Three Point Control – Analysis and Recommendations

J. Nigel Ellis **Ph.D., CSP, P.E., CPE**

www.FallSafety.com
1.800.372.7775

International Society for Fall Protection Symposium, Las Vegas

28 June 2013

What we will discuss today

Climbing, stepping, holding, moving at heights

"Two hands and one foot
then one hand and two feet
And so on ….."

New Rules on Grip
Design while Falling

"Only Two Point Control?"

Goals of Three Point Control

~~Contact~~

~~Stance~~

- Gripping <u>not</u> leaning
- Holding <u>not</u> touching
- Hand <u>not</u> stomach or other body part
- Flat step or rung <u>not</u> crevice for foot

To Help <u>Assure</u> Your Balance
And Stability

Fall Fatalities at Work USA

Source BLS/OSHA

Fall Height v. % Fall Deaths

Fall Height	% Fall Deaths
Under 6 ft	1%
Under 10 ft	9%
Under 15 ft	20%
Under 20 ft	34%
Under 25 ft	38%
Under 30 ft	42%
Under 35 ft	50%

← 18ft 30% fall deaths

Roofers Union Analysis: 50% fatalities: Harness used but not attached
50% fatalities: Harness not used; 100% exposure

Fall Arrest can take up to 18 ft

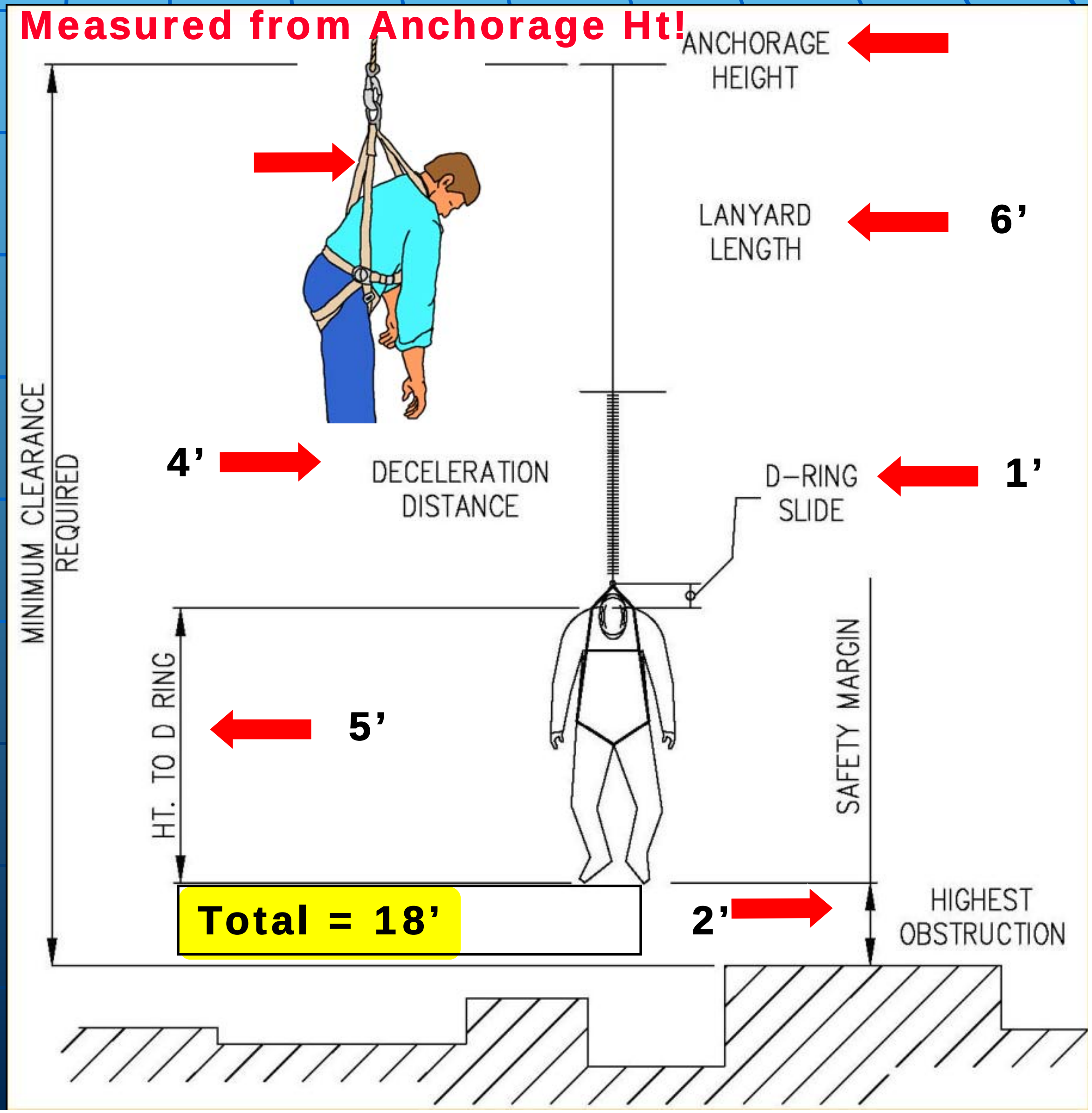
- Harness and 6 ft lanyard attached at waist level produces Free Fall of 7.5 ft and requires Clearance of 7.5 + 3.5 E/A + 6 ft Height of operator + Harness stretch = 18 ft

Ref: Introduction to Fall Protection 4th edition, ASSE 2012 Fall Clearance Requirements: pp 190, 215, 221, 231, 301-2

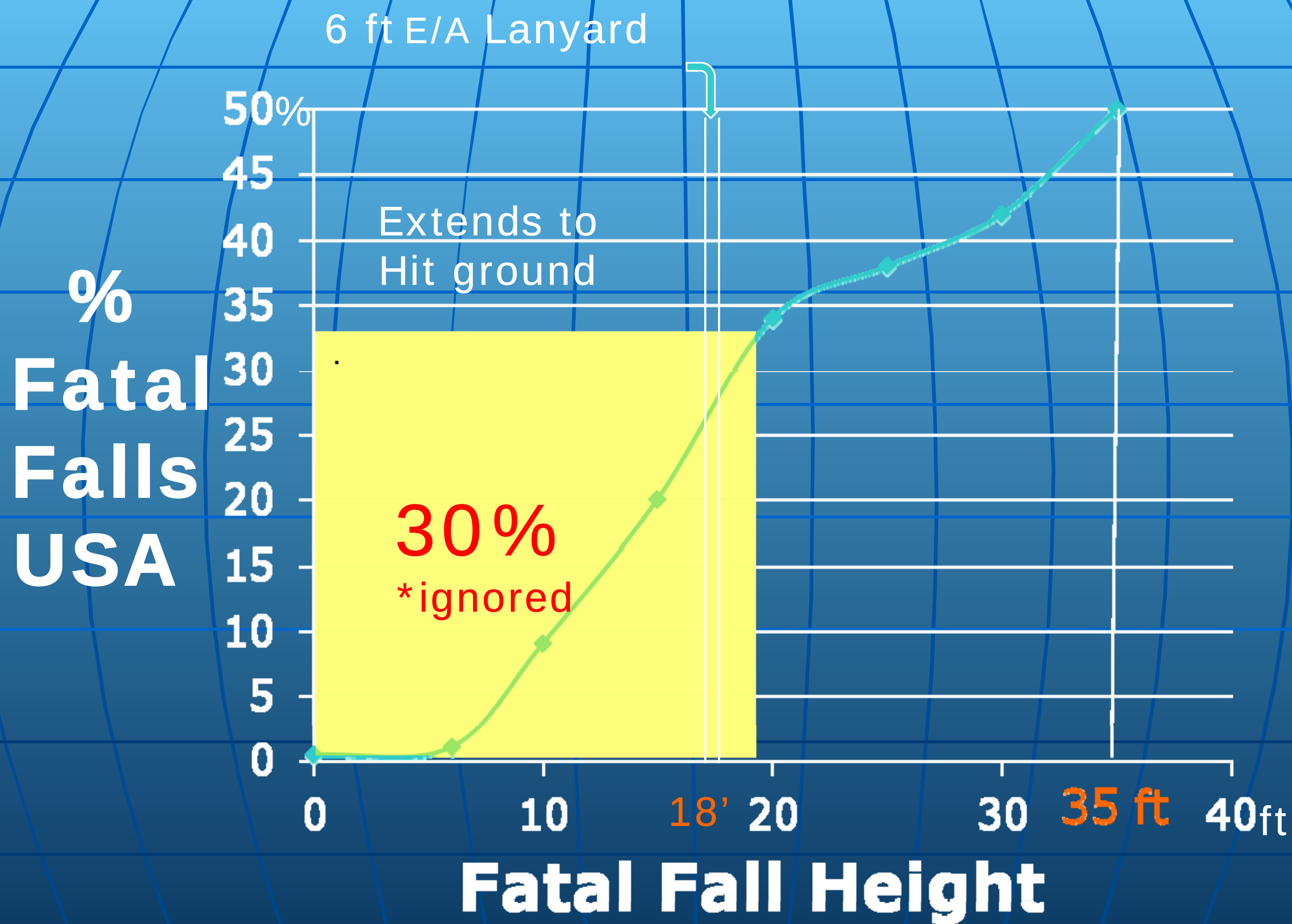
18 ft. Fall Arrest Clearance Diagram

– Energy Absorbing Lanyard

Get those anchor points as high as possible!!!



Lower Falls have been ignored*!

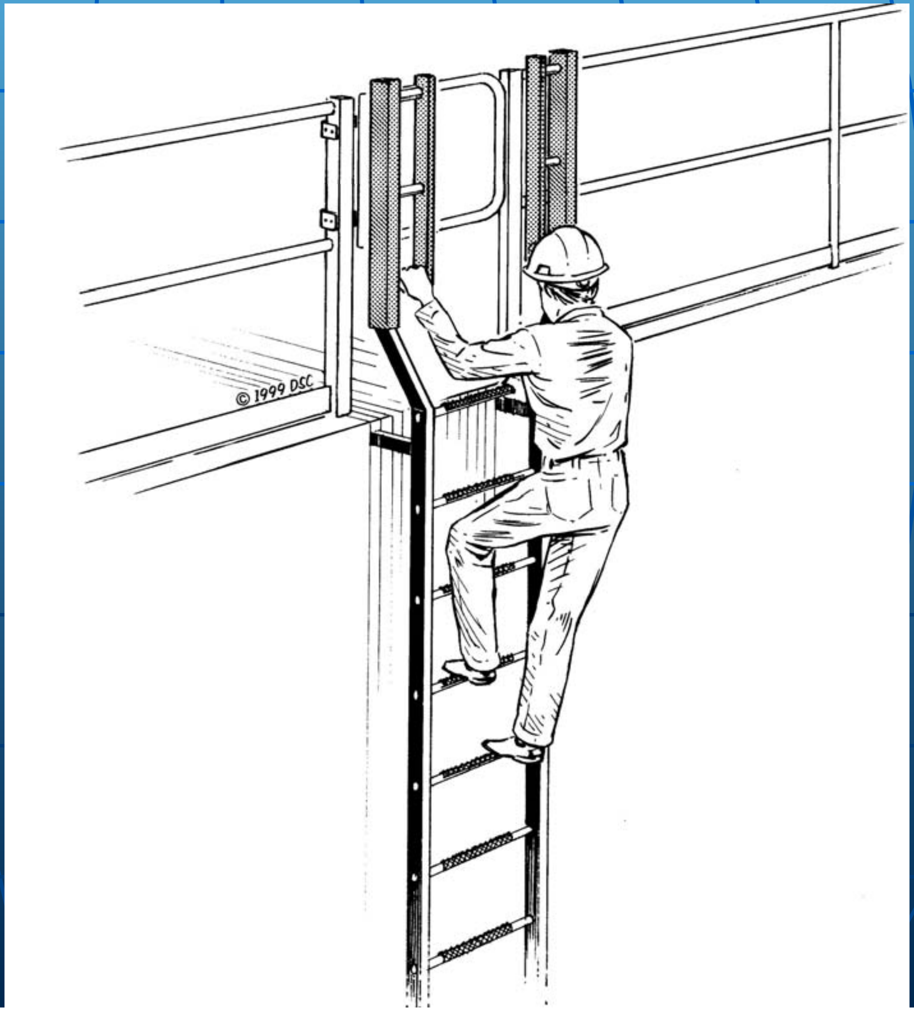


Cumulative data, Source: OSHA

Focus: Fixed and Portable Ladders

- Hold Rungs or Side Rails?
- Size of Rung
- Size of Step
- Side Rail Size

Note: Fall Protection regulations apply at the governmental trigger points



Ladders – The RULE:

Always Hold Rungs

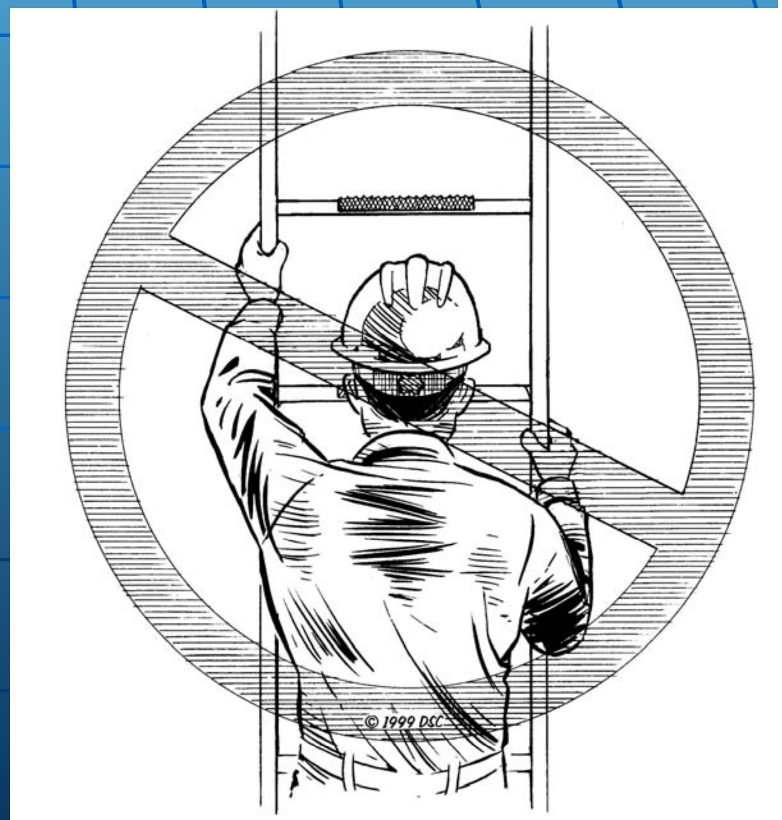
Never hold side rails

Think

“Dynamic”

not

“Static”!



Justin Young Ph.D. Thesis 2011 UMichigan (NIOSH funded)

Hand/Handhold Decoupling Forces

Procedure:

1. Step on platform; secure
2. Hold overhead rung, rail, or grab bar as directed
3. Lower platform (6"/sec -- 2-4 seconds)
4. Measure maximum force on rung to release

Note: Fast Fall Arrest System provided (SRL)
Subjects M/F 50%; IRB Approved

Full Dissertation http://hdl.handle.net/2027.42/84452

Details and Tables by your SmartPhone

Adapted from Young et al, *Human Factors Journal*, Oct. 2009

Perform simulated fall:

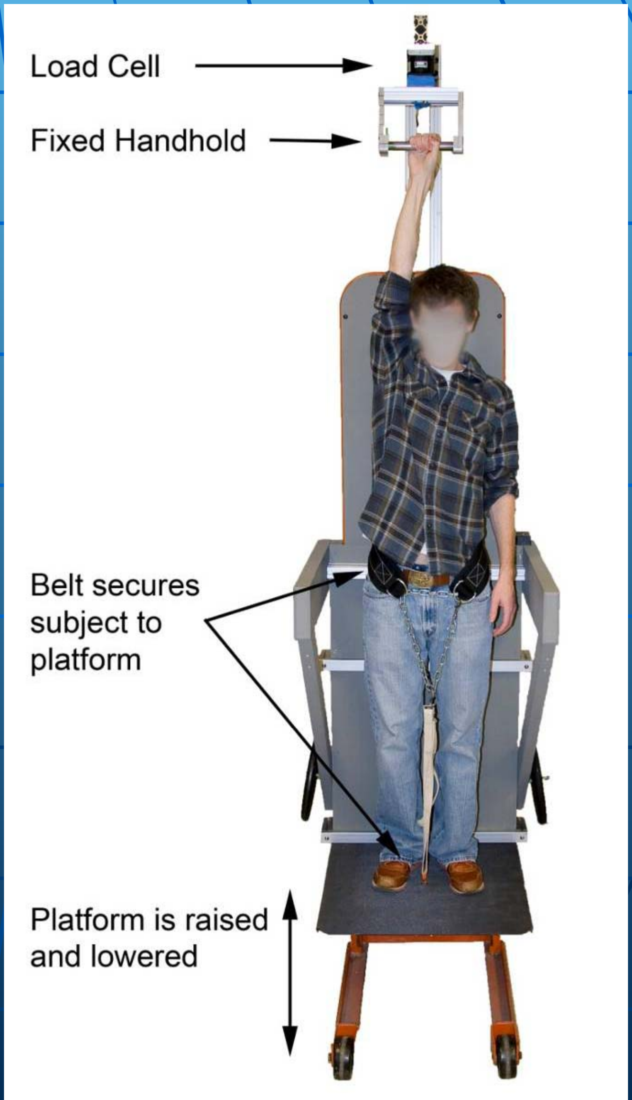
- Platform and subject are lowered slowly, no impulse

  (0.5 ft/sec)

- Posture passively stabilizes upper-limb joints

- Body weight provides external load

SRL



Three Experiments

- Twelve subjects in each experiment (6 male , 6 female)
  - 36 subjects measured forces in same way
- Different handholds for each experiment
  - Several RUNGS and RAILS (or siderails)
    - Size, orientation, friction, shape

Three Experiments: Results

- Compare the force applied by one hand and the subject's bodyweight (can they hang on?)
  - <1.0 suggests "no", <0.5 suggests "not even with two hands"

EXP 1a: Peak breakaway strength, normalized strength, and grip strength (mean ± SD), by handle and gender, for typical ladder handholds. Experiment with 6 males and 6 females, dominant hand measurement.*

Handle	Peak Force (lbs)		Peak Force / Bodyweight		Peak Force / Grip Strength	
	Males	Females	Males	Females	Males	Females
RUNG (cylinder) 1" diameter	189 ± 47	111 ± 21	1.17 ± 0.13	0.94 ± 0.18	1.52 ± 0.26	1.53 ± 0.2
RAIL (cylinder) 1" diameter	116 ± 30	80 ± 10	0.72 ± 0.1	0.68 ± 0.12	0.93 ± 0.15	1.10 ± 0.13
RAIL (plate) 2.5"x0.4"	92 ± 37	59 ± 16	0.55 ± 0.14	0.50 ± 0.13	0.73 ± 0.23	0.81 ± 0.19
Grip Strength (Jamar 45mm)	124 ± 13	72 ± 8	0.85 ± 0.2	0.61 ± 0.08	1	1

½ Fail

*Table adapted from Young et al. 2009 (Table 2) also in Young, JG. Dissertation (Table 2.3.1)

Negative Safety factor for vertical object handholds and non-round rungs

Women subjects selected had low upper body strength

EXP 2a&b: Peak breakaway strength and normalized strength (mean ± SD), by handle and gender, for typical ladder handholds. Experiment with 6 males and 6 females, both hands.*

	Breakaway Force (lbs)			Breakaway Force / Bodyweight		
	Males	Females	All	Males	Females	All
RUNG[a] (cylinder) 1" diameter	188 ± 43	113 ± 24	150 ± 51	1.07 ± 0.33	0.83 ± 0.21	0.94 ± 0.30
RUNG[a] (diamond) 1"x1"	168 ± 34	86 ± 16	127 ± 49	0.96 ± 0.28	0.62 ± 0.11	0.79 ± 0.27
RUNG[a] (square) 1"x1"	146 ± 28	86 ± 29	116 ± 41	0.83 ± 0.21	0.63 ± 0.25	0.73 ± 0.20
RUNG[a] (plate) 2"x5/8"	131 ± 27	73 ± 18	102 ± 37	0.75 ± 0.21	0.54 ± 0.15	0.64 ± 0.21
Grip dynamometer[a] (Jamar 45mm)	123 ± 10	68 ± 11	95 ± 30	0.70 ± 0.15	0.50 ± 0.11	0.60 ± 0.19
RAIL[b] (cylinder) 7/8" diameter	85 ± 19	67 ± 12	--	--	--	--
RAIL[b] (cylinder) 1.25" diameter	96 ± 18	69 ± 12	--	--	--	--
RAIL[b] (tapered cylinder) 7/8" to 1.25"	105 ± 26	83 ± 19	--	--	--	--
Grip dynamometer[b] (Jamar 45mm)	114 ± 14	64 ± 12	--	--	--	--

*Table adapted from Young & Armstrong 2009 (Table 9) and Young, JG. Dissertation (Table 3.3.1)

[a] dominant hand measurement

[b] non-dominant hand measurement

½ Fail

Rails << Rungs Grip Strength

EXP 3a: Peak breakaway strength and normalized strength (mean ± SD), by handle and gender, for typical ladder handholds. Experiment with 6 males and 6 females, dominant hand measurement.*

	Breakaway Force (lbs)			Breakaway/ Bodyweight		
RUNGS (cylinders)	Males	Females	All	Males	Females	All
2" diameter	147 ± 32	75 ± 26	111 ± 46	0.90 ± 0.24	0.61 ± 0.16	0.76 ± 0.25
1.25" diameter	157 ± 34	84 ± 24	121 ± 47	0.98 ± 0.30	0.71 ± 0.17	0.84 ± 0.28
0.875" diameter	169 ± 38	90 ± 25	129 ± 51	1.04 ± 0.28	0.78 ± 0.27	0.91 ± 0.30
All Diameters Pooled	157 ± 35	83 ± 25	120 ± 48	0.97 ± 0.28	0.70 ± 0.21	0.84 ± 0.28
RAILS (cylinders)	Males	Females	All	Males	Females (< ½ !!!)	All
2" diameter	84 ± 20	48 ± 18	66 ± 26	0.52 ± 0.15	0.39 ± 0.13	0.46 ± 0.15
1.25" diameter	93 ± 16	60 ± 19	76 ± 24	0.57 ± 0.14	0.49 ± 0.12	0.53 ± 0.14
0.875" diameter	87 ± 22	58 ± 21	73 ± 26	0.54 ± 0.19	0.48 ± 0.14	0.51 ± 0.17
All Diameters Pooled	88 ± 20	55 ± 20	72 ± 26	0.54 ± 0.16	0.45 ± 0.13	0.50 ± 0.15

*Table adapted from Young et al. 2012 (Table 3) also in Young, JG. Dissertation (Table 4.4.2)

RUNGS outperform RAILS! May not be able to support bodyweight with RAILS even with both hands!

In all three experiments, rungs significantly outperformed rails. Some rung designs performed poorly (plates, corners, large cylinders).

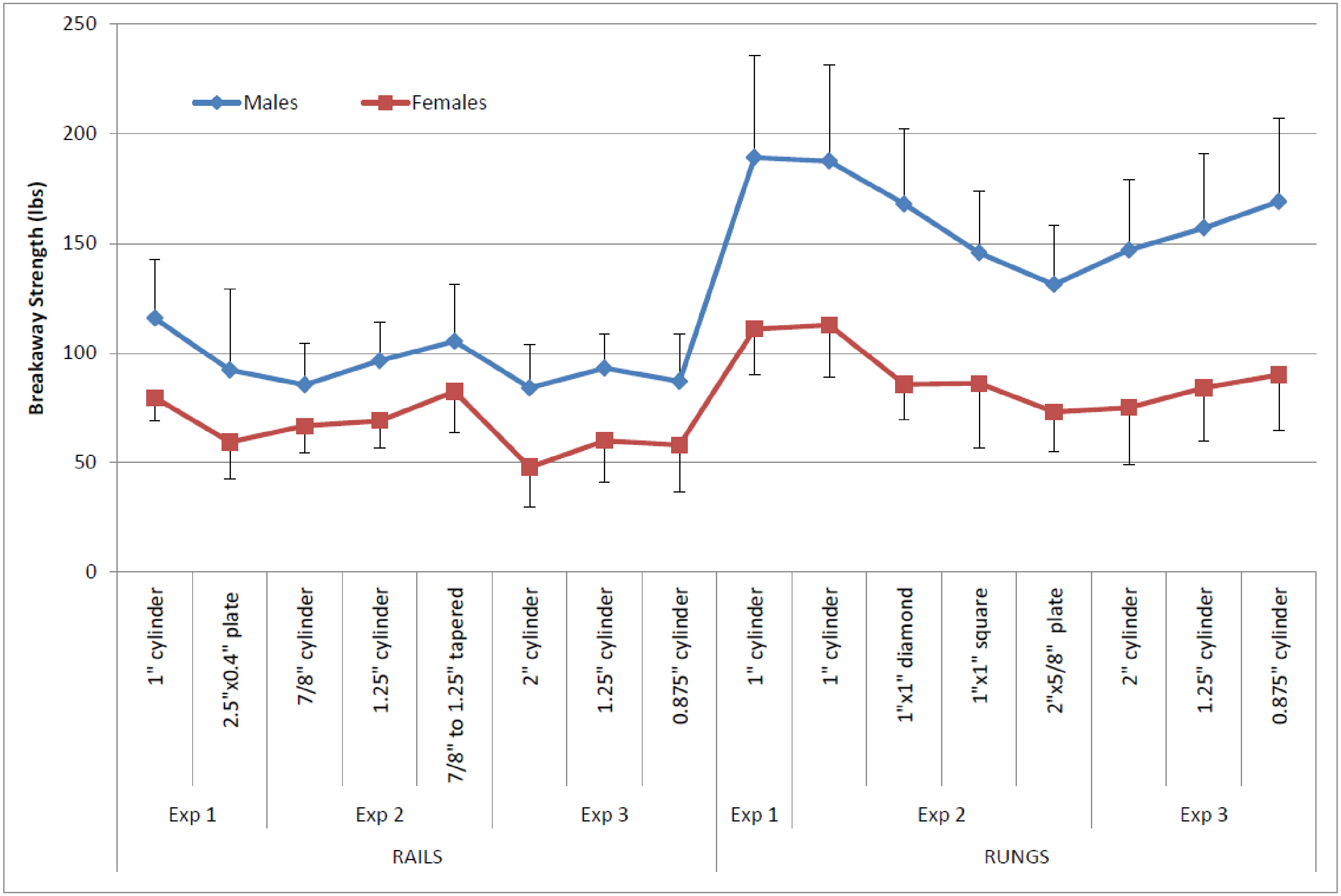
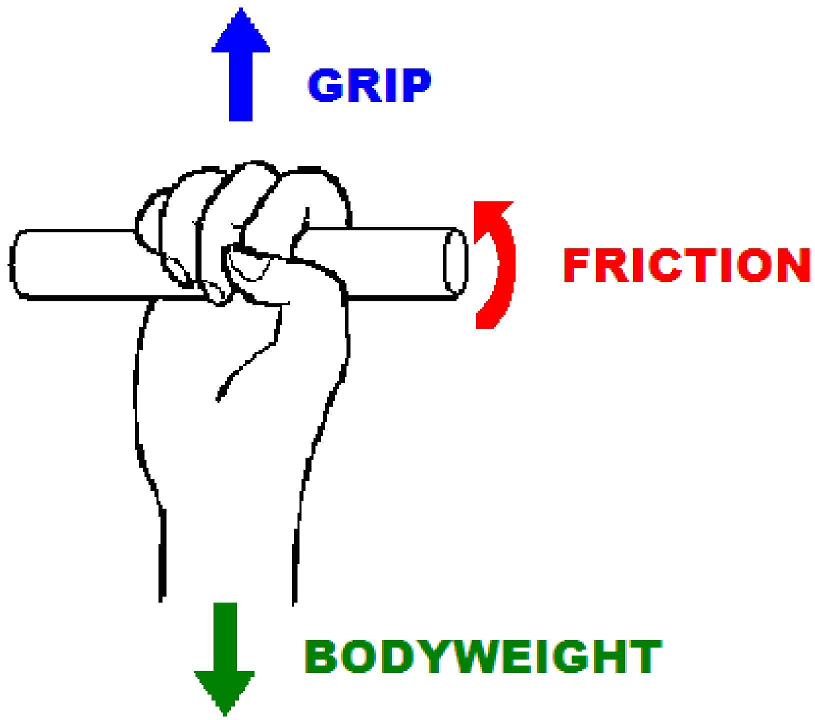


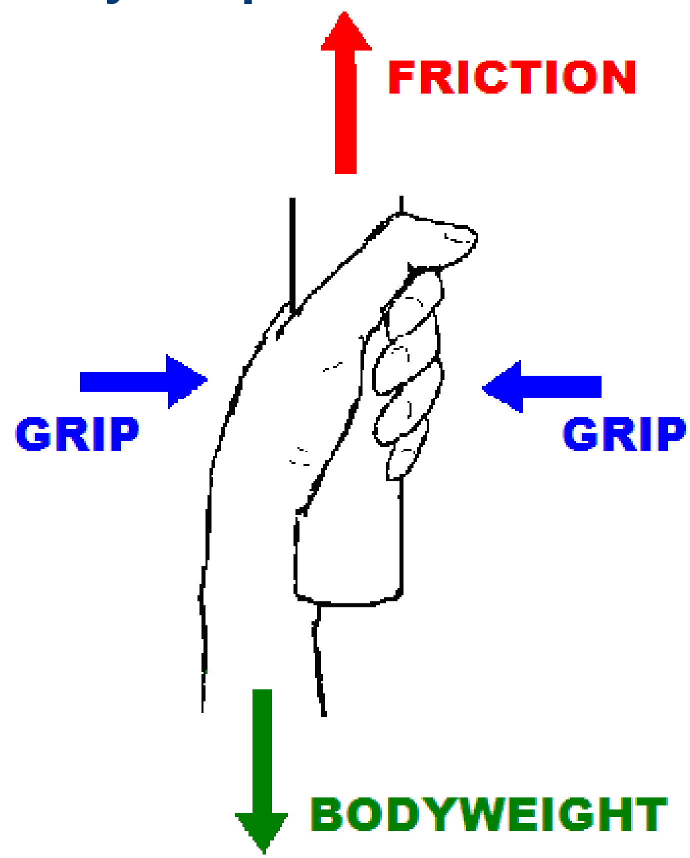
Figure 1. RAILS vs. RUNGS for all 3 experiments. For males, mean strength is greater for any of the rung designs compared to any of the rail designs tested. For females, only the 1" cylinder rail and the tapered cylinder rail afford greater strength than the 2" cylinder rung or the plate rung, otherwise rungs afford greater strength than rails on average.

Result: Rungs SideRails

In all three experiments, rungs significantly outperformed rails.

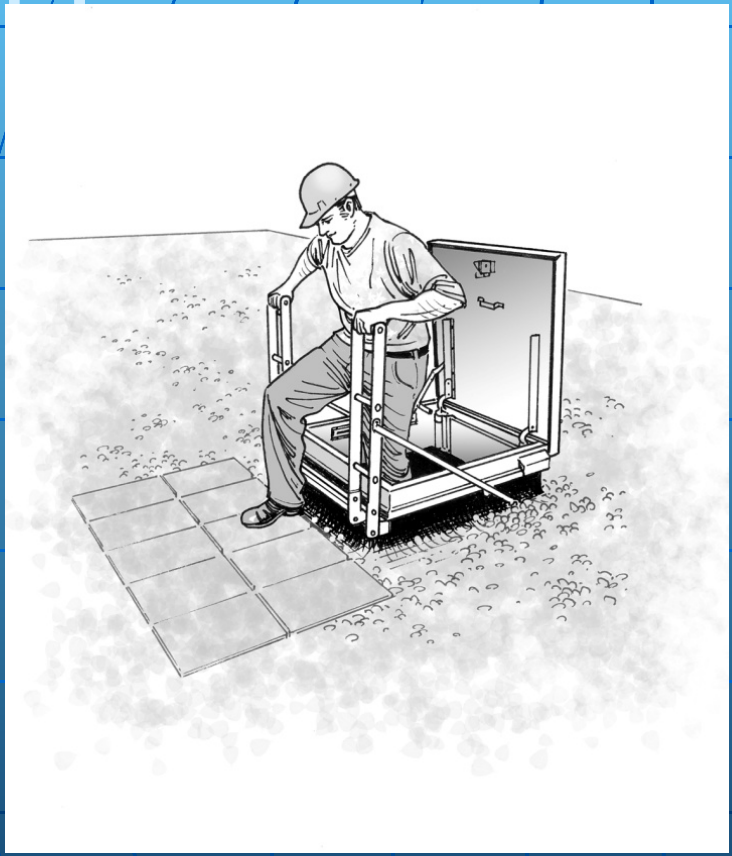


a. Ladder Rung



b. Ladder Rail

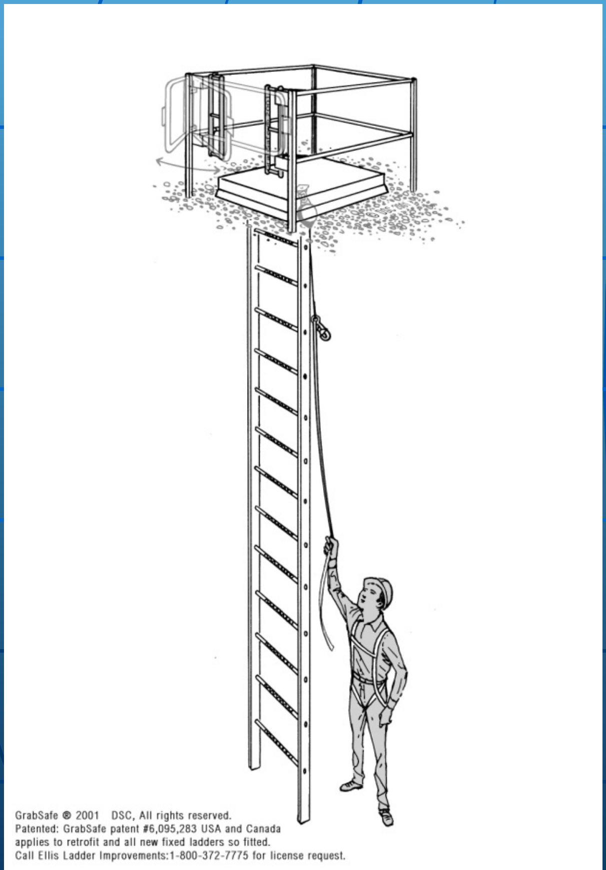
Applications: Roof Hatches 1

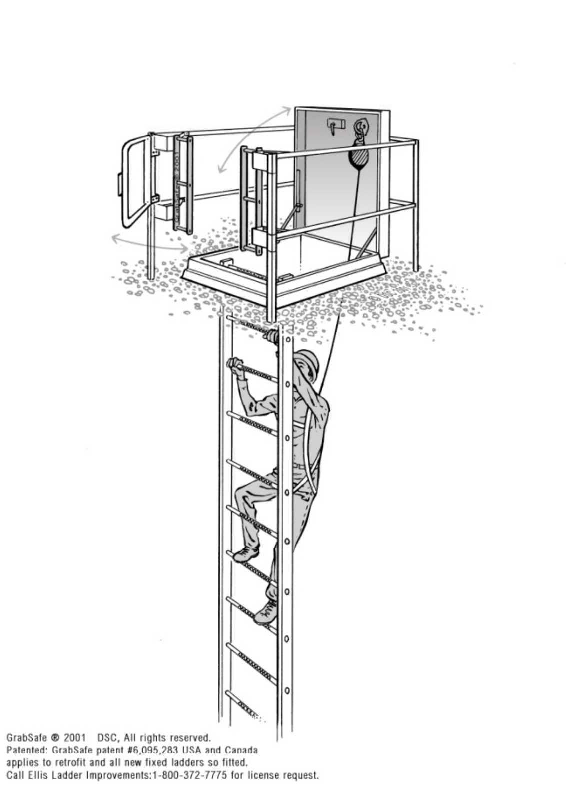


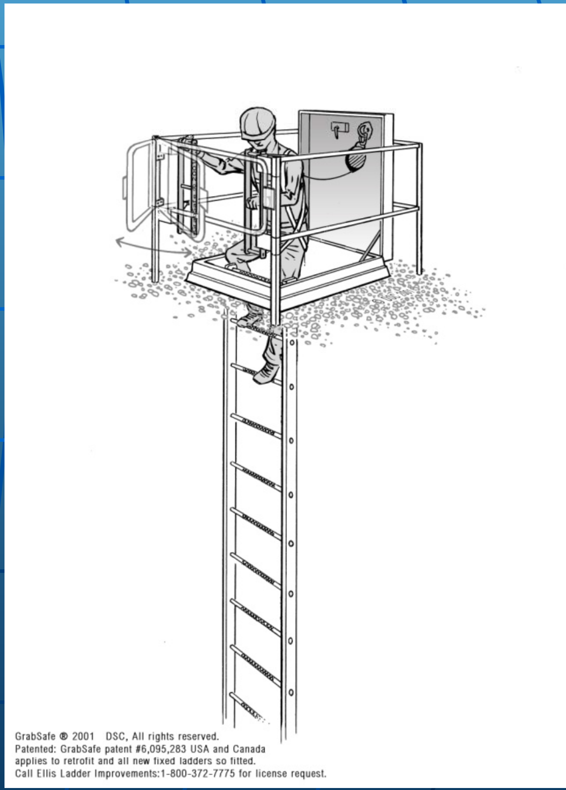
PS Doors

Walk In and
Walk Out

Roof Hatches 2







Portable Ladders

Commercial

Residential

Walk-through design safer
Horizontal grab appears intuitive

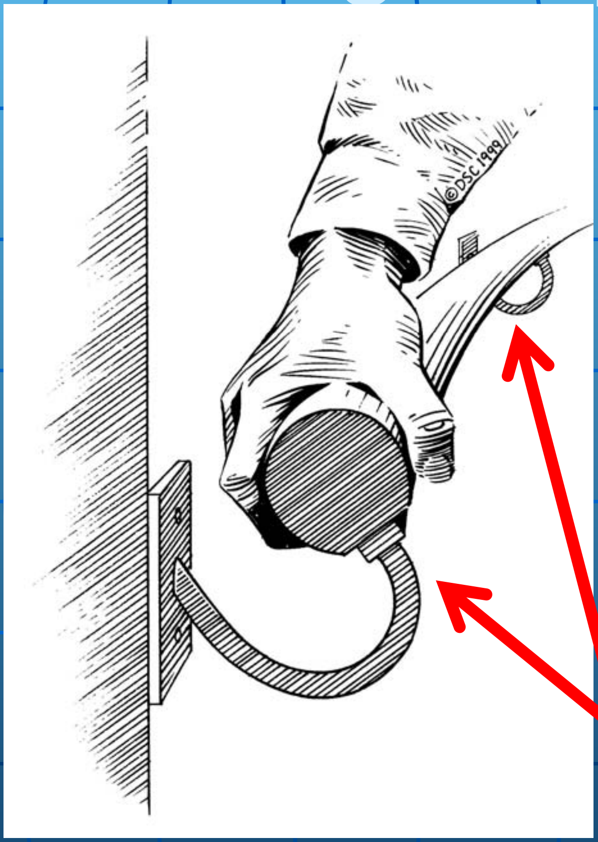
Top view on Residential ReRoof

AES Raptor

Achieves 3 ft Projection (OSHA)
Adds 3 ft to any Portable Ladder
Walk-Through each direction
Compatible with most Stand-Offs
Horizontal Grab Bars are reliable

Stair Rails: Continuous Sliding Grip Possible

Hand does not leave stair rail

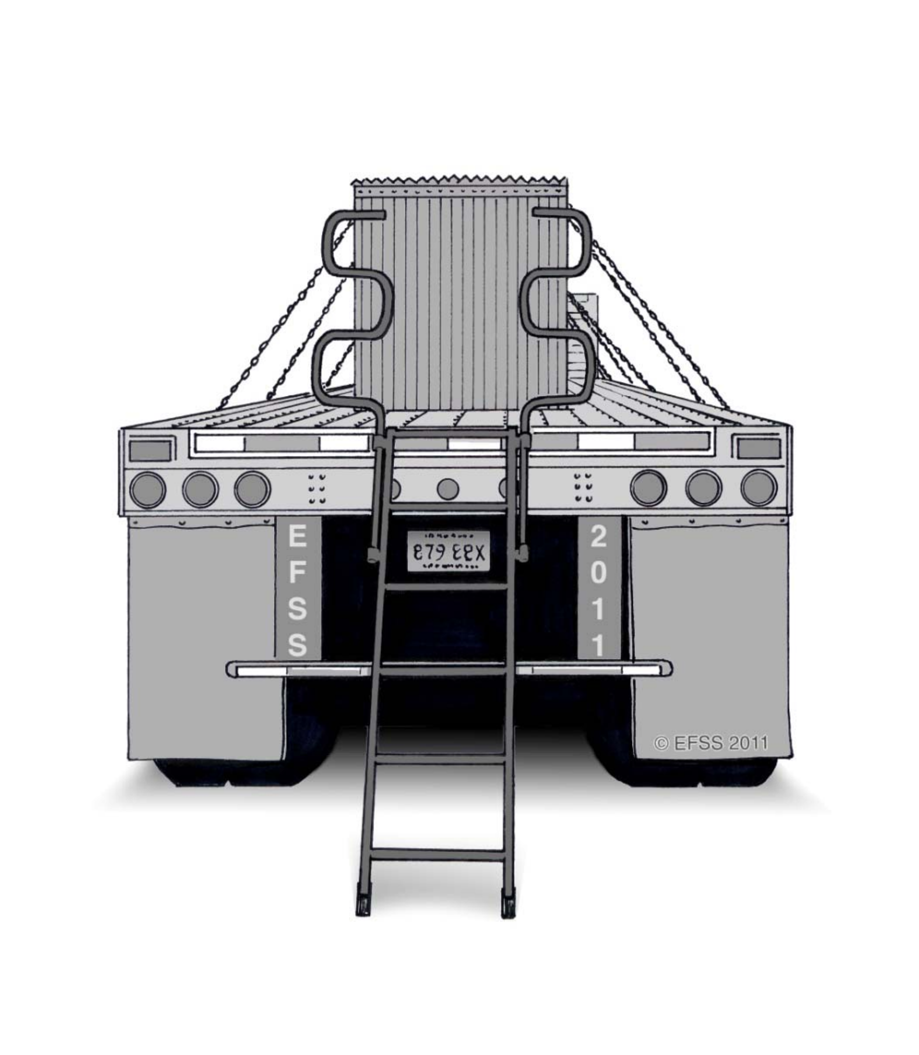


Two stair rails required for Three Point Control height 42", 44-60" apart

No Hand Obstruction

Protection for falls down stairs: Two hands and one foot with alternating feet

Flatbed Trailers



Flatbed Trailer Access Locks into rubrail

Access with Handhold

Tank Truck catwalks

Three Point Control

Two hands and one foot repeated with each step …..

Standfastusa.com

Summary:

Design Rules for Climbing:

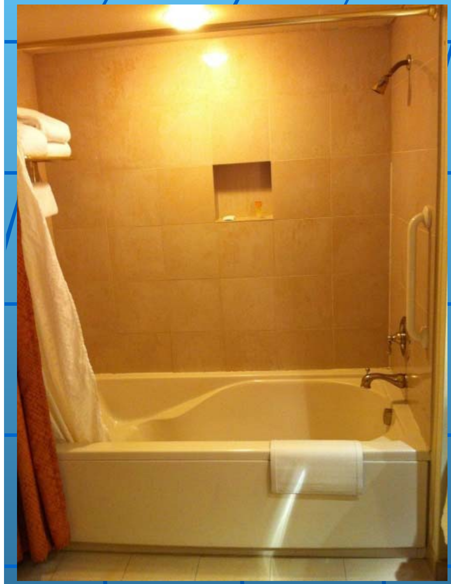
All handholds should be horizontal
Footing should be flat and horizontal
Never hold side rails of ladders

Application at Heights:

Always hold ladder rungs
Hold stair rails

Result: Fewer fall injuries & deaths

The Hotel Bathtub!

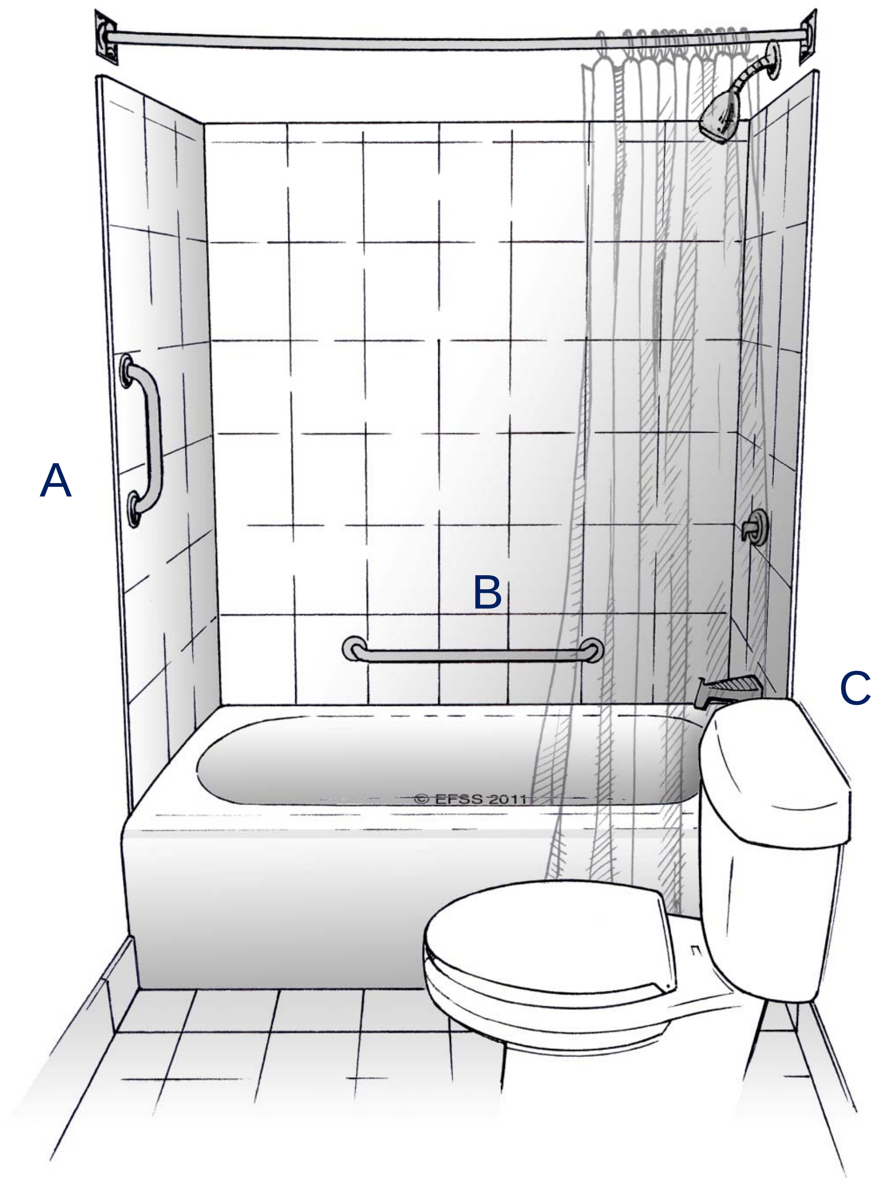


Vertical Bar
Next to
shower
head end

Vertical Bars

Vertical Bar
next to toilet

No Two Hotels the Same



The Standard for Hotels in USA

Each Hotel in the USA now has a unique arrangement for Grab Bars in bathrooms:

Which is correct? Answer....

A 6” Vertical slide for hand allowed. Grab Bar becomes lateral if step down occurs

B Horizontal Grab Bar to leverage arm up from either end laying in the tub

C Not put Bar (A) here where toilet obstructs exit

Questions/Discussion

Together we need to establish the proper shape criteria for "Three Point Control" – a horizontal grip is key

All industries need to redesign their handholds and decide on Fall Protection Systems at lower heights

- Ref. Three Point Control paper
- Professional Safety Journal publication date: November 2012
- J. Nigel Ellis: dsc@FallSafety.com
- 302 571 8470 x121

Slides provided to Nigel Ellis for presentation on Three Point Control Analysis and Recommendations,

Taken from:

Young, JG (2011) Biomechanics of hand/handhold coupling and factors affecting the capacity to hang on. *Doctoral dissertation*, University of Michigan, Ann Arbor, MI

Young, JG; Woolley, CB; Armstrong, TJ. (2010). Effect of handhold orientation, size, and wearing gloves on the ability to hang on. (presentation) *International Conference on Fall Protection and Prevention 2010*. Morgantown, WV.

Friction helps you hang on:

Table 2.3.2 Peak breakaway strength and grip strength (mean ± SD) by handle and gender, for high- and low-friction handholds (Exp 2).

Handle	Peak Force (N)		Peak Force / Bodyweight		Peak Force / Grip Strength	
	Males	Females	Males	Females	Males	Females
25mm horizontal cylinder	766 ± 121	617 ± 97	1.07 ± 0.18	0.93 ± 0.14	1.61 ± 0.25	1.55 ± 0.25
25mm horizontal cylinder (low-friction)	628 ± 95	477 ± 33	0.88 ± 0.15	0.73 ± 0.10	1.32 ± 0.22	1.21 ± 0.12
Grip dynamometer (overhead measurement)	481 ± 76	399 ± 46	0.68 ± 0.13	0.61 ± 0.10	1.00	1.00
Grip dynamometer	474 ± 84	390 ± 44	0.67 ± 0.14	0.59 ± 0.09	0.98 ± 0.05	0.98 ± 0.05

Friction helps you hang on:

Table 4.4.5 Mean (±sd) breakaway strength for Experiment 2 (non-dominant hand)

	Peak Force (N)			Peak Force / Bodyweight			Peak Force / Grip Strength[1]		
Glove type	Males	Females	All Subjects	Males	Females	All Subjects	Males	Females	All Subjects
	45° Orientation			45° Orientation			45° Orientation		
Low-Friction Glove (cotton)	274±69	185±53	230±76	0.38±0.10	0.35±0.11	0.36±0.10	0.69±0.16	0.67±0.18	0.68±0.17
Bare Hand	550±127	300±92	425±167	0.76±0.21	0.57±0.18	0.67±0.22	1.30±0.29	1.00±0.27	1.15±0.32
High-Friction Glove (PVC dots)	598±126	362±114	480±168	0.83±0.23	0.69±0.21	0.76±0.23	1.45±0.19	1.30±0.33	1.38±0.28
All Glove Types Pooled	474±180	282± 115	378± 179	0.66±0.28	0.54±0.22	0.60±0.25	1.14±0.4	0.99±0.37	1.07±0.39
	60° Orientation			60° Orientation			60° Orientation		
Low-Friction Glove (cotton)	424±98	249±61	336±120	0.58±0.16	0.47±0.11	0.53±0.14	1.06±0.2	0.89±0.13	0.98±0.19
Bare Hand	650±149	331±112	490±207	0.90±0.25	0.62±0.18	0.76±0.26	1.53±0.34	1.10±0.34	1.31±0.40
High-Friction Glove (PVC dots)	709±153	391±142	550±217	0.99±0.29	0.74±0.24	0.87±0.29	1.72±0.27	1.40±0.40	1.56±0.37
All Glove Types Pooled	582±182	324± 123	459 ±206	0.82±0.29	0.61±0.21	0.72±0.28	1.44±0.39	1.13±0.37	1.28±0.41
	75° Orientation			75° Orientation			75° Orientation		
Low-Friction Glove (cotton)	575±114	298±77	436±170	0.79±0.19	0.57±0.14	0.68±0.20	1.44±0.2	1.07±0.21	1.26±0.27
Bare Hand	691±145	352±143	521±223	0.96±0.28	0.66±0.24	0.81±0.30	1.63±0.37	1.17±0.44	1.40±0.46
High-Friction Glove (PVC dots)	716±175	408±179	562±234	1.00±0.33	0.77±0.28	0.88±0.32	1.73±0.28	1.44±0.49	1.58±0.42
All Glove Types Pooled	660±157	353± 144	507 ±215	0.92±0.28	0.67±0.24	0.79±0.29	1.60±0.31	1.23±0.42	1.41±0.41
	90° Orientation			90° Orientation			90° Orientation		
Low-Friction Glove (cotton)	596±115	318±95	457±176	0.82±0.19	0.60±0.17	0.71±0.21	1.49±0.17	1.14±0.27	1.31±0.29
Bare Hand	717±133	374±133	545±218	0.99±0.23	0.71±0.21	0.85±0.26	1.69±0.32	1.25±0.43	1.47±0.44
High-Friction Glove (PVC dots)	743±173	396±128	570±231	1.03±0.31	0.76±0.23	0.90±0.30	1.81±0.31	1.43±0.40	1.62±0.40
All Glove Types Pooled	685±154	362± 122	524 ±213	0.95±0.26	0.69±0.21	0.82±0.27	1.66±0.30	1.27±0.39	1.47±0.40
	All Orientations Pooled			All Orientations Pooled			All Orientations Pooled		
Low-Friction Glove (cotton)	467 ±164	263 ±88	365 ±167	0.64±0.24	0.50±0.16	0.57±0.22	1.54±0.36	1.13±0.38	1.33±0.42
Bare Hand	652 ±150	339 ±122	495 ±208	0.90±0.26	0.64±0.21	0.77±0.27	1.17±0.37	0.94±0.27	1.06±0.34
High-Friction Glove (PVC dots)	691 ±164	389 ±141	540 ±215	0.96±0.30	0.74±0.24	0.85±0.29	1.68±0.29	1.39±0.40	1.53±0.38
All Glove Types Pooled	604 ±187	330 ±129	467 ±211	0.84±0.30	0.63±0.23	0.73±0.28	1.46±0.40	1.15±0.40	1.31±0.43

[1]Normalized by subject's mean grip strength measured while wearing corresponding glove type on the grip dynamometer (position 2)

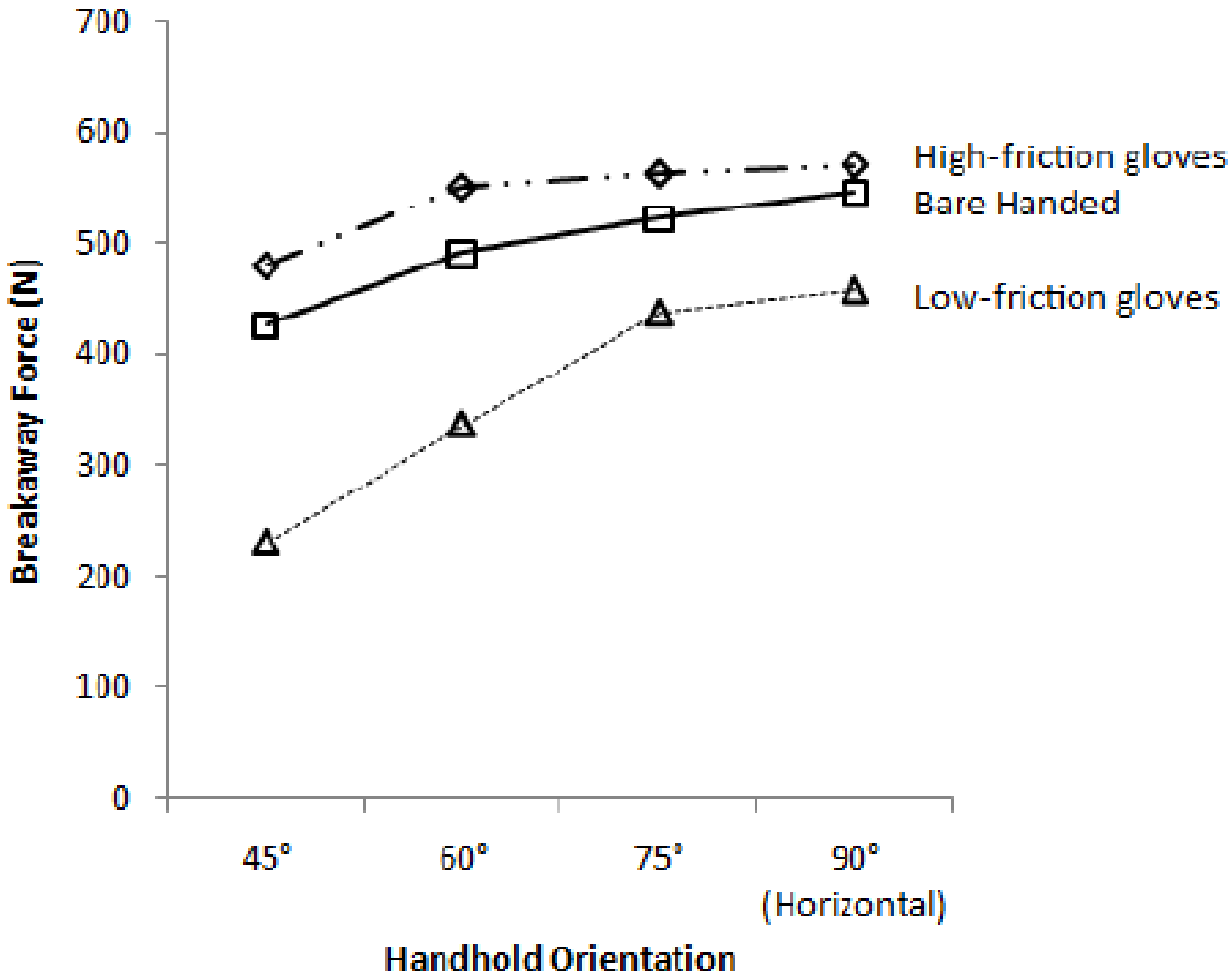


Figure 4.4.2 Breakaway strength (N) by orientation and glove type (non-dominant hand) across all subjects. Strength decreases non-linearly as the handle inclination was increased from the horizontal for all glove types over this range of handle orientations. Strength was consistently least for the low-friction glove and greatest for the high-friction glove.

Commercial Roof

Metric/English

1 cm = 0.4 inches

25 mm = 1 inch

5.12 newton = 1 lbf