Short Rope Tests

Alpine Recreation & Lincoln University Outdoor Leadership course

Objective: Measure the probability of a guide's ability to hold a fall using different short-roping methods and modes without prejudice.

The tests should resemble a real sudden and unexpected client fall situation on an icy 30^0 surface as may be encountered in the field.

Conditions:

1. Create a laboratory set up that imitates good grip cramponing conditions on a 30^0 slope with a hard surface

2. Eliminate changing environmental conditions such as deterioration of the slope during the testing time

3. Eliminate risk of injury

4. Standard sudden application of force, NOT gradual application

5. Build in surprise factor

Method

1. Use a sample of test persons that has no prior knowledge of the current short-roping debate, 10 test persons + myself

2. Construct purpose built ramp of 30^0

3. Provide safe run-out zone

4. Build scaffolding for drop load management

5. Use standard drop load to simulate a standard fall, increase loads in increments of 10 Kg

6. Set up rigging to keep rope always gently tight

7. Use high performance pulleys to keep friction minimal

8. Use static 8 mm rope to eliminate energy absorption of a long line

9. All persons except two had mountaineering experience with the use of crampons

10. All test persons were equipped with short point crampons

11. All test persons were shown different methods of short roping and were given the opportunity to practice walking up and down the test slope with crampons. When holding the rope the belay hand was always high against the chest in order to provide maximum ‘give’.

12. All persons’ holding ability was tested for the three methods:

- direct tie in on the harness without hand loop for “base line study”
- short hand loop with transfer of force onto the harness
- long hand loop with no transfer of force onto the harness

13. Test persons were not to look at the drop load being released in order to build in a surprise factor. They knew that a fall was imminent.

14. All three methods were tested for the following modes:

- standing, facing downhill
- walking uphill
- walking downhill

15. Recorded:

- test persons' weight
- method and mode
- drop load (kg)
- hold / failure (yes / no)
- peak force (N) in front of the hand loop (dynamometer)
- total of 256 samples taken

16. A “fall” = falling / running down out of control

= drop load reaching the ground

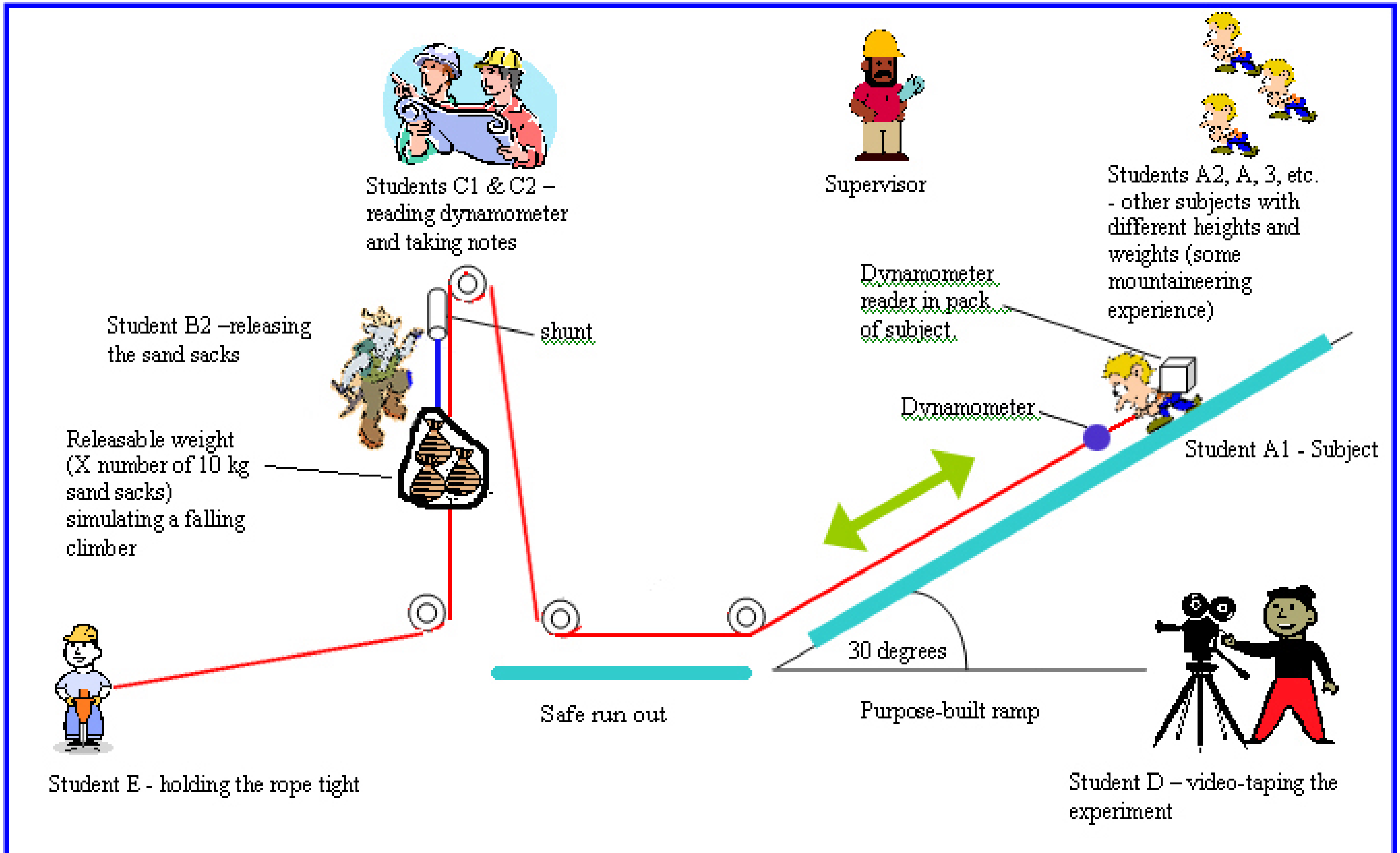
= the dynamometer reaching the first pulley

17. A “hold” = none of the above, stepping down allowed

18. After testing all test persons were asked to comment on their preferred method of short roping.

19. All tests were recorded on video for analysis

Experimental Set-Up: Laboratory Experiment



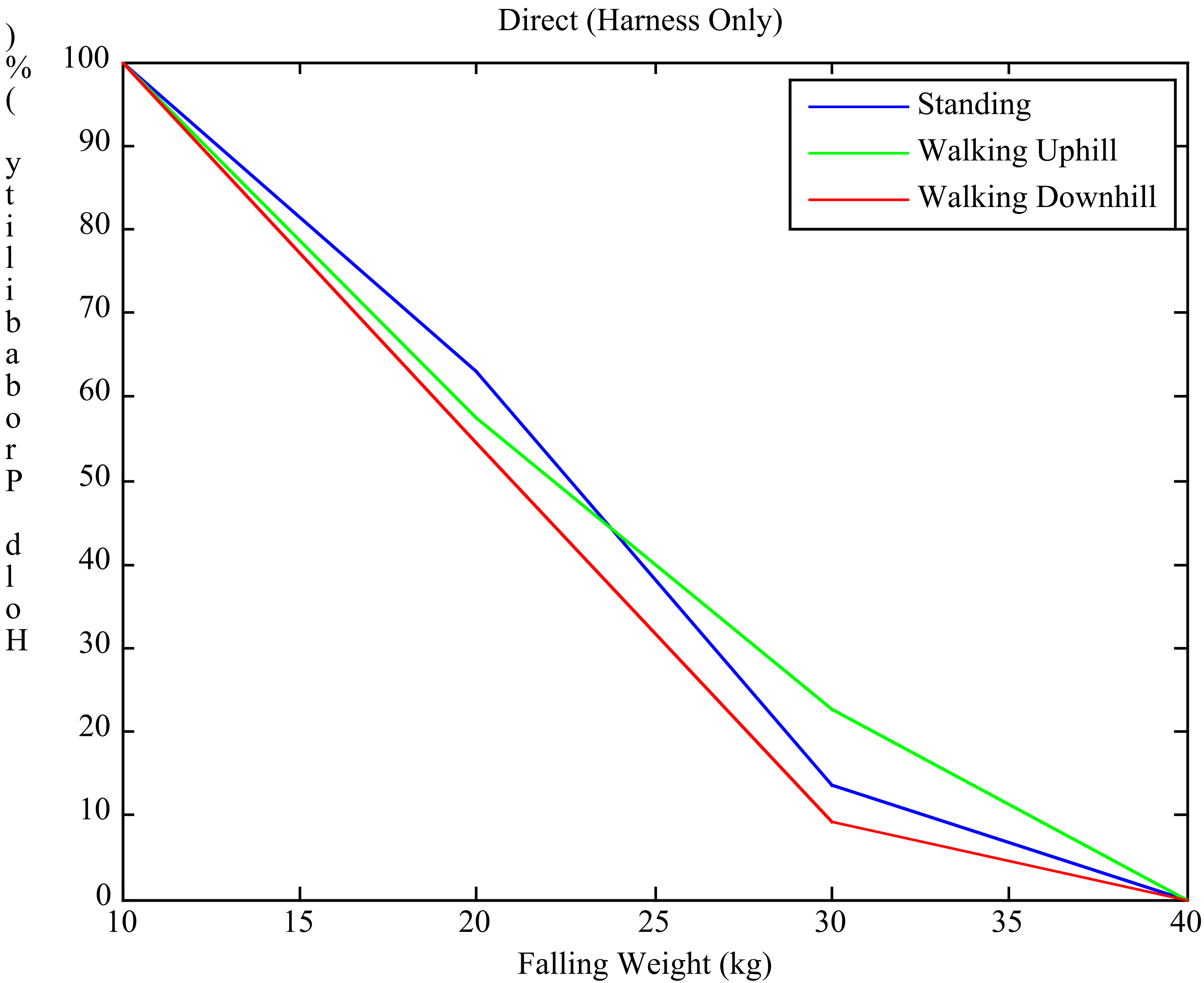

drop load 20 kg
237 N

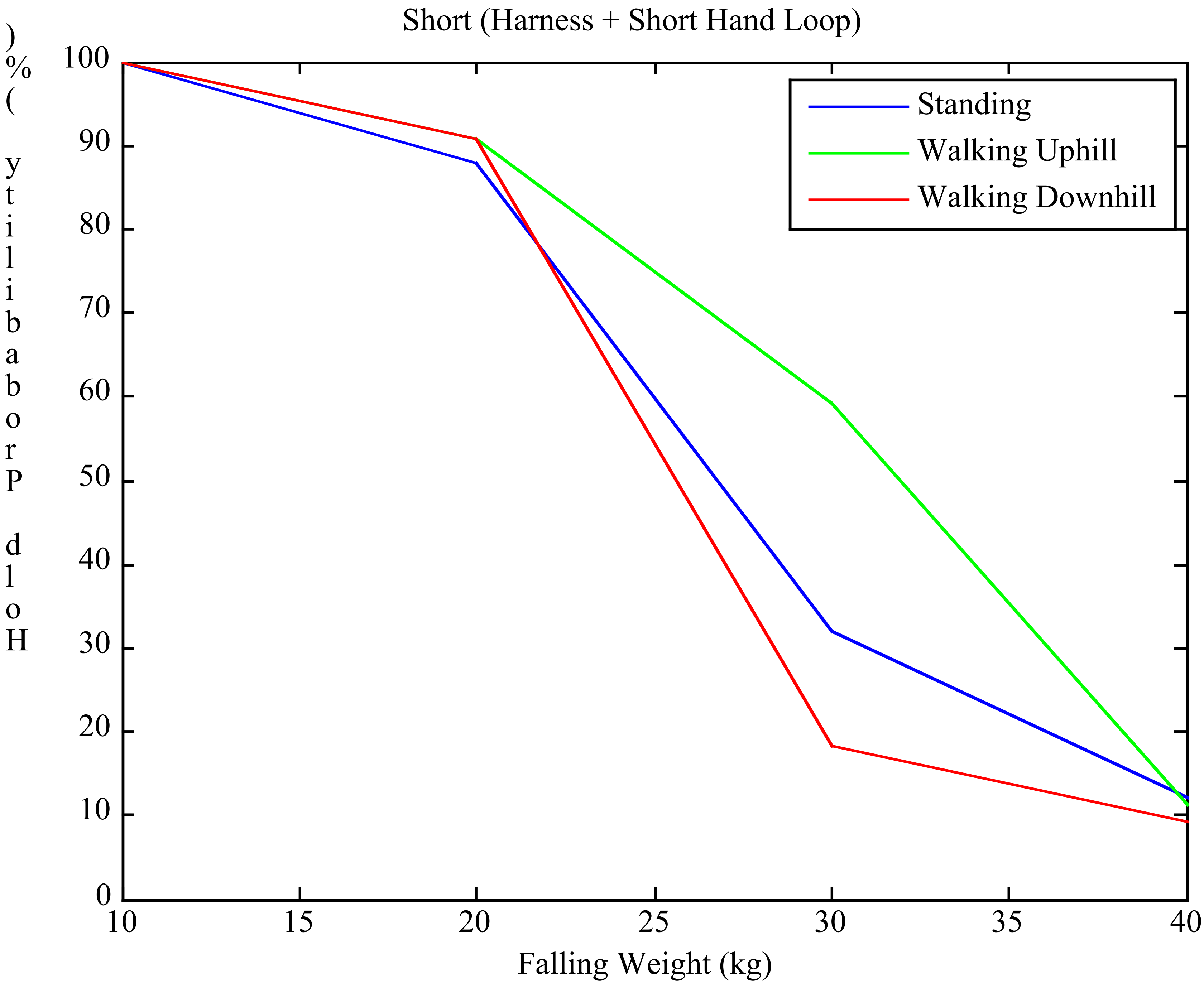
Results:

The probability of holding a fall was plotted against the mass of the drop load for

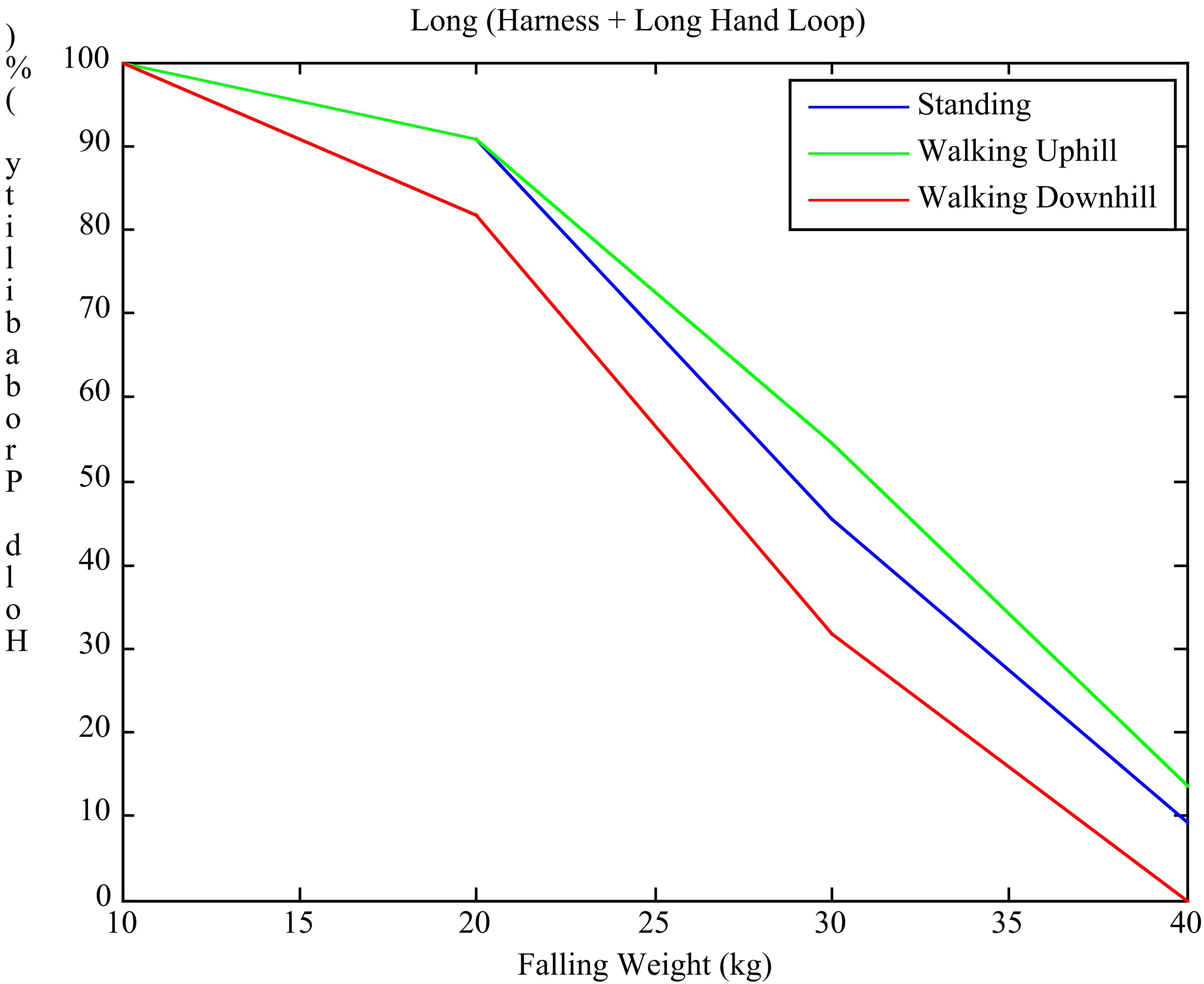
- harness only
- short loop
- long loop
- position comparison
- technique comparison

For statistical analysis please refer to http://www.alpinerecreation.com/ShortRopeTestStats.pdf

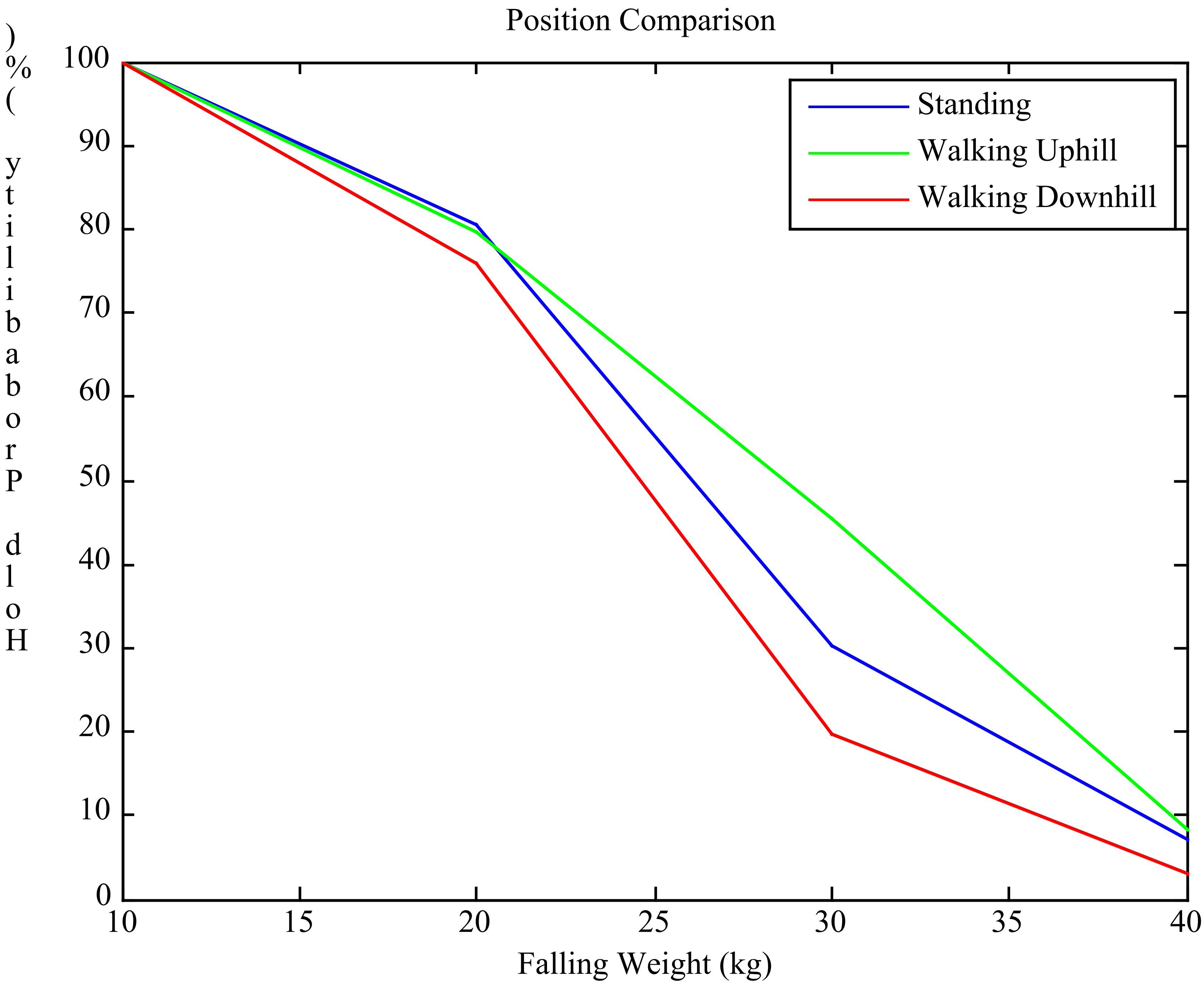

Direct (Harness Only)
Hold Probability (%)
Falling Weight (kg)
Standing
Walking Uphill
Walking Downhill
0
10
20
30
40
50
60
70
80
90
100
10
15
20
25
30
35
40



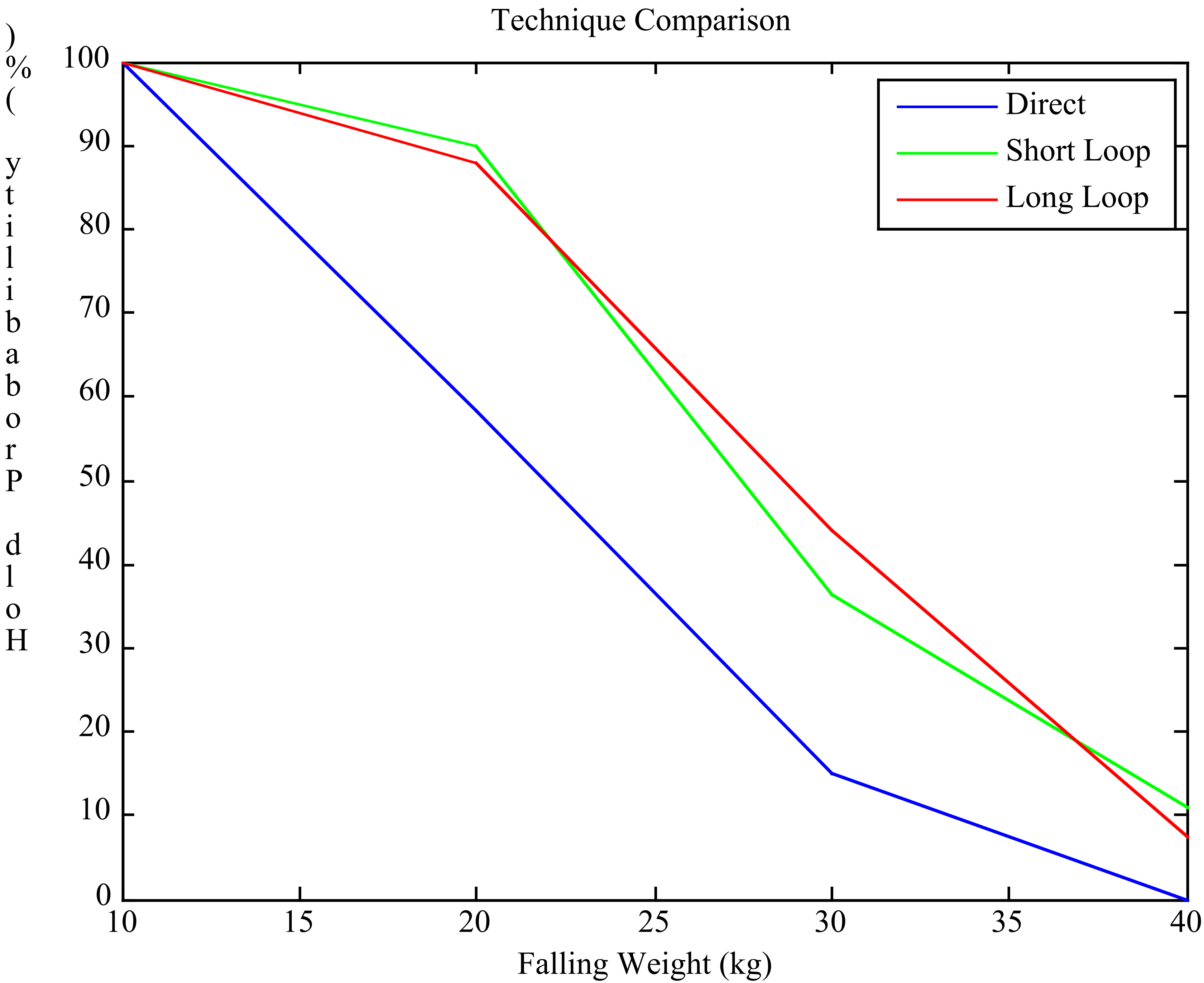
Short (Harness + Short Hand Loop)
Hold Probability (%)
Falling Weight (kg)
Standing
Walking Uphill
Walking Downhill
100
90
80
70
60
50
40
30
20
10
0
10
15
20
25
30
35
40



Long (Harness + Long Hand Loop)
Hold Probability (%)
Falling Weight (kg)
Standing
Walking Uphill
Walking Downhill
0
10
20
30
40
50
60
70
80
90
100
10
15
20
25
30
35
40



Position Comparison
Hold Probability (%)
100
90
80
70
60
50
40
30
20
10
0
10
15
20
25
30
35
40
Falling Weight (kg)
Standing
Walking Uphill
Walking Downhill



Technique Comparison
Hold Probability (%)
100
90
80
70
60
50
40
30
20
10
0
10
15
20
25
30
35
40
Falling Weight (kg)
Direct
Short Loop
Long Loop

Observations from data recorded (sudden loading only)

- Direct attachment on harness results in least holding power

- There is no visible trend between short loop and long loop

- Heavier (stronger?) persons hold more than lighter persons

- Walking uphill shows highest holding power

- Walking downhill shows least holding power

- Overall average for failing forces (long loop , short loop, uphill, downhill, standing) = 356 N, standard deviation = 111 N

- Overall average for holding forces (long loop , short loop, uphill, downhill, standing) = 345 N, standard deviation = 101 N

- Holding / failing forces need to be adjusted downwards in order to reflect the surprise element when a fall occurs in a real situation.

Observations from video, on sight and test persons' comments

- Fast reaction improves chances of holding a fall (fatigue, age may play a role in low reaction times)

- Lowering of centre of gravity improves chances of holding a fall

- Tall persons find it more difficult to hold a fall than short persons

- There was an even split in preferred method (short loop / long loop) by test persons when asked after the tests. This subjective assessment adds substantial support to the objective assessment given by the numerical results

- Stability of test person (footing) influences his/her holding power significantly

- Leaning into the slope increased holding power significantly. This is an unnatural position that skewed results upwards in a number of cases.

Conclusions

When a <u>sudden</u> force is applied to a short-roping guide a direct attachment to his/her harness yields the lowest holding power. This should be considered when roping up in this fashion during glacier travel.

- The advantages of a lower attachment point (height where force acts on the guide) when using the short loop method are balanced against the disadvantages of a reduced reaction time and a reduced ability to absorb energy through upper body movement.

- There is no visible trend in a guide's holding power between short loop and long loop attachment when exposed to <u>sudden</u> loading.

- When paired with the expected acting force of a client's fall the chances of a guide holding a single client are possibly not high enough to rely on short-roping for client safety. (Experiments still need to be conducted to measure the likely forces coming onto a guide by a falling climber, estimated to be > 0.5 of the bodyweight of the falling person on a 30^0 hard icy slope.)

- The chances of a guide holding two clients on such a slope appear to be very slim indeed.

- Short roping on a hard icy surface of > 25^0 needs to be regarded as "confidence-roping" only, regardless of attachment method.

- It brings with it the dangerous addition of a multiple fatality accident in case of a single climber's fall as simultaneous self arrest of the entire party is near impossible.

- Alternative guiding methods should be considered

Qualifying explanations

1. Force gauge / dynamometer

Forces were recorded with a force gauge in maximum load setting and a refresh rate of 0.2 seconds.

Recording only peak forces can lead to erroneous results: In order to get a complete picture one needs to look at the transfer of momentum (impulse), i.e. the product of force x time = mass x speed. Recording forces in a dynamic situation, i.e. when fast loading is applied, requires continuous data logging over a set time period, and integrating the respective forces over time.

Only the comparison of measured impulses of both a “standard fall” and a test person’s “standard hold” will enable us to determine whether that test person is likely to hold a person’s fall in a given setting.

Measuring forces when a person is actually falling and being held by another person inevitably leads to a mixing of results (action = reaction, Newton’s third axiom). Hence we introduced a standard drop load.

In order to eliminate the uncertainty of the force gauge we only plotted the probability of holding a fall against the mass (kg) of the drop load. Thus we were able to compare short roping methods for sudden loadings, i.e. long loop, short loop, harness only, and during different modes, walking uphill, walking downhill and standing.

2. Biomechanics

A short roping fall / hold / slip can be divided into the following four phases:

Phase 1: The rope from the guide to the client is gently tight with only about 10 to 15 N. The guide's belay arm is angled. Guide and client are moving at the same pace.

Phase 2: The client falls. His centre of gravity accelerates until he hits the ground. With little or no friction on the icy surface he starts sliding downhill. During this phase the client gathers momentum mass x speed, m x v. The guide's arm is forced in the direction of the pull. The force on the guide's arm increases. The guide needs to react quickly. Having the arm angled, not outstretched, buys the guide valuable reaction time.

Phase 3: Client's momentum is transferred to the guide. If the guide reacts fast enough he / she absorbs momentum and energy by moving his / her upper body and by stepping down. The guide transfers momentum to the ground and shifts his her centre of gravity reclining from the vertical. If the pull comes onto the guide's harness (centre of gravity) during this phase the guide may not be able to shift his / her centre of gravity and is pulled off balance (tests with harness only attachment consistently resulted in high failure rates).

Phase 4: If the guide is able to hold the fall he / she reaches an equilibrium with the fallen climber: The force of the guide's reclined centre of gravity counterbalances the force of the fallen client on the slope below. Now the force of the rope may be transferred to the harness.

For the final phase the following applies:

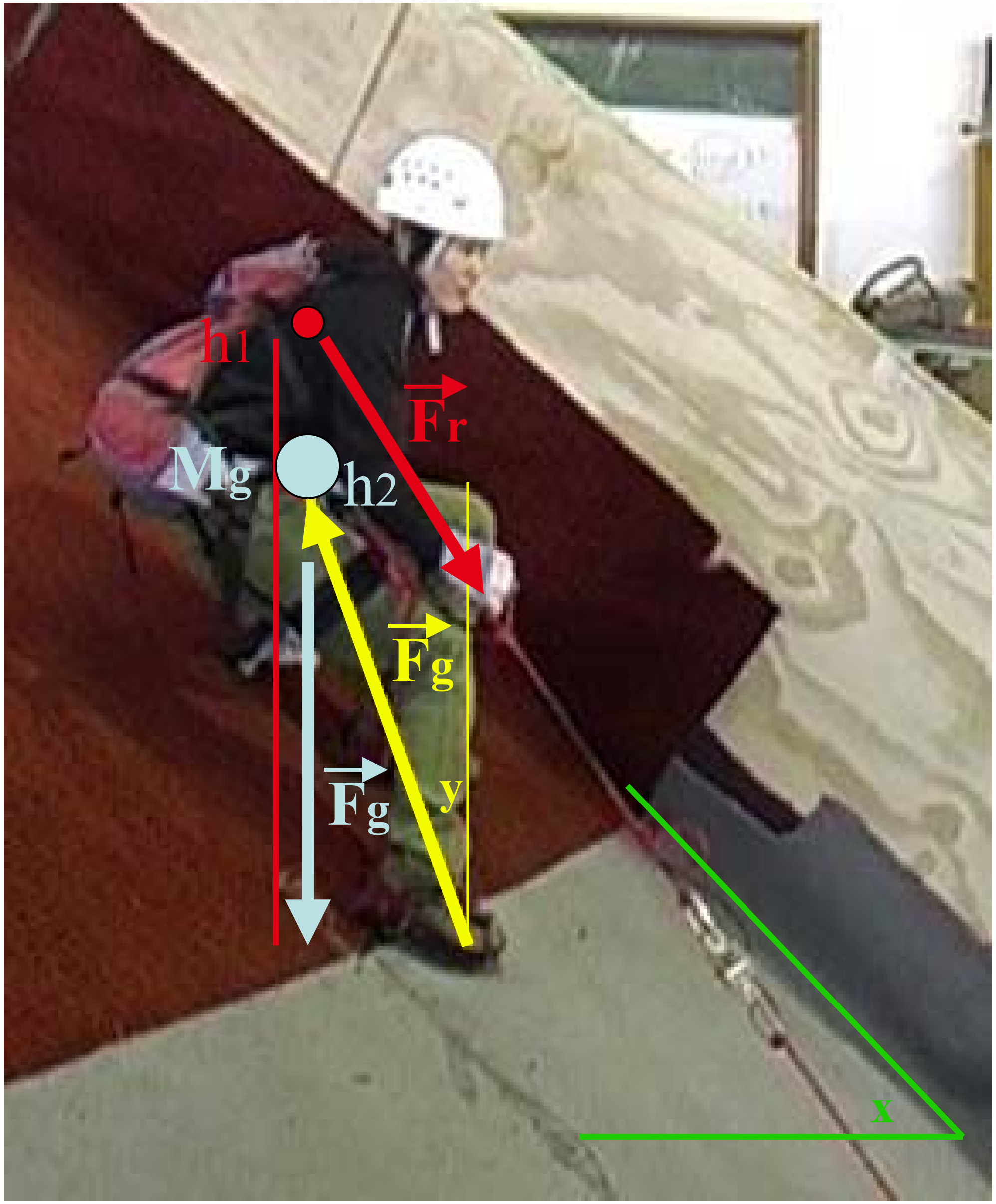
A guide with mass Mg is reclining with his/her centre of gravity by the angle y from the vertical.

A client with mass Mc on a frictionless slope of gradient x is being held by the guide's rope, parallel to the ground.

In order to achieve an equilibrium the force F of the ground on the climber, the gravitational Force F_g acting on the climber's centre of gravity and the force F_r of the rope acting on the climber's arm must add to zero.

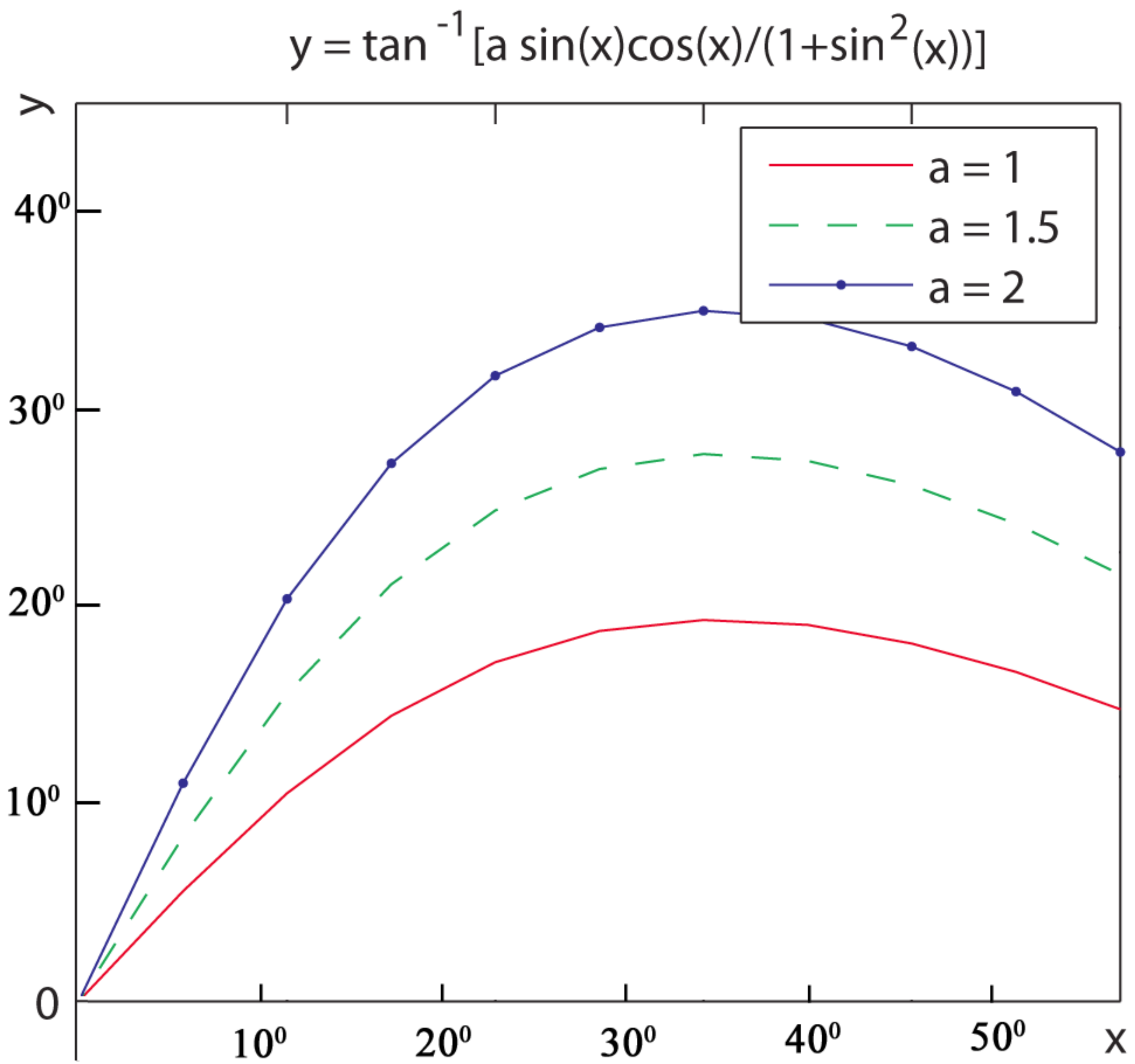
h_1 is the height above ground where F_r is acting.

h_2 is the height above ground where F_g is acting.

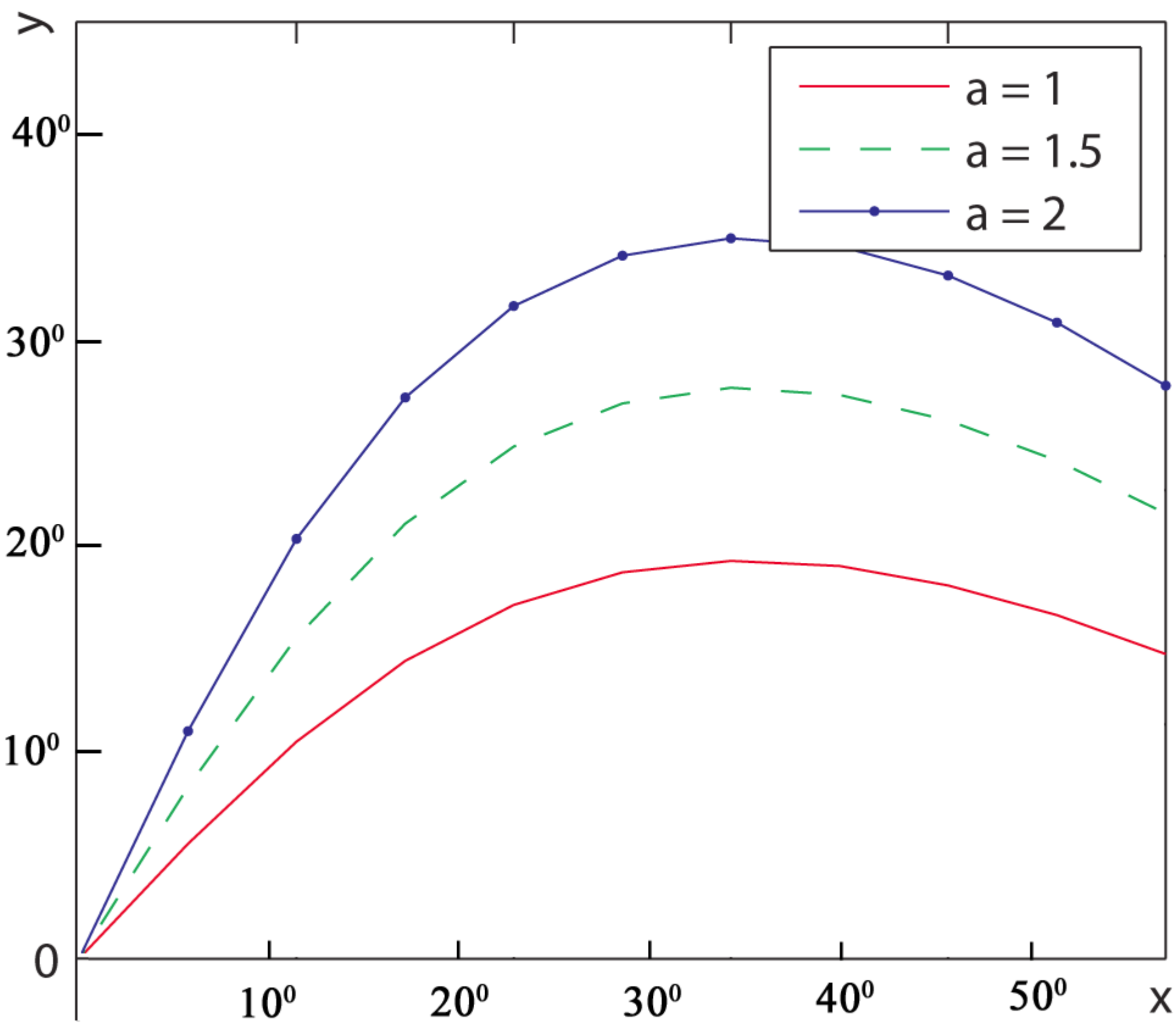


$\tan(y) = h_1/h_2 \times M_c/M_g \times [\sin(x)\cos(x) / (1 + \sin^2(x))]$

For different values of $a = h_1 / h_2 \times M_c / M_g$



$$y = \tan^{-1}[a \sin(x)\cos(x)/(1+\sin^2(x))]$$



$a = h_1 / h_2 \times M_c / M_g$

If the reclining angle y is a measure for the difficulty of staying in balance then it is obvious that

1. The smaller the ratio h1 / h2 the better

2. The smaller the ratio Mc / Mg the better

Gottlieb Braun-Elwert

UIAGM, guiding since 1971

MSc (Physics, Technical University Munich 1976)

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