What Heavy climbers need to know.

Ever taken a fall that jolted your belayer for a short ride towards that first clip? Or perhaps you've seen a piece or two of that "maybe it will hold" gear you just placed pop out while you're catching some air, hoping the next one will hold? Or maybe people comment, "Gee, you're awfully big for a climber."

The common denominator in these events could simply be that you are in fact a "heavy" climber, bigger than most of your climbing friends. And when we heavy climbers take falls common sense tells us that catching our falls will always generate higher loads on our safety system, including belayer, than when our lighter-weight climbing companions take that same fall. Of course there's nothing wrong with heavy climbers - or I'd never find a partner. We just have this additional issue to be concerned about.

We've all seen those UIAA test numbers attached to new climbing ropes or in catalogs. But did you know that those IMPACT FORCE and NUMBER OF FALLS HELD figures are based on using an 80-kg test mass dropped on the rope in the laboratory? (See sidebar for more info.)

So, if you're more than 80 kg, where does that leave you? When you take that hard fall, could you be subjecting yourself and your gear to possibly unsafe loads? Serious questions indeed, but they're not directly addressed by the UIAA testing results. To better understand this possible safety issue, PMI conducted a series of 39 special drop tests in our UIAA replicate Drop Tower.

The Tests

The tests we performed were modified UIAA drop tests with two main parts. The first part was to simply drop five different test masses, all greater than the normal 80 kg, in the normal UIAA dynamic rope drop test setup (see sidebar) and record the impact forces. These test masses ranged from 91 to 137 kg (200 – 301 #).

The second part was more involved. For each of these five "heavy" test masses, we conducted a series of drop tests in which we lowered the fall factor by 0.1, dropped the test mass, and recorded the impact force. Using a new section of test rope for each individual drop test, we continued in this manner until the recorded impact force was comparable to the impact force created by the 80-kg test mass in the standard UIAA drop test setup.

The Results

The results of our testing are shown in the table and graph at the end of this article. Here's a summary of our most important findings:

1) Greater weight = greater impact force

Looking at all the tests from the same drop height (holding the fall factor constant), it is clear that as you increase the test mass the impact force also increases. You can see this on the graph by picking any fall factor and going straight up, noting where each test mass line is intersected. This relationship would also be true for other fall factors and test masses that are not presented here.

When you compare the 80 kg and 91 kg test masses, you find that dropping them the same distance gave different impact forces. The falling 80 kg generated 8.3 kN while the 91 kg registered at 9.1 kN, 10% more.

Then if you follow the reduced fall factor drops on the 91 kg test mass, you can see that it approximately equaled the "standard" drop when we got to the 1.4 fall factor. This means that we had to reduce the length of the drop by 0.9 meters (or 19%) to make the impact forces of the 91 and 80 kg test masses comparable.

2) Fall Factor is key

If you haven't acquired a good understanding of fall factor you need to! Perhaps this article and test data can help provide you with a better understanding.

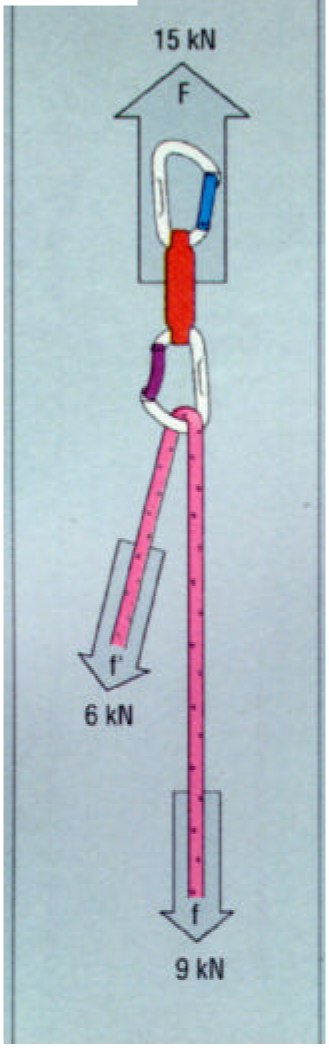
The graph demonstrates this simple rule – for all the weights tested, increasing the fall factor will always generate **higher** impact forces. This is easy to see on the graph. Just follow any of the five test mass's line up and to the right.

An applicable real-world climbing situation is the possible short fall onto your belayer or first piece(s) of protection during a multi-pitch climb. Be especially wary of these short falls as they might generate higher forces than you'd expect. As much as possible, keep the fall factors low by NOT being sparse on your pro when leaving the belay to start that next pitch.

3) Dangerous loads

It is important to realize that our carabiners, bolt hangers, pieces of pro, etc. are **directly related** to this 12 kN upper limit for ropes. Without going into all the details, the widely accepted rule of thumb is that the top piece of gear in your system will experience **2/3 MORE** force than that felt by the falling climber (see figure 3 for example). So, one could apply this rule using any of these test result impact forces (see data table and graph) and estimate the forces on other pieces of gear in the protection system.

Figure 3



Take this test result for example.
We found that a 114 kg dropped in a 1.7 fall factor generated 11.1 kN force at the climber's end of the rope. This is dangerously close to the UIAA's 12 kN safety limit! This impact force on the climber's end of the rope translates to 18 kN on the top anchor point. If this number exceeds the capacity of your top anchor pieces they might fail.

These combinations of weights and fall factors may sound unlikely to ever occur for most climbers. BUT, say you're about a 91 kg climber. **How much do you really weigh with all your extra clothes, gear, pack, etc.?** Whichever styles of climbing you pursue: aid, alpine, big-wall, ice, mixed, trad, whatever; it is always critical for you to realize the limitations of all your gear.

Remember that heavier loads and higher fall factors **ALWAYS** add up to higher impact forces that your gear will have to absorb if you fall.

The Truth

The truth of the matter is that today's climbing ropes and gear bless us with very safe performance as we engage in our potentially dangerous past time. Today's climbing ropes rarely ever fail, but when they do they're cut versus pulled to failure from excessive loads. Most of your other climbing equipment will fail or pull out of the rock from high loads before your rope will ever break. So don't worry about impact forces breaking a rope if you're a heavy climber, it won't happen. However, ALWAYS remember that the ropes and gear are NOT indestructible and high impact forces and sharp rock edges are our enemy!

Important Notes about this testing

The data presented here should only be used for general comparisons and understanding of the relationship between fall factors, weights, and impact forces. Do not misinterpret the data as an absolute method for determining impact forces. Other name brands, diameters, and types of ropes were not tested and should NOT be assumed to have the exact same numbers.

The purpose of this article is simply to share these testing results with the intent of helping climbers make safer climbing situation decisions. The results of this testing may be useful in determining whether a severe fall situation is capable of generating forces high enough to cause failure of a component in a climbing system.

Reference:

(1) 1950's US military parachute research which led to publication of test report WCLE-53-292 as well as Pilot ejection tests by Henzel in 1967, and Webb in 1964.

(2) Figures 2 and 3 compliments of BEAL 1999 and Petzl 1996 Catalogs, respectively.

Special thanks to:

Austin Newman who performed all the testing represented in this article in the PMI drop tower while he worked at PMI for two summers before completing his studies at local UTC.

About the author:

Chuck Weber has been climbing for 10 years and for the last 5+ years has been putting his engineering background to use as PMI's Quality Manager and ISO System Coordinator. He has the uncommon luxury of access to a UIAA replicate drop tower at PMI. In addition to his routine ISO Quality System and testing duties, he occasionally has the opportunity to do more interesting stuff in the drop tower. This article is one example.

SIDEBAR:

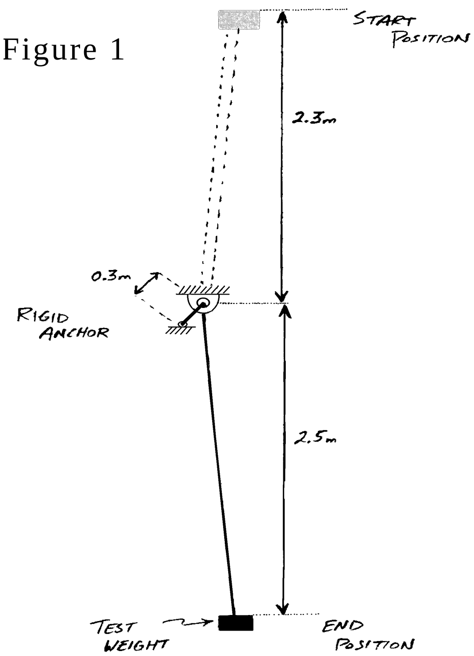
What are 80 kg and 12 kN all about?

80 kg (176 pounds) is this nice round magical number the UIAA selected to represent an "average climber" for the falling body in the required drop test.

In the standard drop test the weight is connected to a rigid anchor by about a 4 meter length of rope. The "belay end" of the rope is anchored a short distance below a smooth edged hole in a steel plate (simulating a "fat carabiner").

Then the "climber's end" of the rope is threaded through this hole (top anchor) and tied to the test weight. Before the drop test the length of the rope is adjusted so that the weight hangs exactly 2.5 meters below this top anchor (see figure 1).

Figure 1



To perform the drop test the weight is raised 2.3 meters above this top anchor and released for a 4.8 meter fall. Using the details of the drop test configuration this fall factor (length of fall divided by length of rope out) measures in at a hefty 1.7. As many of you already know, the maximum fall factor you could achieve in a lead-climbing fall is 2.0. To do this you'd have to fall directly onto and past your belay (see figure 2).

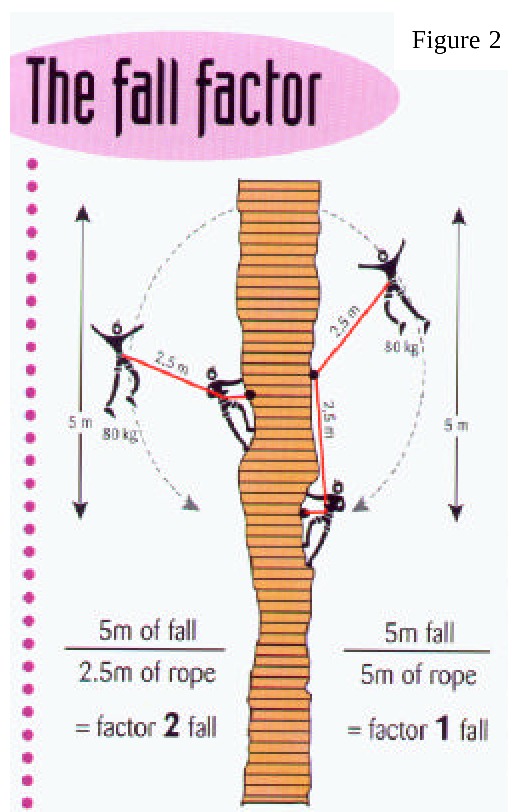
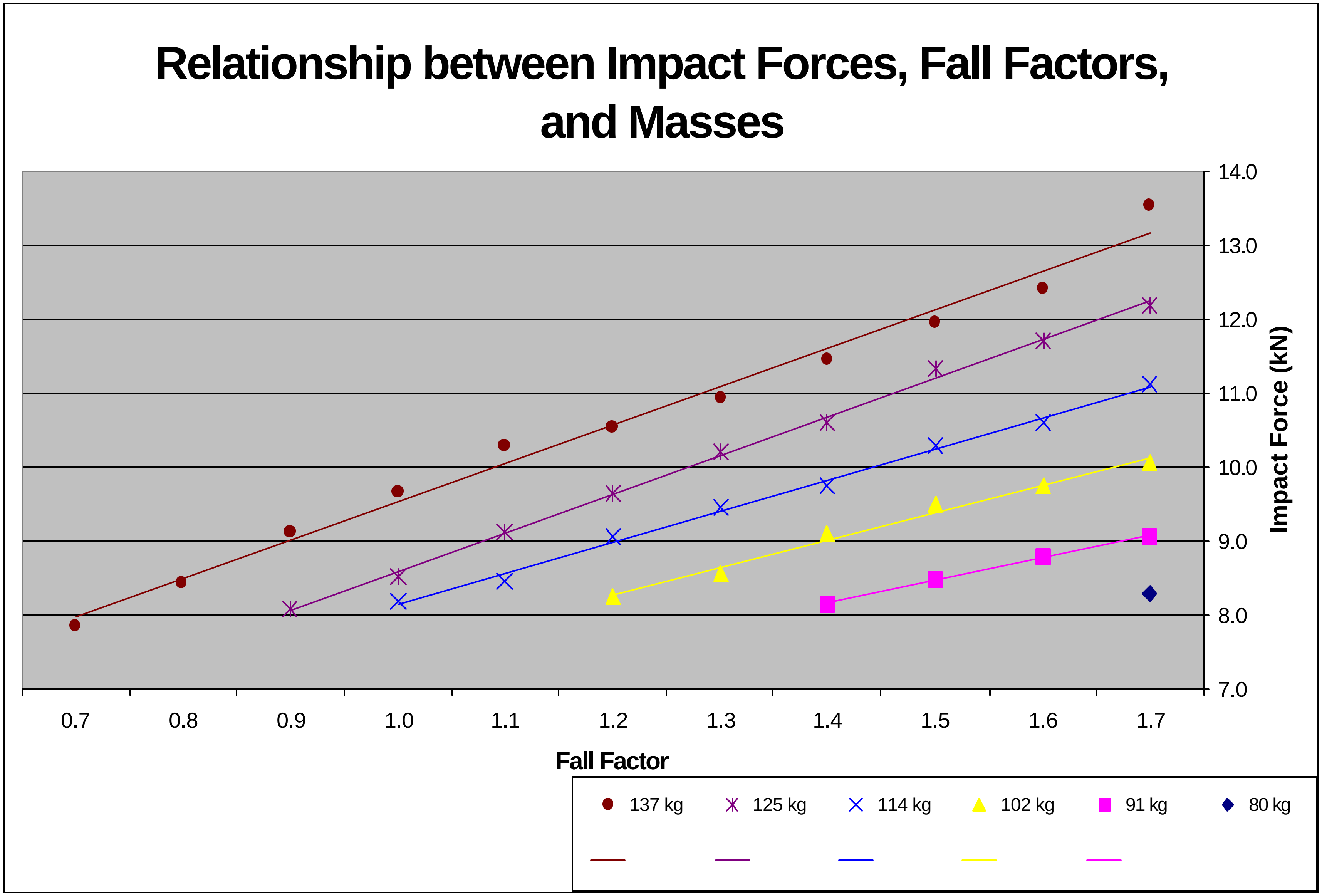


Figure 2

To go along with this 80 kg test mass, the UIAA also adopted an old US Military specification (1) of 2700 lbf (pounds force), aka 12 kN. This number is what our government once accepted as the maximum allowable force that a paratrooper could withstand when his parachute deployed and jerked his free falling body to a much slower rate of descent. So, simply translate all that to a climber taking a severe fall and you get the picture. Luckily, most of today's climbing ropes are well below that safety limit when tested with 80 kg.

Relationship between Impact Forces, Fall Factors, and Masses



What Heavy climbers need to know.

Drop #	Fall Factor	drop length (m)	Test Weight (lb)	Test Mass (kg)	Impact force (lbf)	Impact force (kN)
1	**1.7**	**4.8**	**176**	**80**	**1866**	**8.3**
2	1.7	4.8	200	91	2038	9.1
3	1.6	4.5	200	91	1978	8.8
4	1.5	4.2	200	91	1908	8.5
5	1.4	3.9	200	91	1830	8.1
6	1.7	4.8	225	102	2261	10.1
7	1.6	4.5	225	102	2190	9.7
8	1.5	4.2	225	102	2136	9.5
9	1.4	3.9	225	102	2048	9.1
10	1.3	3.6	225	102	1925	8.6
11	1.2	3.4	225	102	1854	8.2
12	1.7	4.8	250	114	2499	11.1
13	1.6	4.5	250	114	2383	10.6
14	1.5	4.2	250	114	2315	10.3
15	1.4	3.9	250	114	2190	9.7
16	1.3	3.6	250	114	2128	9.5
17	1.2	3.4	250	114	2039	9.1
18	1.1	3.1	250	114	1900	8.5
19	1.0	2.8	250	114	1842	8.2
20	1.7	4.8	276	125	2740	12.2
21	1.6	4.5	276	125	2632	11.7
22	1.5	4.2	276	125	2549	11.3
23	1.4	3.9	276	125	2383	10.6
24	1.3	3.7	276	125	2297	10.2
25	1.2	3.4	276	125	2167	9.6
26	1.1	3.1	276	125	2051	9.1
27	1.0	2.8	276	125	1915	8.5
28	0.9	2.5	276	125	1816	8.1
29	1.7	4.8	301	137	3046	13.5
30	1.6	4.5	301	137	2793	12.4
31	1.5	4.2	301	137	2686	11.9
32	1.4	3.9	301	137	2575	11.5
33	1.3	3.7	301	137	2460	10.9
34	1.2	3.4	301	137	2368	10.5
35	1.1	3.1	301	137	2312	10.3
36	1.0	2.8	301	137	2175	9.7
37	0.9	2.5	301	137	2052	9.1
38	0.8	2.3	301	137	1895	8.4
39	0.7	2.0	301	137	1768	7.9

Test Notes:

1) Forces were measured at the "falling climber's" end of the rope, NOT the anchor / belay end.
2) All data are actual measurements recorded in the PMI laboratory – not by equations.
3) Each drop was onto an identical but virgin piece of PMI 10.5mm dry treated dynamic rope.
4) PMI's 1997 model 10.5mm rope was tested. Its UIAA test results are 10 falls held, 7.8 kN (1755 lbf) impact force, and an elongation of 6.8%.
5) Other name brands and types of ropes were not tested.