
Occupant



- Rescue Randy
 - Control for size, shape, weight
 - 73 kg (160 lbs)

Measures

- Duration of evacuation
- Electromyography
 - Erector Spinae,
 - Latissimus Dorsi,
 - Deltoid,
 - Biceps
- Heart Rate
- Perceived exertion ratings
- Spine motion
- Usability information via post study interview.

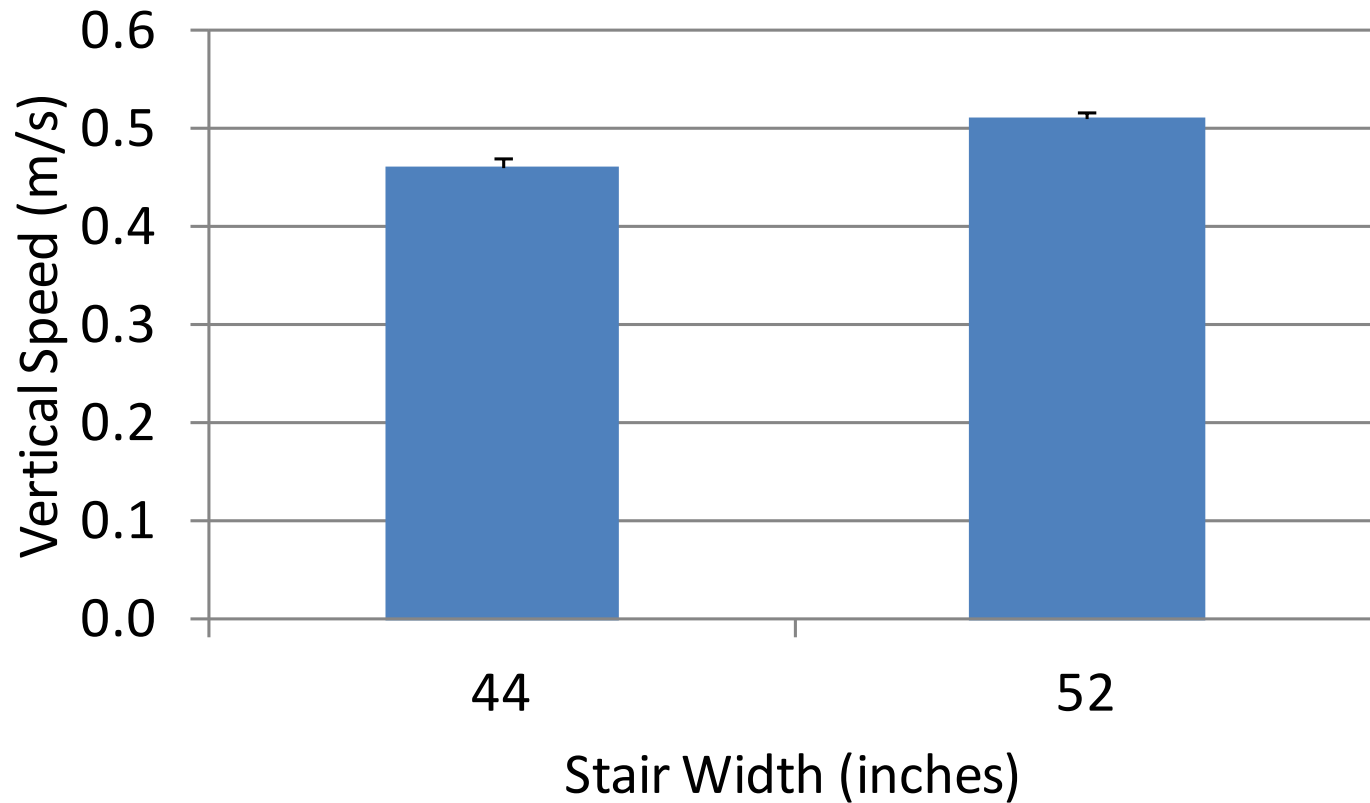


Perceived Exertion Ratings

- “How hard physically was this task for you?”
 - 0 Not at All
 - 1 Very Easy
 - 2 Fairly Easy
 - 3 Moderate
 - 4 Somewhat Hard
 - 5 Hard
 - 6
 - 7 Very Hard
 - 8
 - 9
 - 10 Very, Very Hard

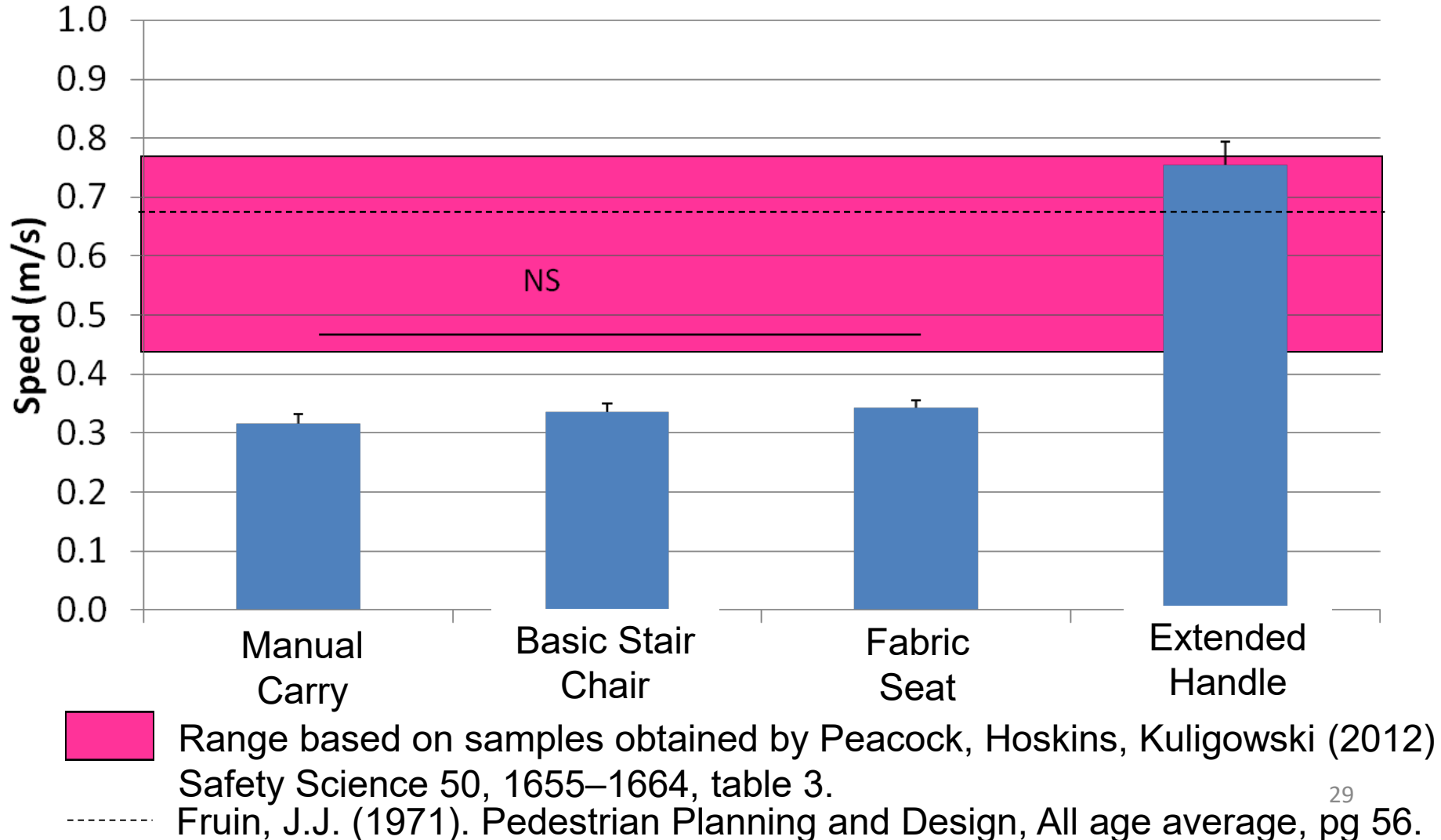
Descent Speed Results

Looking Across Studies: Descent Speed as a function of Staircase Width

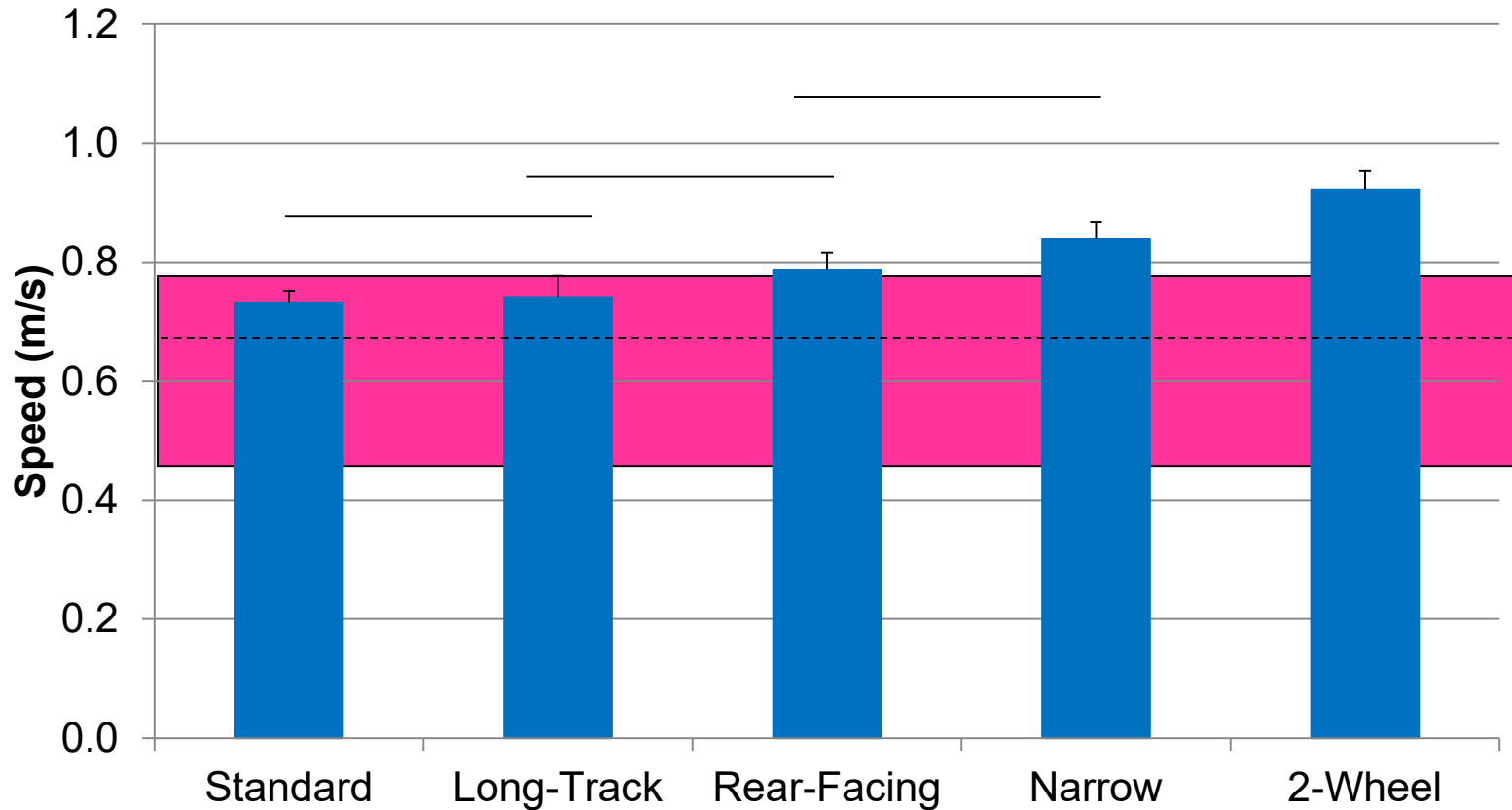


p<0.001


Stair Descent Speeds: Hand-Carried Devices (44" Staircase Width)



Stair Descent Speed by Track-Type SDDs: 44 and 52 inch staircase widths

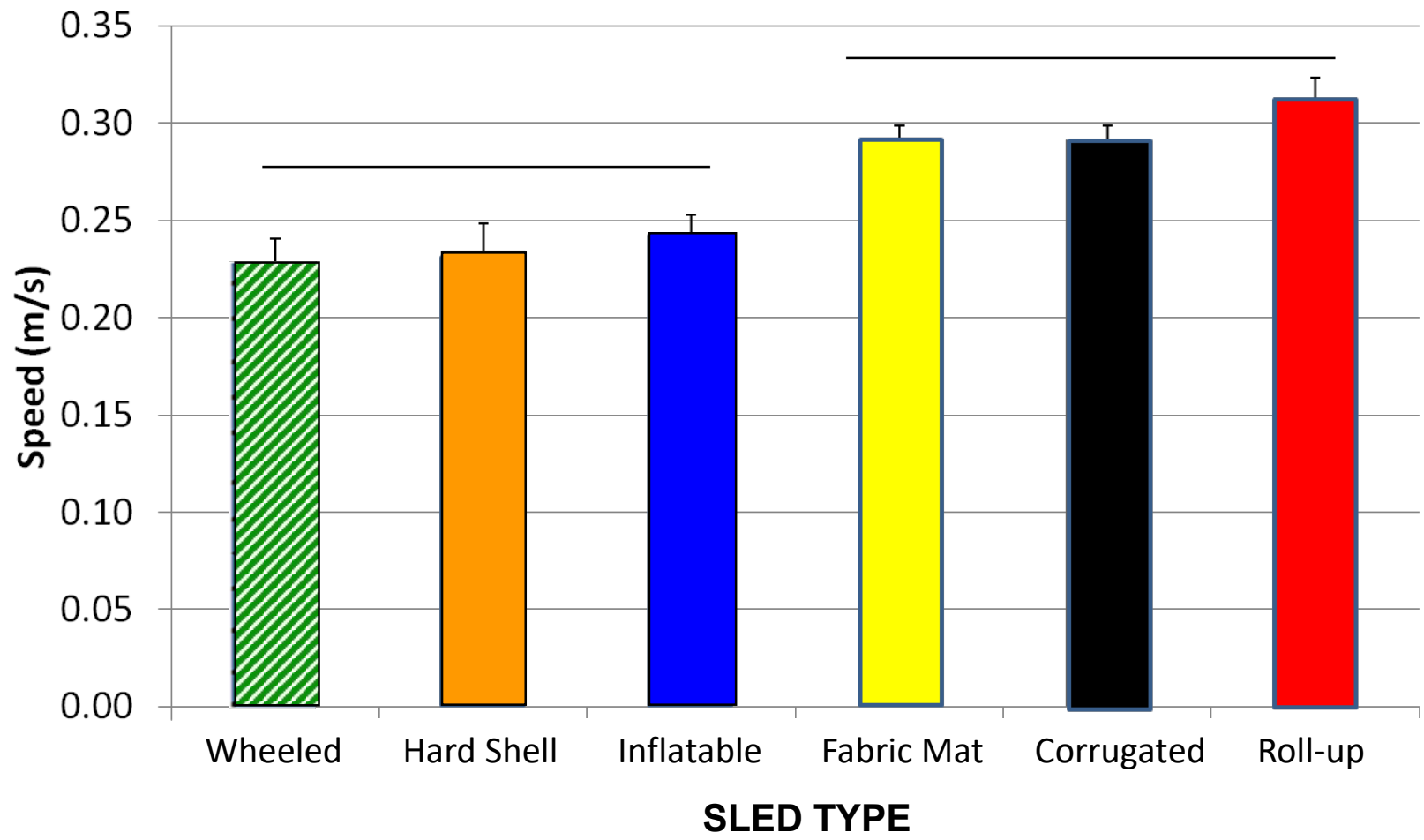


Chair Style

 Range based on samples obtained by Peacock, Hoskins, Kuligowski (2012) Safety Science 50 1655–1664, table 3.

 Fruin, J.J. (1971). Pedestrian Planning and Design, All age average, pg 56.

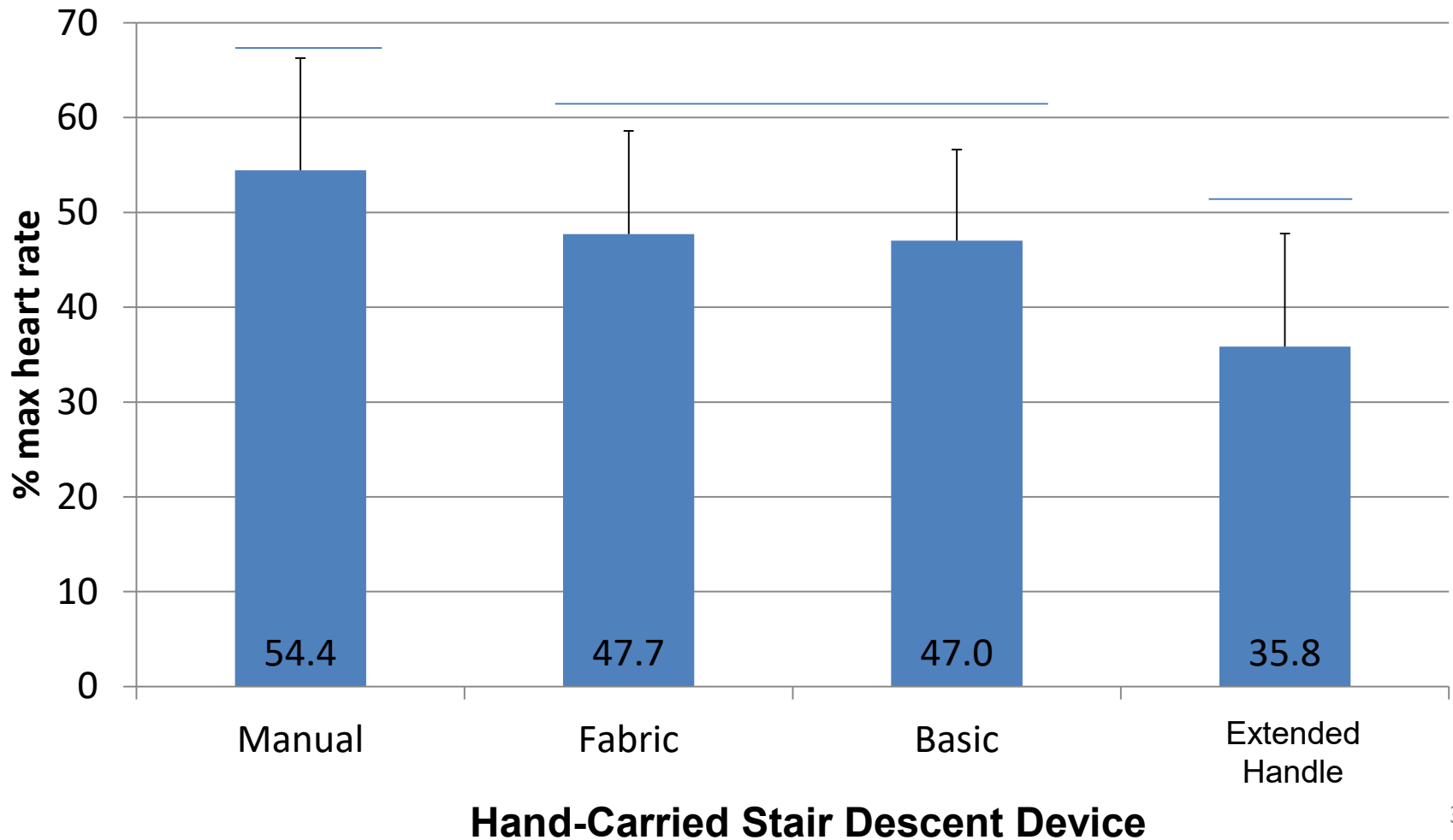
Stair Descent Speed by Sled SDDs: 44 and 52 inch Staircase Widths



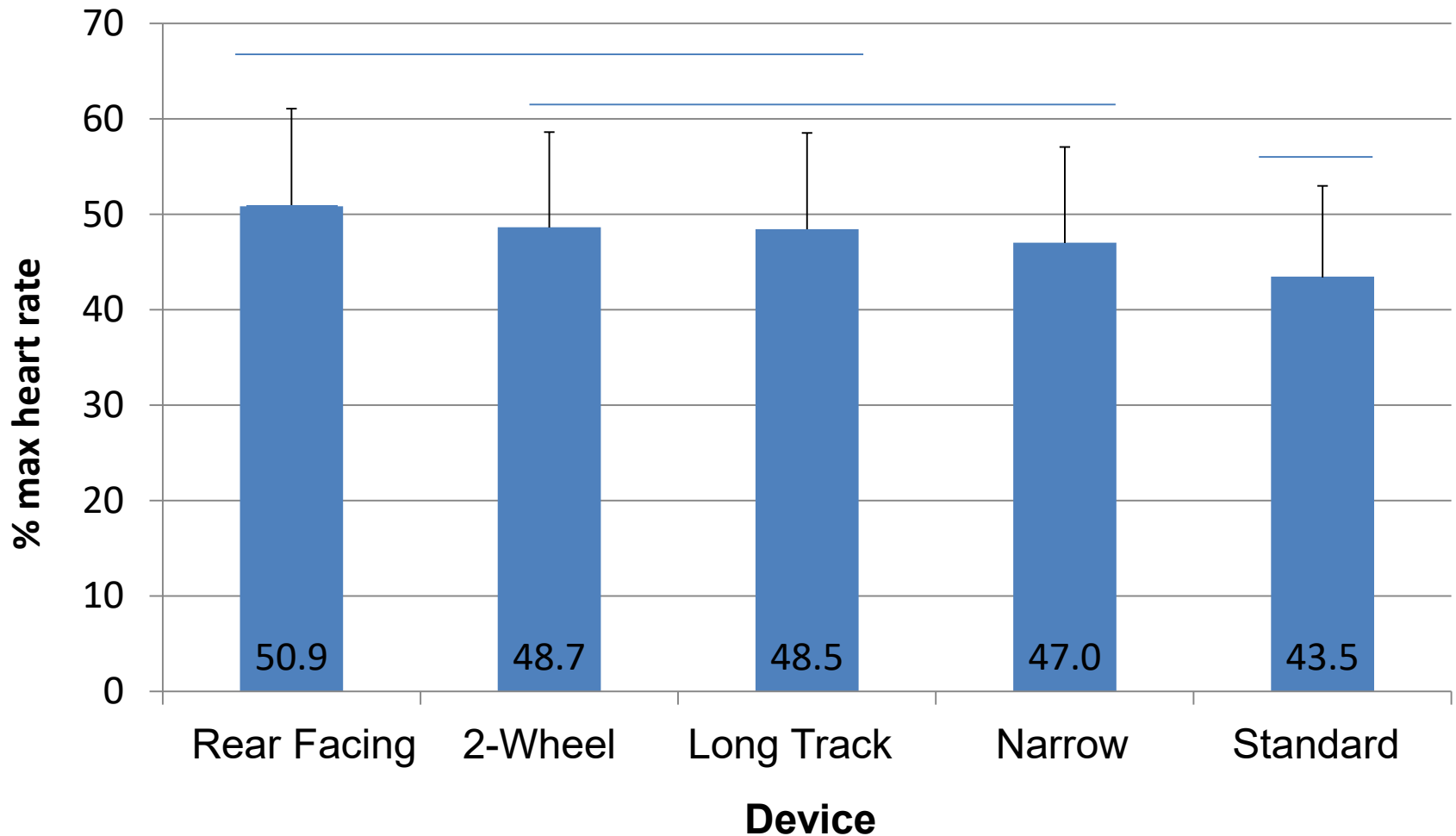
p values (Width <0.001 Device <0.001 Device x width = 0.553)

Heart Rate Results

Heart Rate – Percent Max – Hand Carried SDDs

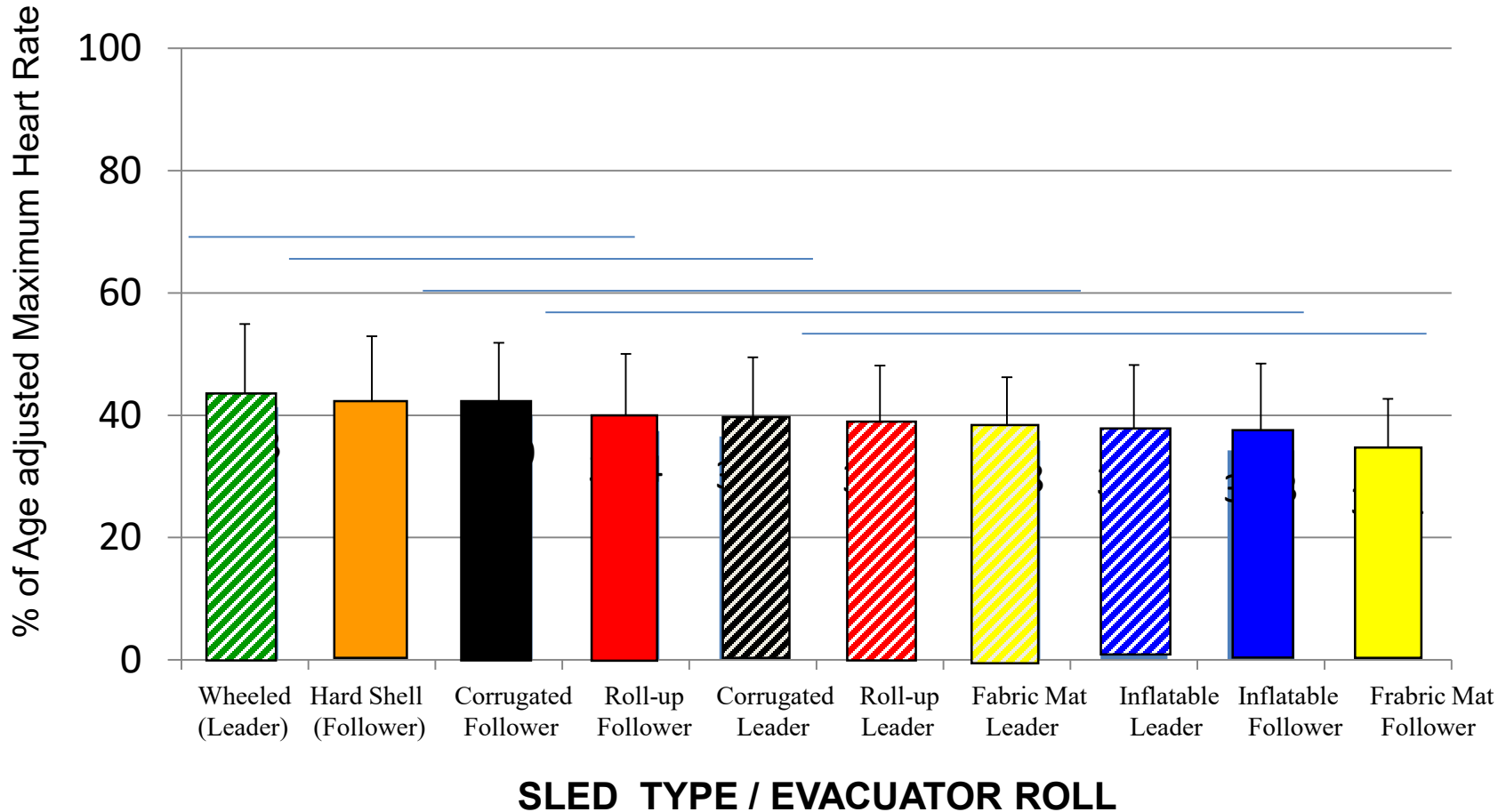


Heart Rate – Percent Max-Track-type SDDs



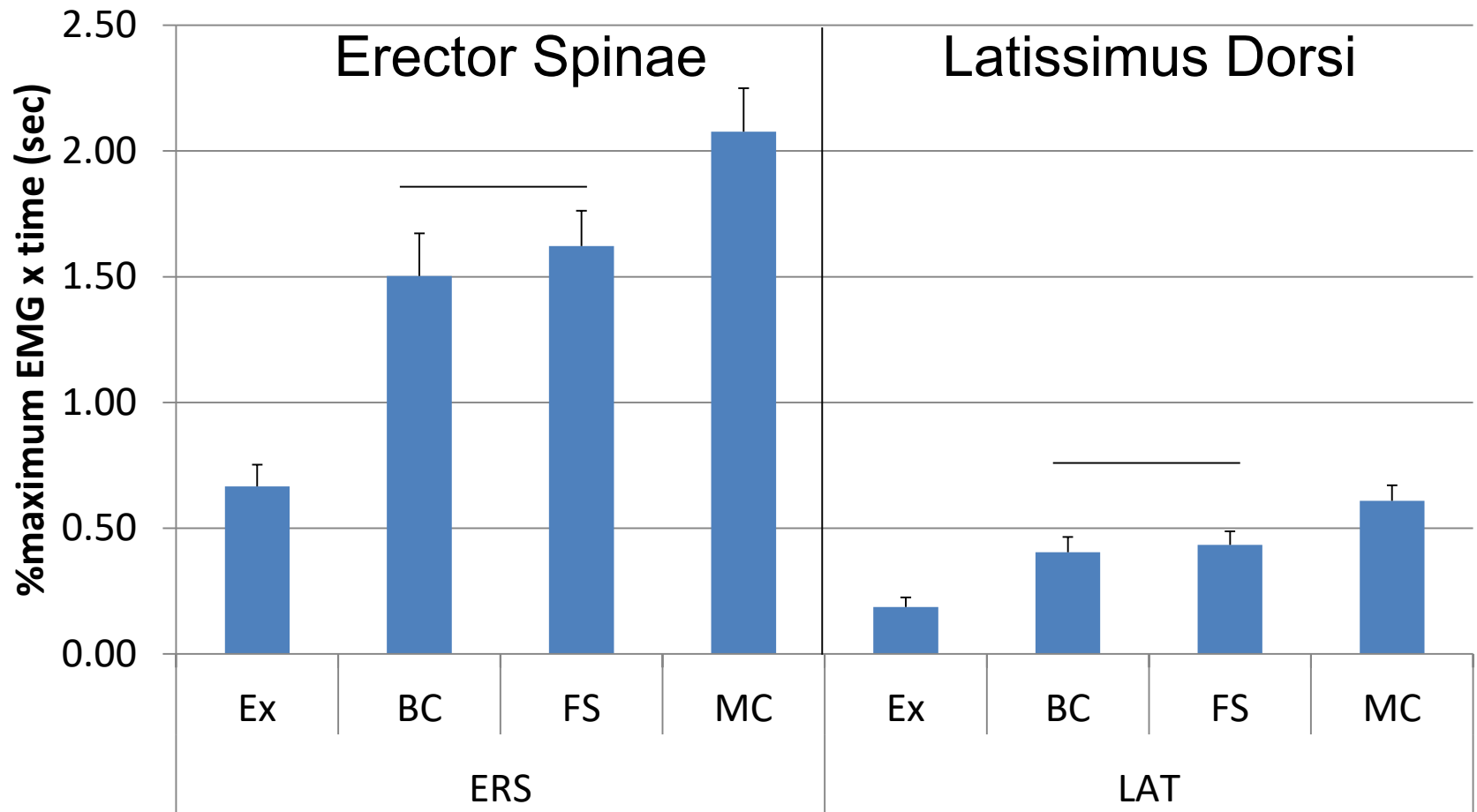
Heart Rate – Percent Max

Sled Type SDDs



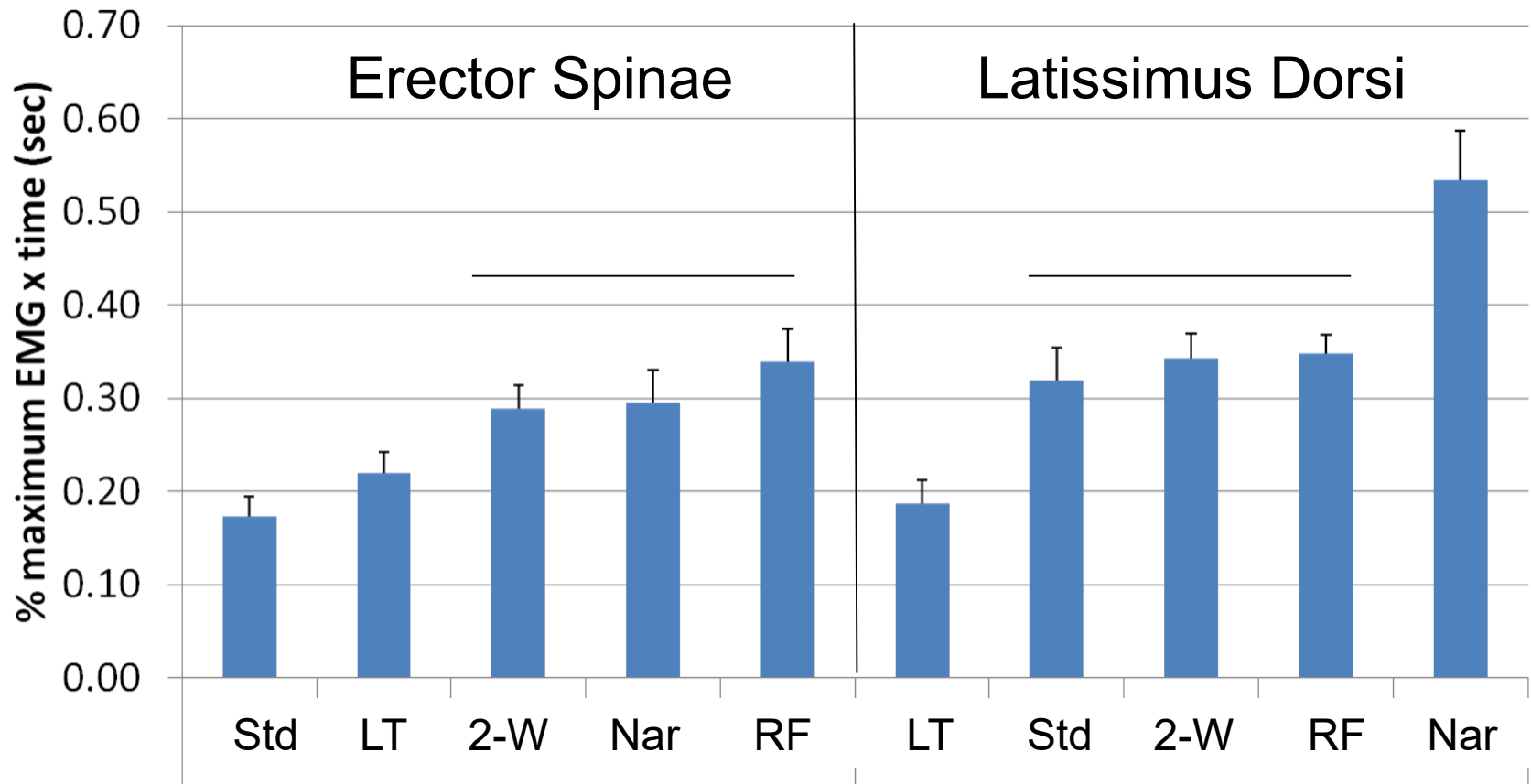
Results – Muscle Use

Hand-Carried SDDs – Stair Data Mean*time, (44" Width)



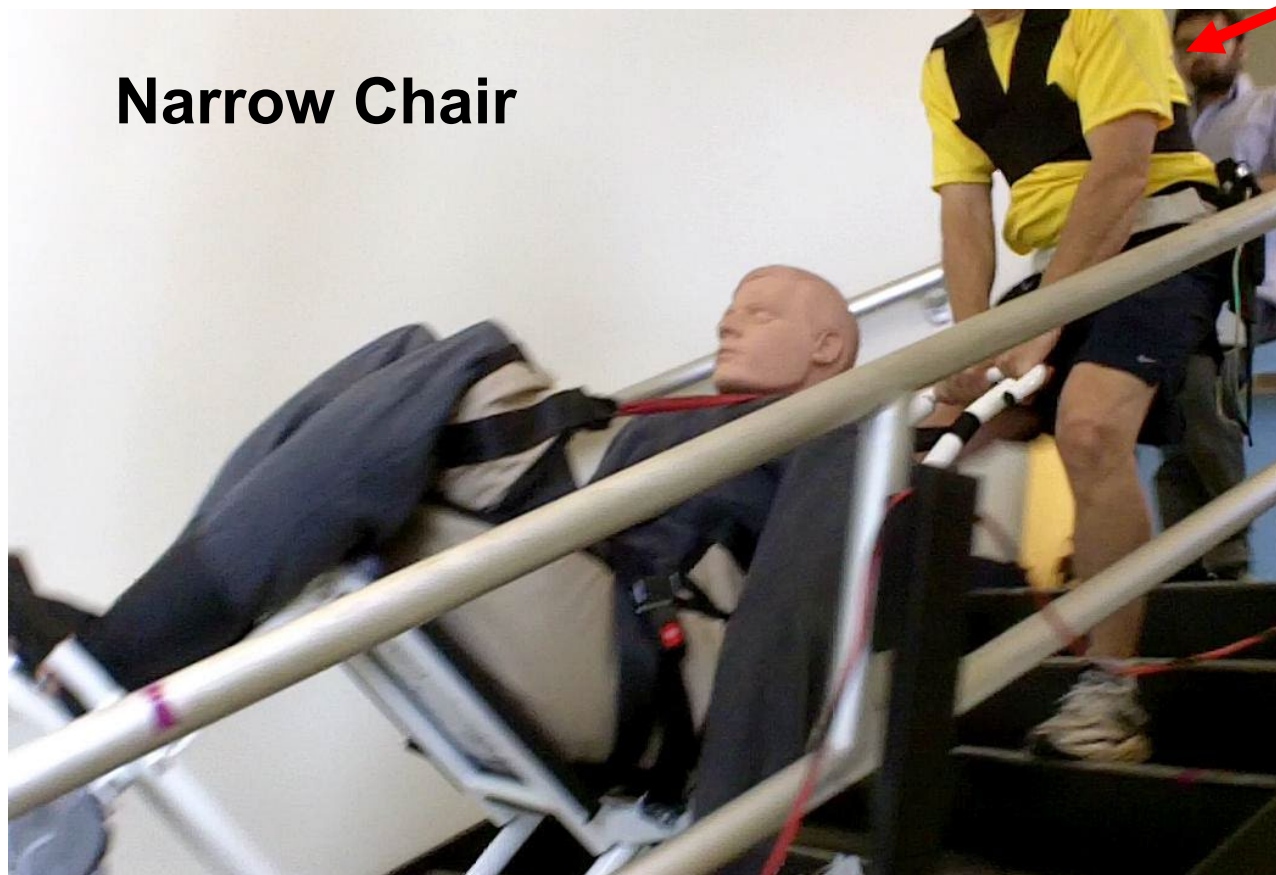
BC=Basic / **FS** = Fabric Seat / **Ex** = Extended Handles / **MC** = Manual Carry

Track Type SDDs: Stair Data Mean*time (1.12 and 1.32m):



2-W=2-Wheel / Nar = Narrow / Std = Standard/ RF = Rear-Facing / LT = Long-Track

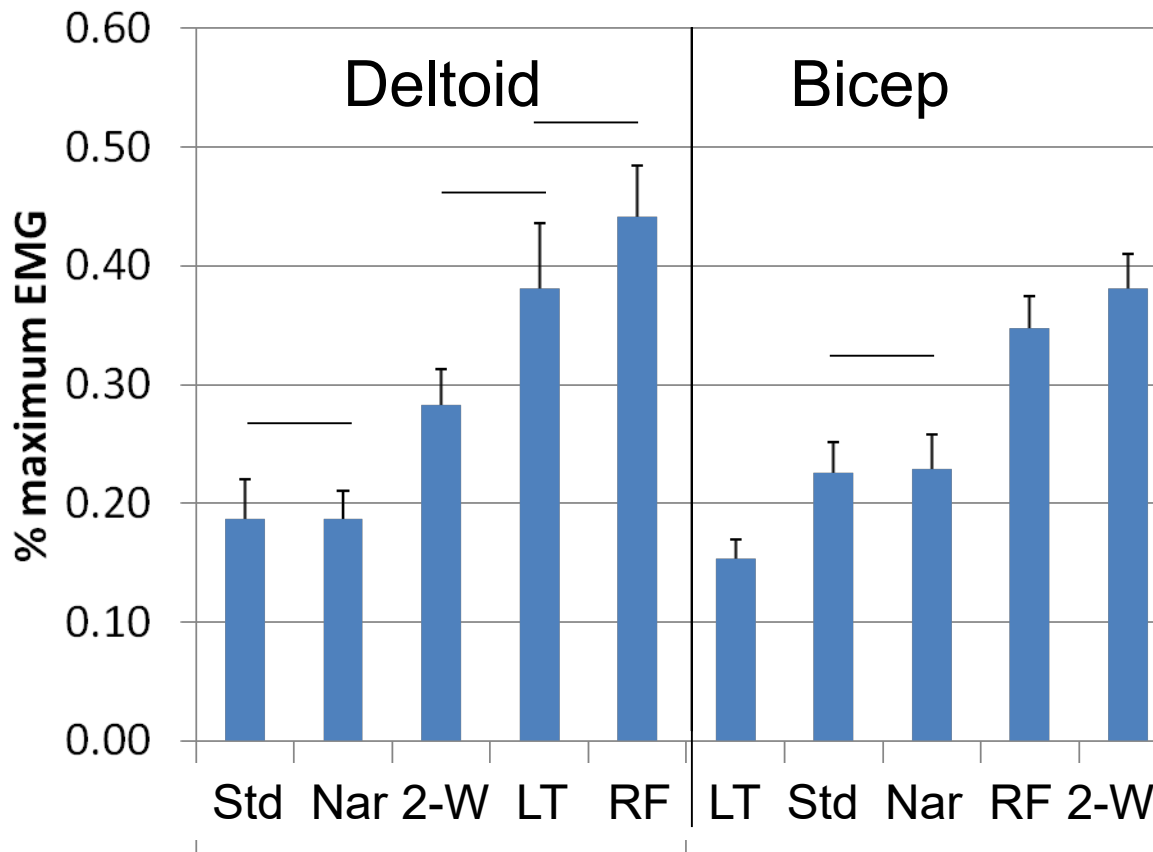
**Latissimus
Dorsi**



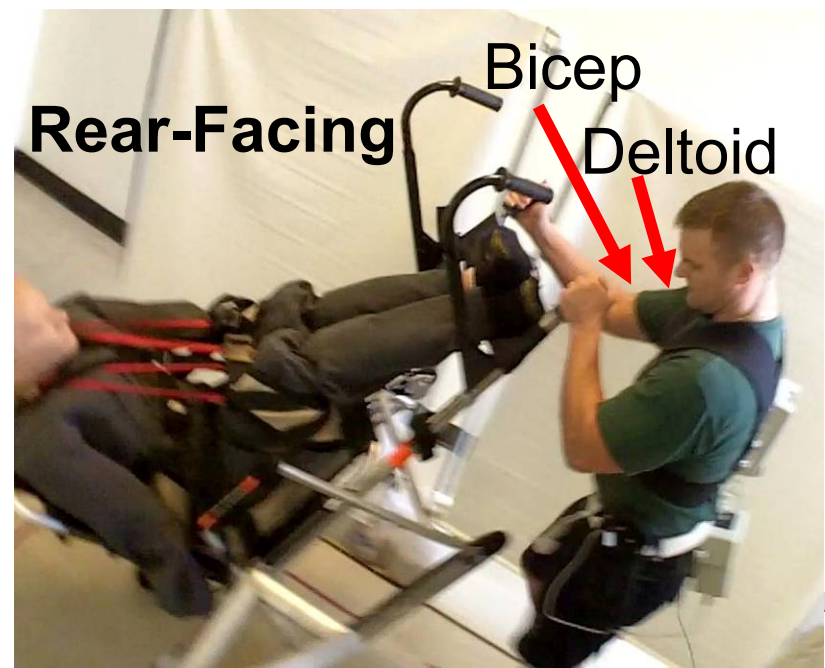
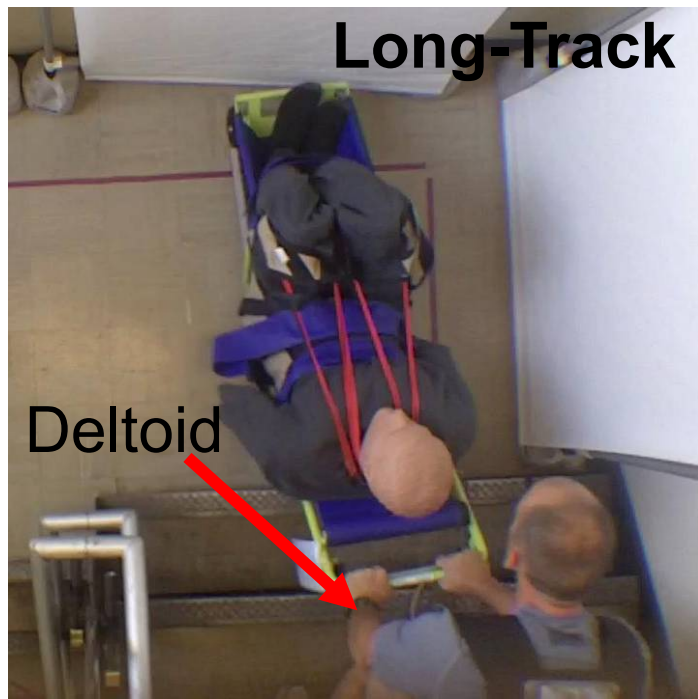
Narrow Chair

Track Type SDDs: Landing

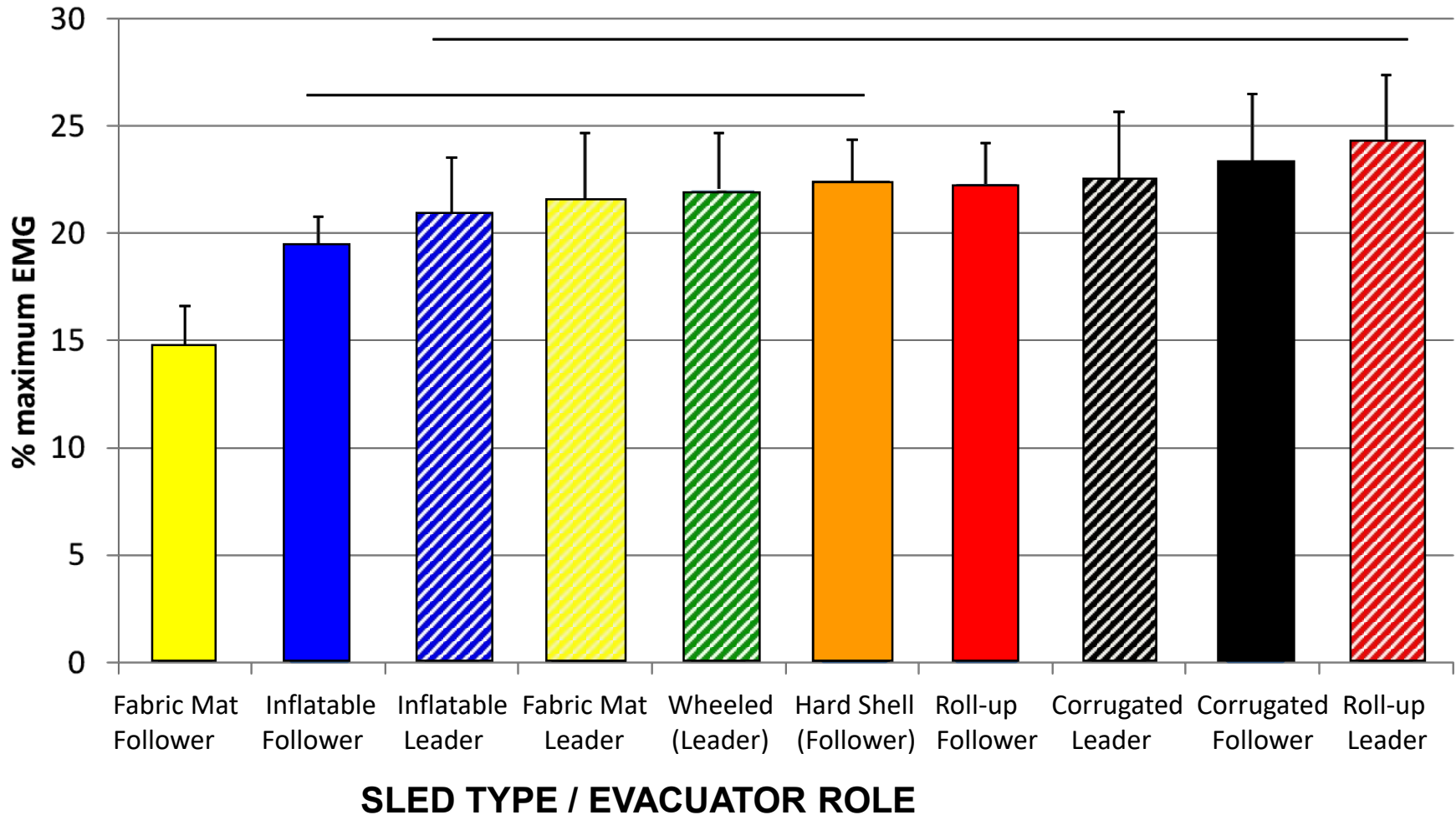
(1.12 and 1.32m): Arm Muscles - 90th percentile



2-W=2-Wheel / **Nar** = Narrow / **Std** = Standard / **RF** = Rear-Facing / **LT** = Long-Track

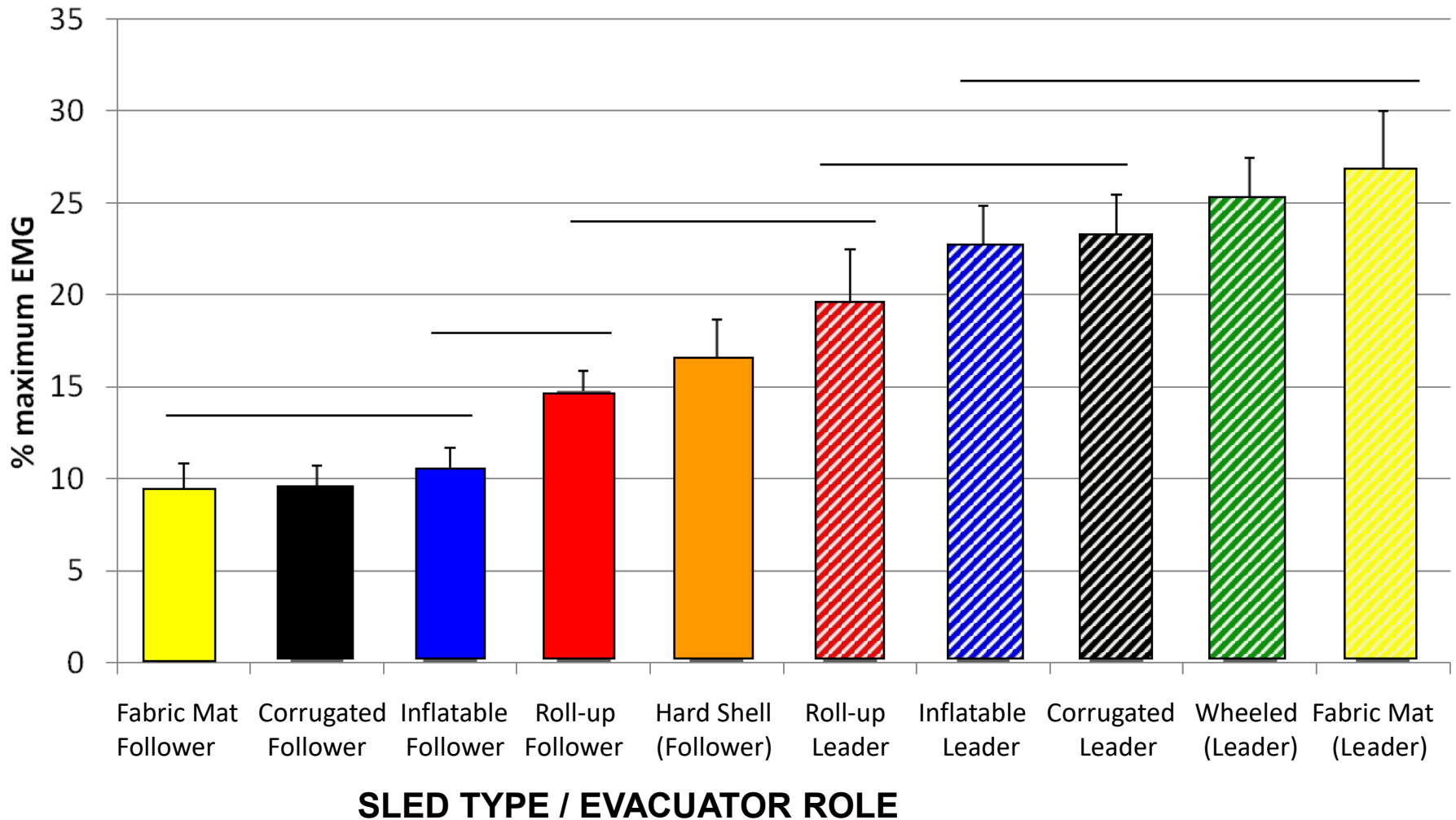


Sled-Type SDDs: Stair Data Erector Spine (Back) Muscles



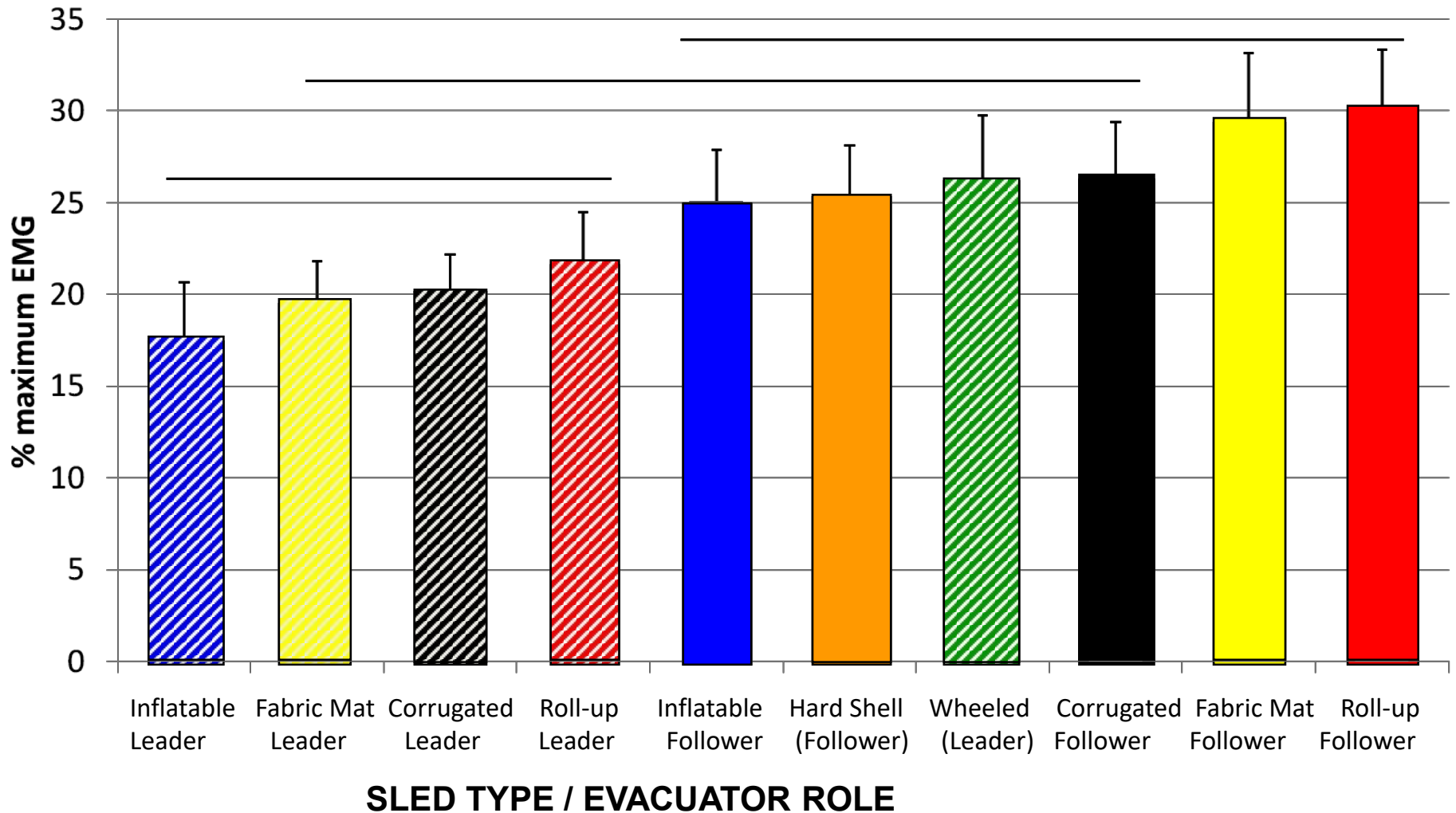
Sled-Type SDDs: Landing Data

Latissimus Dorsi Muscles



Sled-Type SDDs: Landing Data

Bicep Muscles



Objective Measures - Analysis Summary

Device	Positives	Negatives
Hand-Carried	Less Expensive	Higher Physical Demands Slower – Unless lead person can face forward
Track-type	Reduced Back muscle use – Faster	Latissimus use – on stairs, landings
Sled-type	Low muscle demands on stairs.	Transfer in/out, High demands on Landing

Hand-Carried SDDs-Interviews

Device:	Basic Stair Chair	Extended Handle Stair Chair	Fabric Seat	Manual Carry
Positive Comments	<ul style="list-style-type: none"> • Lighter • Smaller • Easy operation • More Portable • Works in narrow spaces • Can keep arms straight 	<ul style="list-style-type: none"> • Easier to set up • All components lock • Wider • Natural position • Foot spacing better • Hands shoulder-width apart • Synchronizing better • Can go faster 	<ul style="list-style-type: none"> • Handy • Easy to have in small bag • Easy operation • Occupant torso up, away from body • Can keep arms straight • Less room required to turn 	<ul style="list-style-type: none"> • Easy, quick, gets job done • Can hold weight against chest • No rocking • Arms around occupant • Less anxiety • More secure • Requires less room to make turn • OK for 1-2 floors
Negative Comments	<ul style="list-style-type: none"> • Too narrow • Hard to lift • Footing a problem • Synchronizing with partner a problem • Unstable – side to side • Rear handles too short • Rear handles do not lock 	<ul style="list-style-type: none"> • Width makes it difficult to turn corners in tight spaces • Handle height • Difficult to lift higher • Difficult clearing steps during urgent condition (arms are at 90-degrees) 	<ul style="list-style-type: none"> • Cumbersome to get occupant on it • Straps get in the way • Handles hurt hands • Need to use wider stance • Not sturdy enough • Cannot stop on steps or landing to rest 	<ul style="list-style-type: none"> • Difficult to grip occupant, especially larger individuals • Stressful, especially for operators in turnout gear • Limits dexterity • Cannot see stairs • Cannot stop on stair to rest

Track-type SDDs - Interviews

Device	Narrow	2-Wheel	Standard	Long Track	Rear Facing
Pros	<ul style="list-style-type: none"> • Works well in narrow space • Easy to move from track to wheel • 4 wheels (<i>available when on landing</i>) • Liked tracks • Easy to pull back (<i>easy to prepare for the stairs</i>) • Brakes (<i>has a brake system</i>) • Smooth ride • Easy (to get) around corners 	<ul style="list-style-type: none"> • Simple, Fast ,Little effort to operate: maneuverability, and steering • Good wheel placement - patient weight is between you and the wheels • Moved easily on stairs • Good for apt building and for lay people to use • Handle bar with curve • Didn't have to bend over as much 	<ul style="list-style-type: none"> • Easier to operate • 4 wheels on landing • Easy to use – (tracks) caught (gripped) stairs well • Sturdy, Wider • Easy to steer • Easy to turn on landing • Doesn't take off on you 	<ul style="list-style-type: none"> • Liked brake • Tracks can stop device • More controlled speed • Strap easy to put on but a little cumbersome 	<ul style="list-style-type: none"> • Descent was smooth • Had control on stairs • Liked patient facing me – can observe patient • When tilt patient back, (their) legs don't get in way so (I) can make a tighter turn • Treads easy to control
Cons	<ul style="list-style-type: none"> • Narrow device • Rocks a lot with larger patient • Tended to tilt sideways • Slides sideways • No place to kick it back like on hand truck • Hand position limits balance 	<ul style="list-style-type: none"> • Takes a little time to get used to • Hard to maneuver corner on narrow staircase • Can't put (<i>rear</i>) wheels down at end of stairs (<i>when on landing</i>) • (<i>Rear</i>) Wheels not in fixed down position • On landing, bar in front of wheels got in way 	<ul style="list-style-type: none"> • More difficult to set up • Noisy – minor issue • Lap swivel belt hard to use 	<ul style="list-style-type: none"> • Most difficult to use • Rough (difficult) transition from stairs to landing • Braking system is counter intuitive • Handle too low • Operator's foot got caught on back bar with weight of patient on his toes 	<ul style="list-style-type: none"> • Hard to maneuver because of length • Have to change hand position while in motion • Requires large radius for turning • Required a lot of lifting at turns and therefore more energy • No second set of wheels to put device down (<i>during turn</i>) • Patient faces you ⁴⁷ may be uncomfortable for patient

Sled Type SDDs– Interviews

Device	Corrugated	Fabric Mat	Hard Shell	Inflatable	Roll-up	Wheeled
Positive Design Features	2-Handle straps – good length Easy to get around corner Low profile	Wide Strap- Good length Good Friction Easy to get around corner	None	None	More rigid – less lateral swing Easy to get around corner	Friction from material
Negative Design Features	Length makes getting around corner tough	None	Lack of control Hard to turn Strap to long Strap could slip	Top heavy-tendency to tip Hard to get around corner Bulky	Could slide to fast Long thin strap difficult to grip*	Position of single operator in front of patient / Bending Head-end swing on landing, Awkward to push down on patient’s legs
% that would Recommend* Fire service / Building owners	42% / 67%	50% / 58%	0% / 25%	0% / 25%	58% / 58%	8% / 25%

Consumer Opinion Study

- 2 Components
 - First Impressions
 - Collect initial perceptions of the 13 devices used in the prior studies
 - Asked which, if any, devices they would like to try
 - Post descent impressions
 - Participants will be taken down 2 flights of stairs in up to 5 different devices.

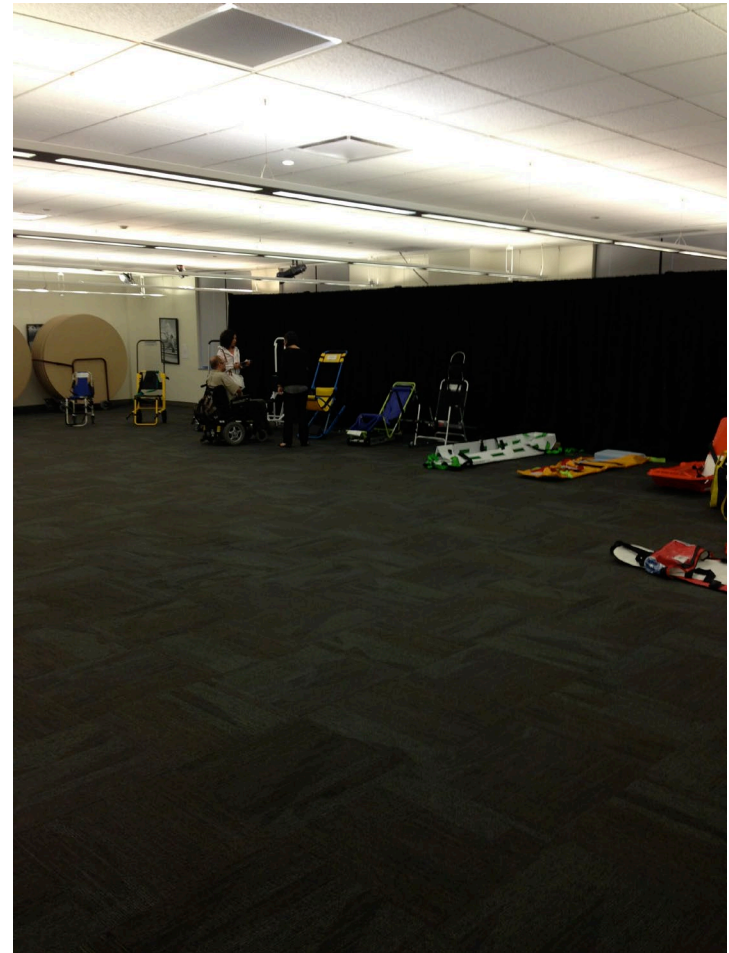
Initial Impression Survey

Transfers

Safety

Security

Nervousness



Initial Impression Survey

1. How easy would it be for you to transfer into the device?

very difficult / difficult / somewhat difficult/ somewhat easy / easy / very easy

2. How easy would it be for you to transfer out of the device?

very difficult / difficult / somewhat difficult/ somewhat easy / easy / very easy

3. How safe would you feel riding in this device?

very unsafe / unsafe / somewhat unsafe / somewhat safe / safe / very safe

4. How securely do you think the straps would hold you?

very unsecurely / unsecurely / somewhat unsecurely / somewhat securely / securely / very securely

5. How nervous would you be about riding in the device?

very nervous / nervous / a little nervous / not at all nervous

Post-Ride Survey

1. How easy was it for you to transfer into the device?
very difficult / difficult / somewhat difficult/ somewhat easy / easy / very easy
2. How easy was it for you to transfer out of the device?
very difficult / difficult / somewhat difficult/ somewhat easy / easy / very easy
3. How safe did you feel riding in this device?
very unsafe / unsafe / somewhat unsafe / somewhat safe / safe / very safe
4. How securely did the straps would hold you in the device?
very unsecurely / unsecurely / somewhat unsecurely / somewhat securely / securely / very securely
5. After having ridden in this device, how nervous would you be if we asked you to repeat the ride in the device?
very nervous / nervous / a little nervous / not at all nervous
6. For an emergency evacuation, were you sufficiently comfortable riding in the device? (Y/N)

After the completion of all rides selected by a participant...

- Which of these devices would be acceptable to you for emergency evacuation from a multi-story building?
- Are there any specific design features you liked or disliked about the devices you rode in today? Please explain.
- Is there anything else you would like to tell us about the devices you have seen today?

Participants

- **Total**
 - 14 participants
 - 8 male
 - 6 female
- **Age range**
 - 29 – 63 years (avg. 49.2 years)
- **Weight**
 - 106 – 365 lb (avg. 208.6 lb)



Participants

- **Disabilities**

- Amputation, arthritis, CVA, diabetes, hearing impairment, low back pain, low vision, paraplegia, quadriplegia, post-polio, spina bifida

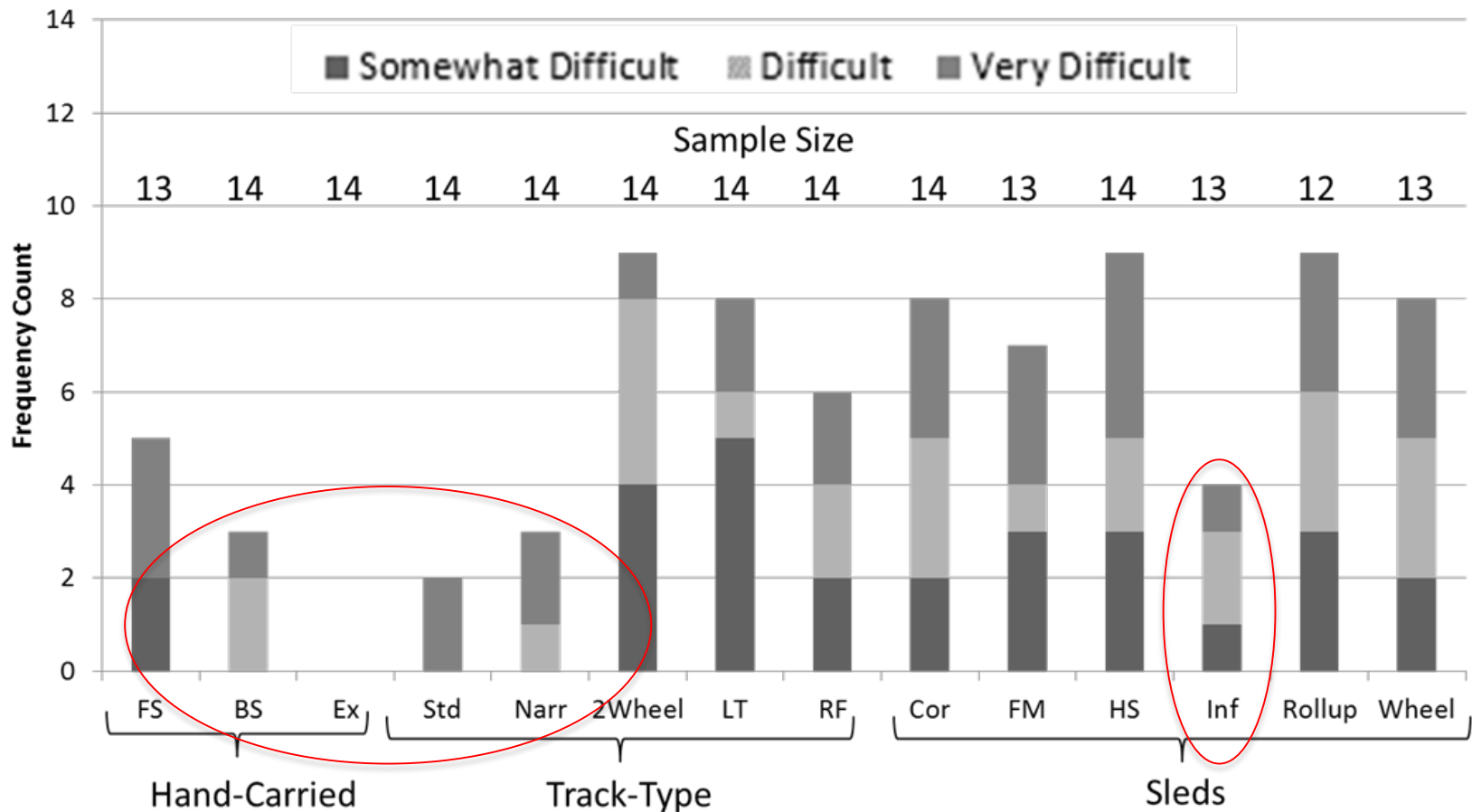
- **Mobility aids**

- Cane, walker, manual wheelchair, powered wheelchair, prostheses



Initial Impressions

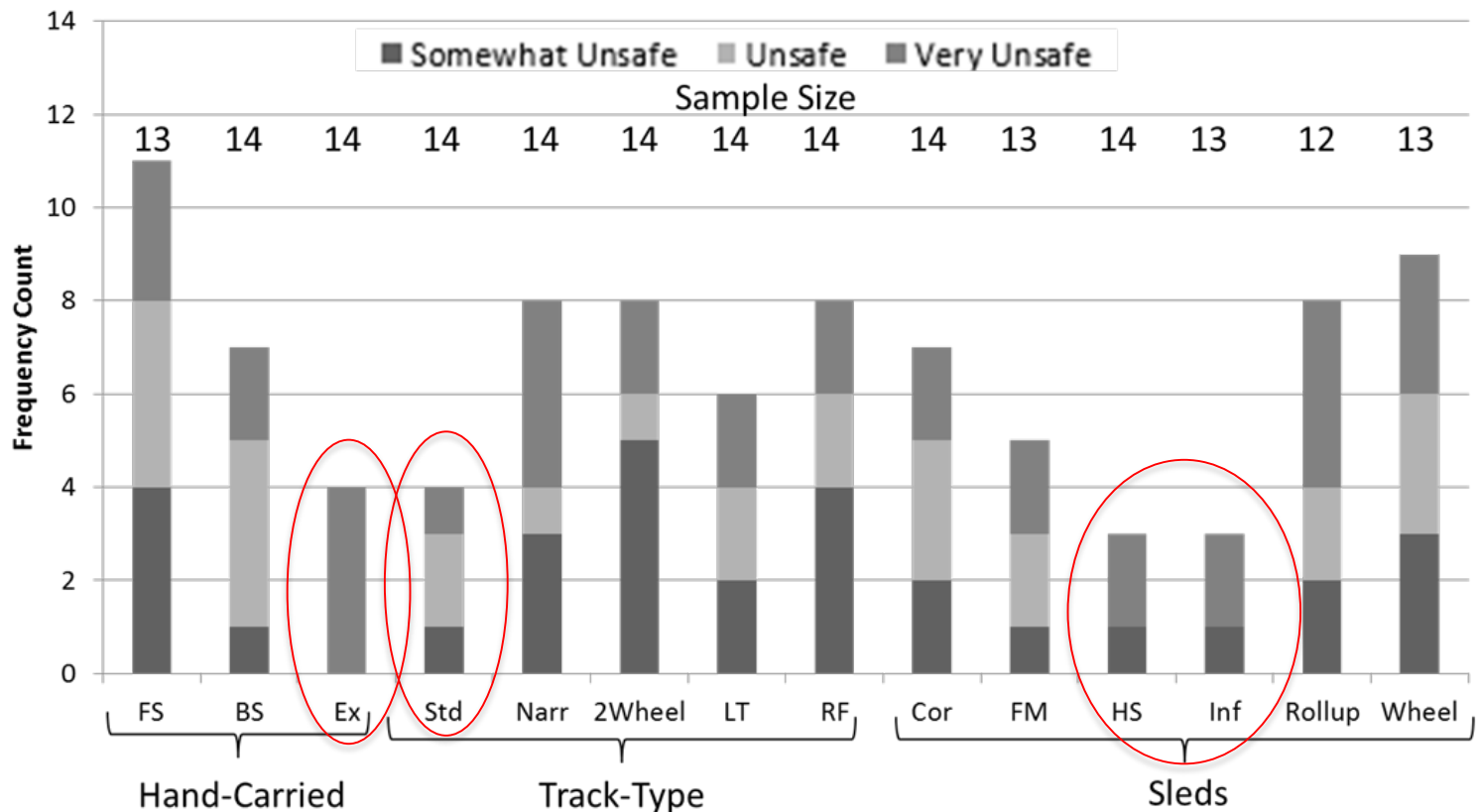
- **Transfers In/Out-** Easiest for Carry-Type and 4 wheeled track type



Initial Impression

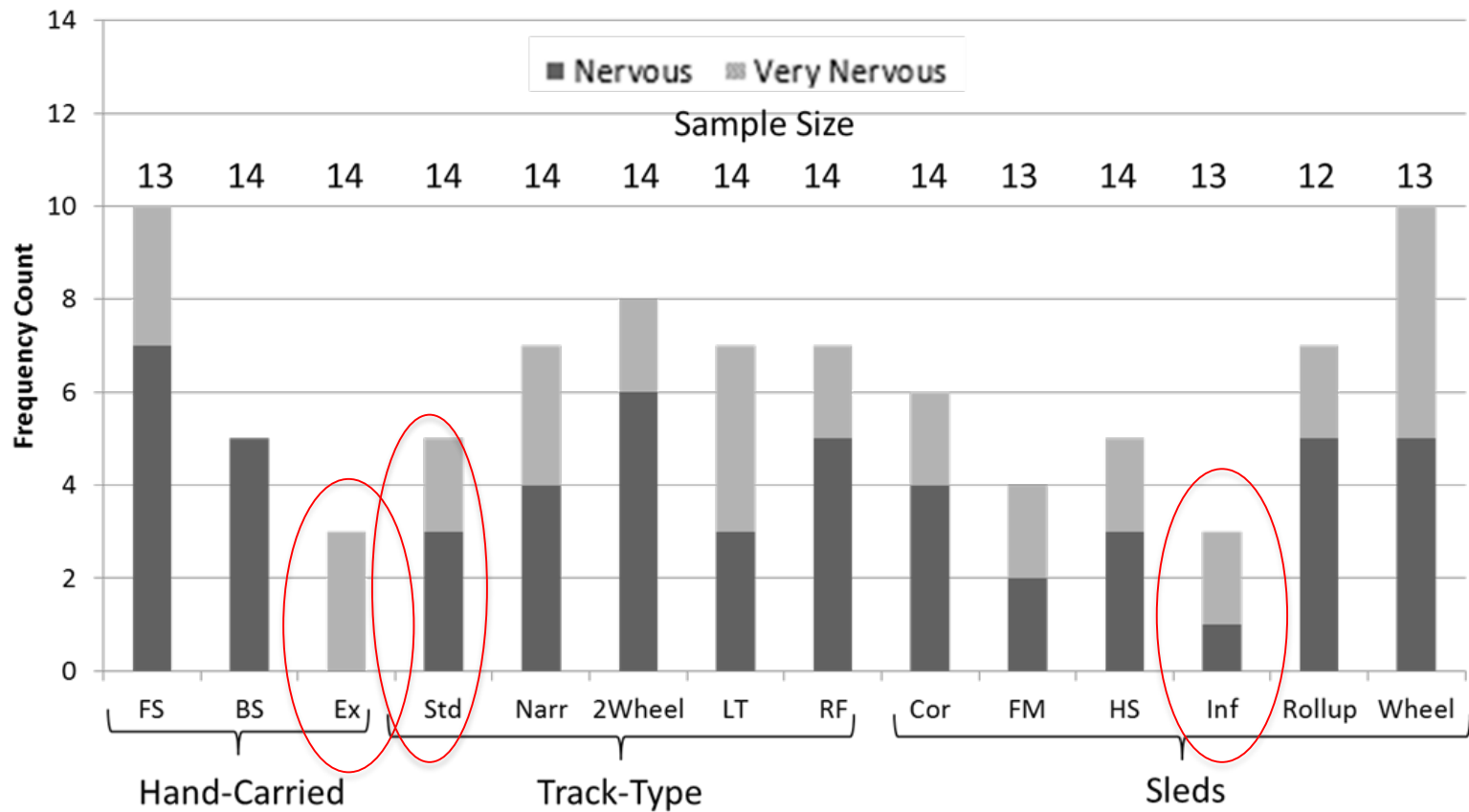
- **Safety**

- Concern over carrying full weight
- Raised edges of Hardshell and Inflatable added to safety

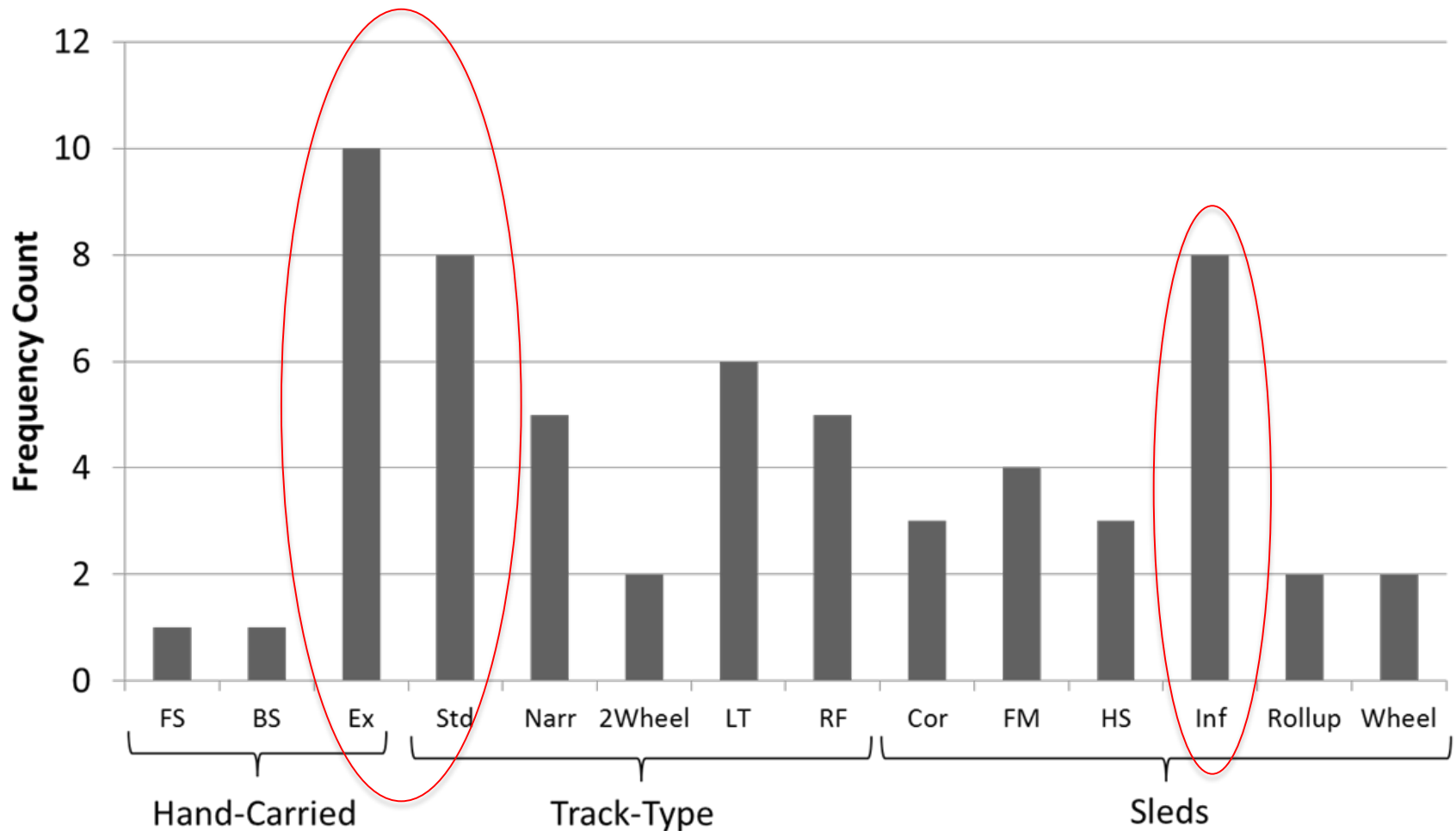


Initial Impression

- Nervousness**



Which of these devices would be acceptable in emergency evacuation situation?

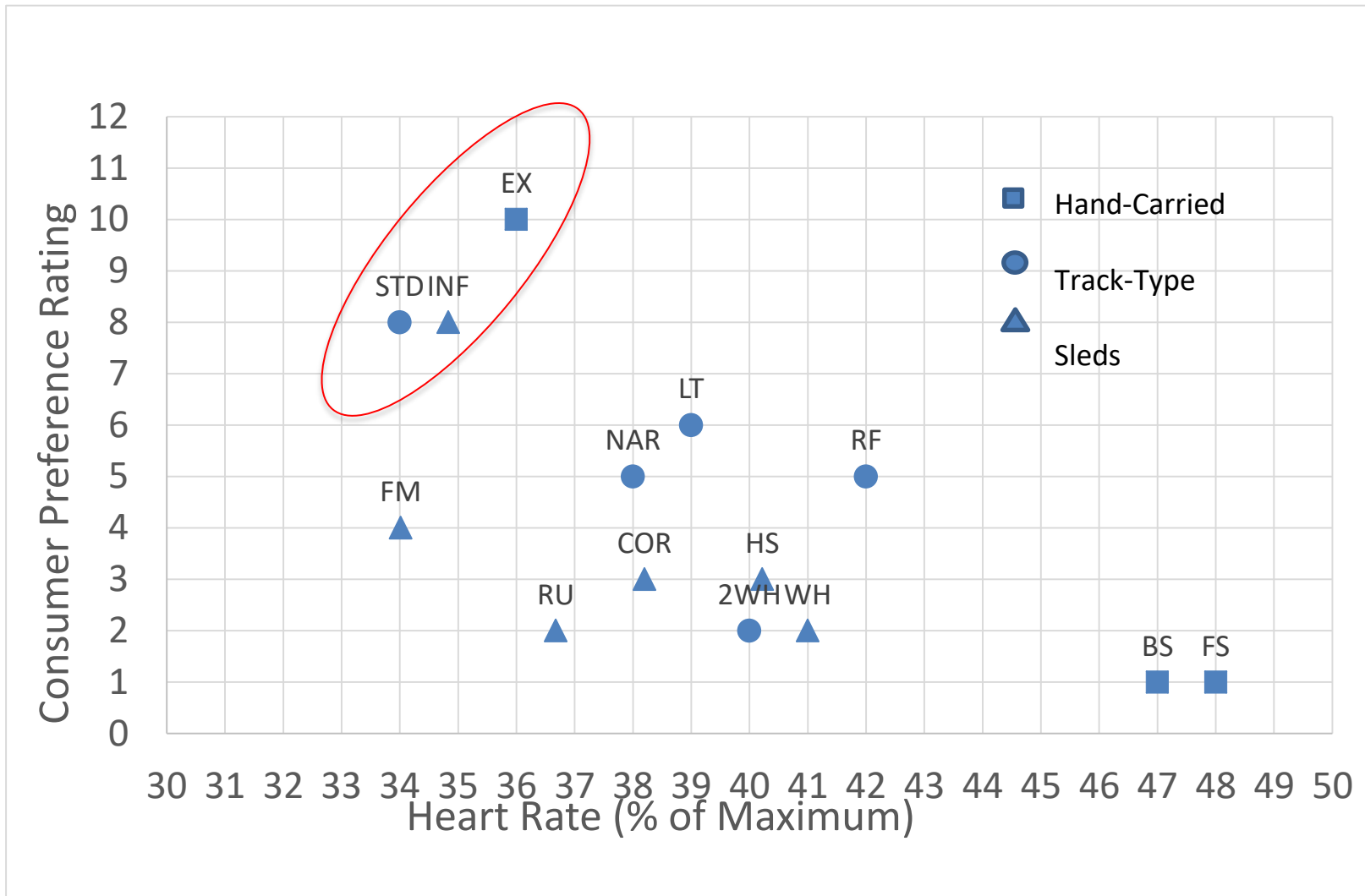


Post-Ride

- **Transfer in and out**
 - Same or improved
- **Nervousness**
 - Same or improved
- **Security**
 - Same or improved
- **Safety**
 - Less safe (2)
 - Unchanged (5)
 - More safe (2)
- **Trial use**
 - Opinion changed in half of instances



Consumer preference (acceptable) rating vs. operator % maximum heart rate



Overall Study Limitations

- Weight of the occupant in FF trials
- Relatively short duration evacuations

American National Standard

for Evacuation Devices –
**Volume 1:
Emergency Stair Travel Devices Used by
Individuals with Disabilities**



Key points re: 2019 Standard

RESNA ED-1:2019

- Performance tests broadened to apply to any design type
- Content broken up into 2 sections
 - Section 1
 - Terminology, Description, & Performance
 - Section 2
 - Inspection, Installation, & Maintenance

American National Standard

for Evacuation Devices –
Volume 1:
Emergency Stair Travel Devices Used by
Individuals with Disabilities



Rehabilitation Engineering and Assistive Technology Society of North America

Key points re: 2019 Standard

- Section 1
 - Occupant features
 - Weight capacity
 - Stability
 - Maneuverability



Key points re: 2019 Standard

- Section 2
 - Storage location
 - Inspection schedule
 - Maintenance

AMERICAN NATIONAL STANDARD

ANSI/RESNA ED-1:2019

Annex A (normative) RESNA ED-1:Sec02:2019 Inspection Results Form

NOTE Use of this form in its entirety is required.

RESNA
ED-1 STANDARD
EMERGENCY STAIR TRAVEL DEVICES USED BY INDIVIDUALS WITH DISABILITIES

A.1 INSPECTION RESULTS REFERENCE

PROVIDER: _____

LOCATION: _____

DATE(S) OF INSPECTION: _____

A.1.1 TRAINING MATERIALS VIEWED? 4.1

PRINTED	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
VIDEO	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
TRAINING SESSION	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A

A.1.2 INSPECTION TIMING 4.2

12-MONTH	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
AFTER USE	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A

A.1.3 STORAGE LOCATION 4.4.1

IN OR NEAR STAIRWAY	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
WALL RACK	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
WALL RACK WITH COVER	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
WALL RACK WITHIN CABINET	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A

A.1.4 LABELING OF STORAGE LOCATION 4.4.1.2

MANUFACTURER-SUPPLIED LABELING PRESENT	<input type="checkbox"/> Yes	<input type="checkbox"/> No	<input type="checkbox"/> N/A
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Weight Capacity

- Occupant features
 - Weight capacity
 - 350 lb (159 kg), min.
 - Test method
 - 1.5 x weight capacity
 - 350 lb, test at 525 lb

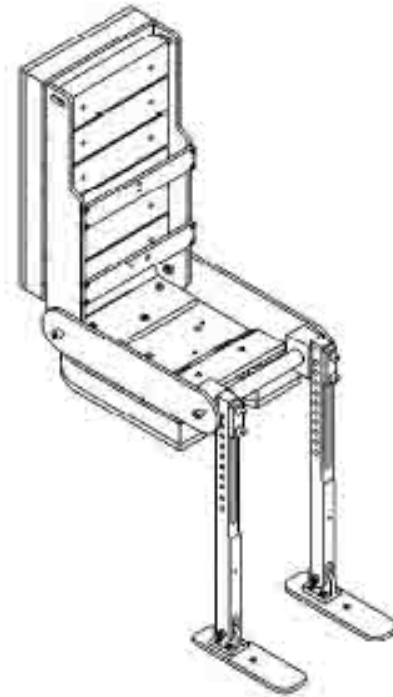


Figure D1. Isometric view – Metal sample test dummy assembly

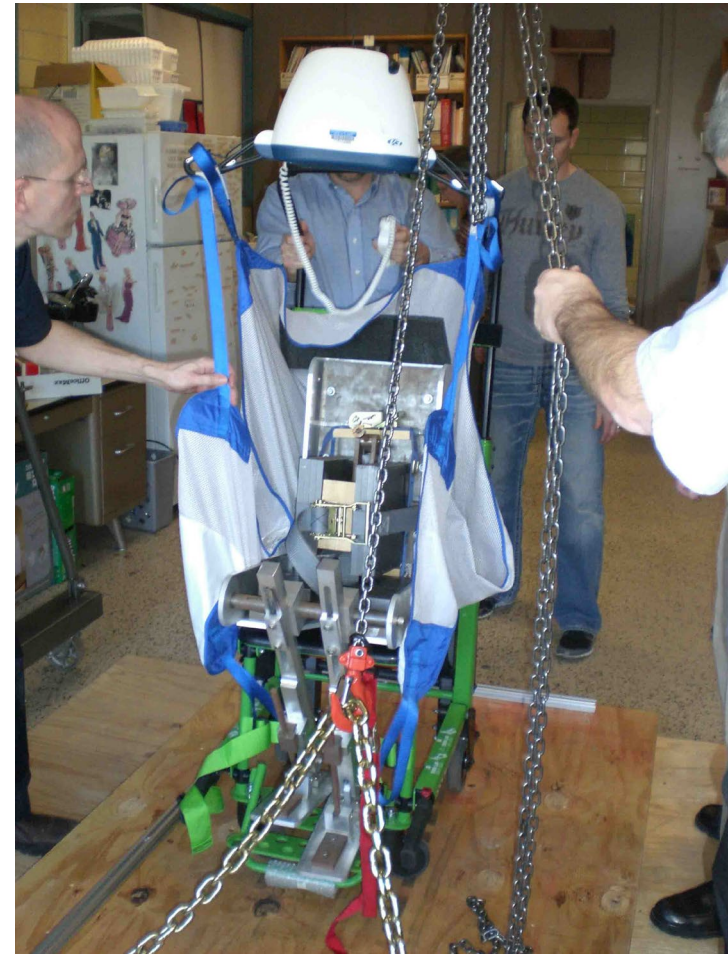
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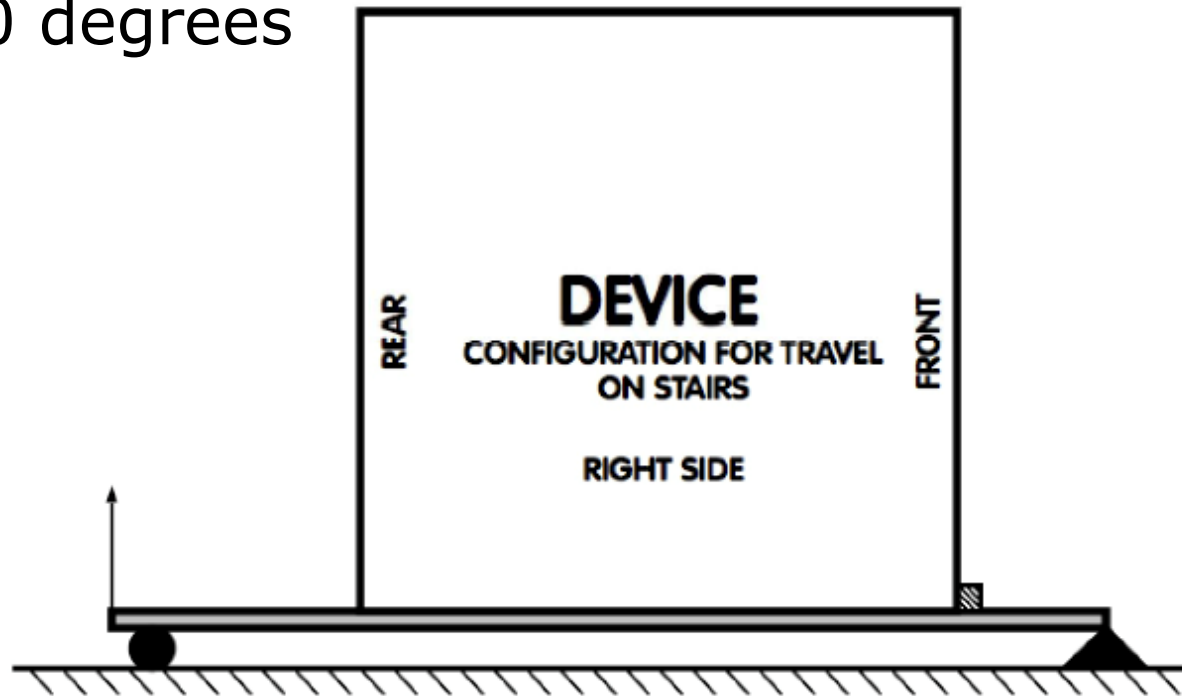
Weight Capacity

- Occupant features
 - Weight capacity
 - 350 lb (159 kg), min.
 - Test method
 - 1.5 x weight capacity
 - 350 lb, test at 525 lb



Stability

- Stability
 - Configuration for travel on **Horizontal Surfaces**
 - Forward: 10 degrees



Stability

- Stability
 - Configuration for travel on **Horizontal Surfaces**
 - Forward: 10 degrees



Stability

- Stability
 - Configuration for travel on **Horizontal Surfaces**
 - Lateral: 10 degrees



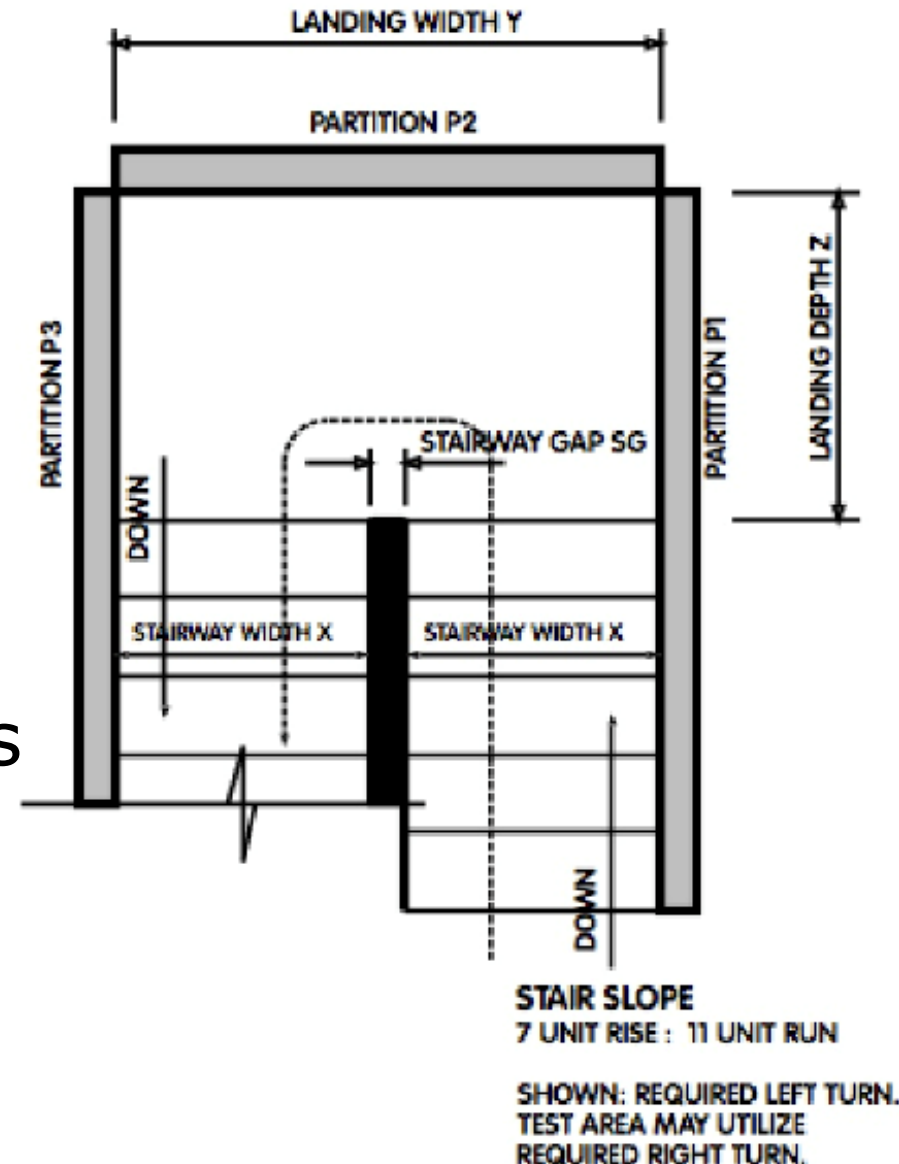
Stability

- Stability
 - Configuration for travel **Downward**
 - Forward: 32.5 degrees



Maneuverability

- Perform 180-degree turn through code-compliant stairway and landing
- Device loaded with mannequin
- Contact with partitions is allowed



Key points re: 2019 Standard

- Section 1
 - Occupant features
 - Weight capacity
 - Stability
 - Maneuverability

Annex A (normative) RESNA ED-1:Sec01:2019 Test Results Form

NOTE Use of this form in its entirety is required.

RESNA
ED-1 STANDARD
EMERGENCY STAIR TRAVEL DEVICES USED BY INDIVIDUALS WITH DISABILITIES

A.1 TEST RESULTS

REFERENCE

TEST OBSERVER: _____

TEST FACILITY: _____

TEST LOCATION: _____

DATE(S) OF TEST: _____

A.1.1 TEST: OCCUPANT WEIGHT WITH SAFETY FACTOR

6.5

Configuration for travel on horizontal surfaces

Compliance?

Yes

No

If no, list material or connection failures:

1. _____

2. _____

3. _____

4. _____

5. _____

Key points re: 2019 Standard

- Section 2
 - Storage location
 - Inspection schedule
 - Maintenance



Summary re ANSI/RESNA ED-1

- 2019 Edition has been approved by RESNA and ANSI
- Covers devices made available January 1, 2020 and after
- Devices of any design type can be tested for compliance
- Sec 01 for Performance
- Sec 02 for Installation & Inspection

Summary- Evacuation Tests

- Track-type devices preferred
 - Evacuation speed
 - Physical Demands
 - Ingress / Egress for occupant
- If a hand-carried device is used - device width and handles should support lead person descending facing forwards.
- Sled-type devices – acceptable for evacuator but getting in/out is a concern for the occupant.

Acknowledgement

- *Federal Emergency Management Agency Assistance to Firefighters Grant Program*
 - *2009-EMW-FP-01944*



FEMA

Questions?

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