Hold On

If you're suddenly confronted with a very heavy item to hold, you may not be able to keep it from falling, but the fact that you're *trying* to hold it up will slow it down as it drops to the ground, perhaps just enough for the person next to you to move their toes out of the way.

How much extra time could you buy?

How much slower would the object be travelling at the moment of impact?

Let's start with a few assumptions:

- You are capable of holding – at least for a few seconds – a weight of 100kg.
- You are handed a 400kg weight (the heaviest unaided deadlift record stands at around 500kg)
- You initially hold the weight at a height of 1m above the ground.

1. Find the **extra** time taken for the weight to reach the ground given that you are trying to hold it up, compared to the time it would take to drop on its own.

2. Find the **reduction** in speed of the weight at the moment of impact given that you are trying to hold it up, compared to the speed if it simply fell.

Extension: The average reaction time is 215 milliseconds. If a jack suddenly fails on a mini (650kg), which then drops 20cm, would your holding it as it fell give the mechanic time to save his toes?

Hold On - Solutions

If you're suddenly confronted with a very heavy item to hold, you may not be able to keep it from falling, but the fact that you're *trying* to hold it up will slow it down as it drops to the ground, perhaps just enough for the person next to you to move their toes out of the way.

How much extra time could you buy?

How much slower would the object be travelling at the moment of impact?

Let's start with a few assumptions:

- You are capable of holding – at least for a few seconds – a weight of 80kg.
- You are handed a 400kg weight (the heaviest unaided deadlift record stands at around 500kg)
- You initially hold the weight at a height of 1m above the ground.

1. Find the **extra** time taken for the weight to reach the ground given that you are trying to hold it up, compared to the time it would take to drop on its own.

$$\boldsymbol{Drop}: \quad s = ut + \frac{1}{2}at^2 \quad \Rightarrow \quad 1 = \frac{1}{2}gt^2 \quad \Rightarrow \quad t = \sqrt{\frac{2}{g}} = \boldsymbol{0.452s\ to\ 3\ s.f.}$$

$$Force\ exerted\ by\ lifter: \quad F = ma = 100g \quad Force\ exerted\ by\ object: \quad 400g$$

$$Resultant\ force: \quad F = ma \quad \Rightarrow \quad 300g = 400a \quad \Rightarrow \quad a = \frac{3}{4}g$$

$$\boldsymbol{Hold}: \quad s = ut + \frac{1}{2}at^2 \quad \Rightarrow \quad 1 = \frac{3}{8}gt^2 \quad \Rightarrow \quad t = \sqrt{\frac{8}{3g}} = \boldsymbol{0.522s\ to\ 3\ s.f.}$$

$$Extra\ time: \quad 0.522 - 0.452 = \boldsymbol{0.0699s\ to\ 3\ s.f.}$$

2. Find the **reduction** in speed of the weight at the moment of impact given that you are trying to hold it up, compared to the speed if it simply fell.

$$\boldsymbol{Drop}: \quad v^2 = u^2 + 2as \quad \Rightarrow \quad v^2 = 2g \quad \Rightarrow \quad v = \sqrt{2g} = \boldsymbol{4.43ms^{-1}\ to\ 3\ s.f.}$$

$$\boldsymbol{Hold}: \quad v^2 = u^2 + 2as \quad \Rightarrow \quad v^2 = \frac{3}{2}g \quad \Rightarrow \quad v = \sqrt{\frac{3}{2}g} = \boldsymbol{3.83ms^{-1}\ to\ 3\ s.f.}$$

$$Reduction\ in\ speed: \quad 4.43 - 3.83 = \boldsymbol{0.593ms^{-1}\ to\ 3\ s.f.}$$

Extension: The average reaction time is around 215 milliseconds. If a jack suddenly fails on a mini (650kg), which then drops 20cm, would your holding it as it fell give the mechanic time to save his toes?
Answer: Maybe. It would buy you an extra 15 milliseconds (up from 202 to 220 milliseconds), so provided he's in the faster 50% of the population he should be ok. (Note: athletes react in between 120 and 160 milliseconds).