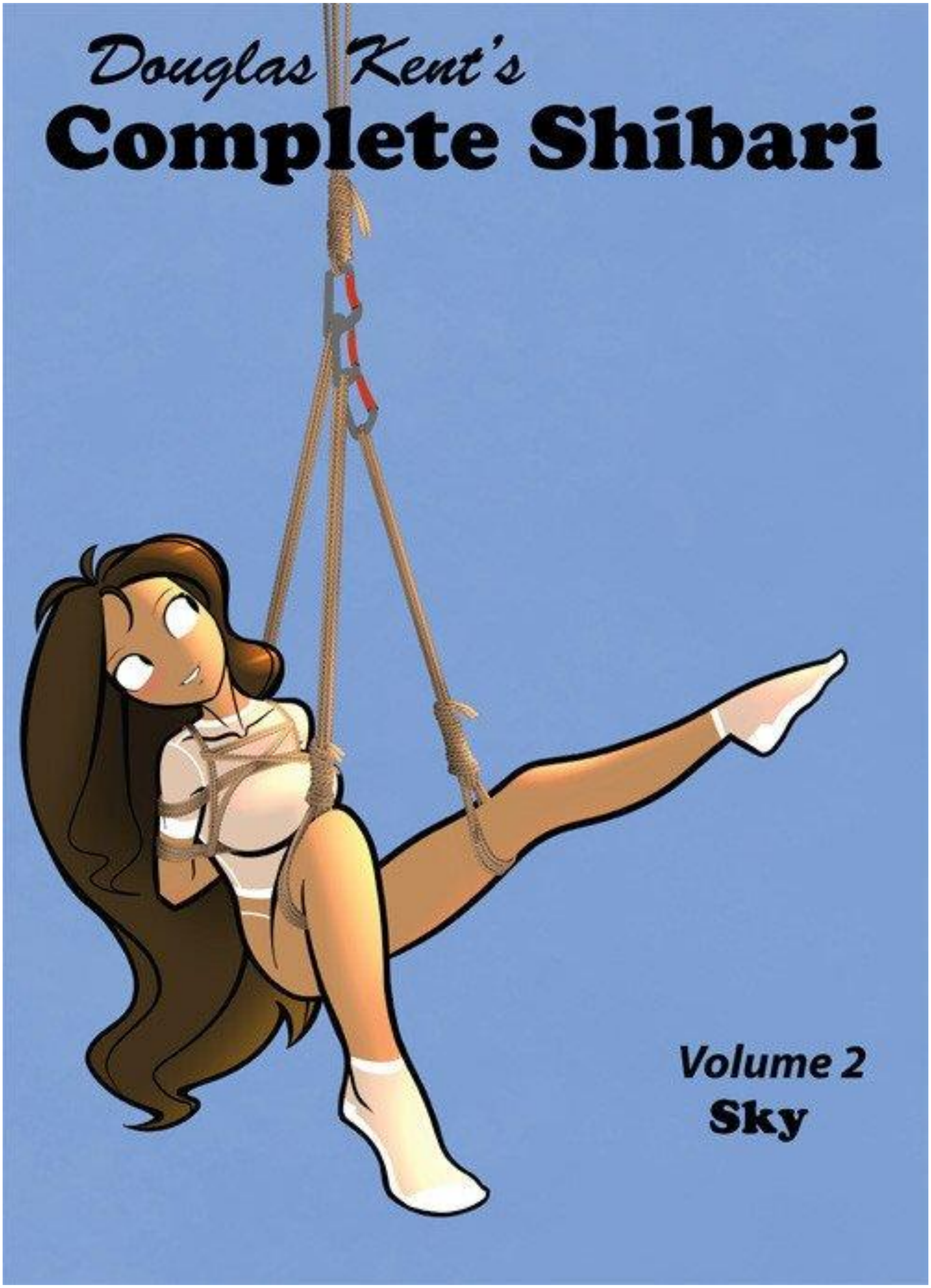


Douglas Kent's

Complete Shibari

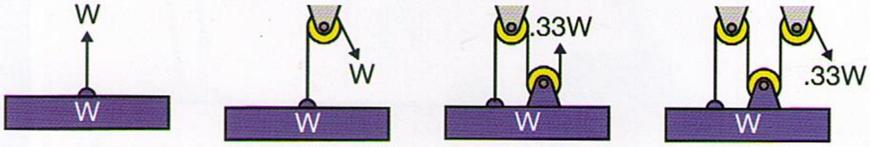
Volume 2

Sky

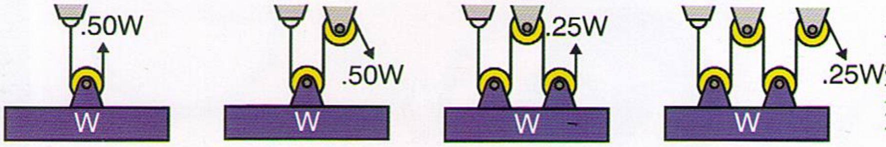
Understanding suspension physics

Mechanical advantage I – Pulley ratios

Pulleys act as load dividers to let you lift objects using less force.

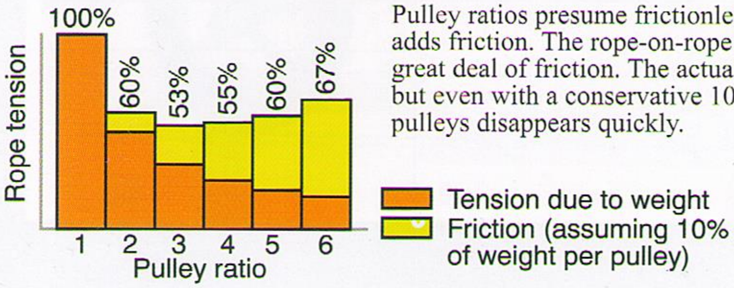


Pulley arrangements starting at the bottom tend to have pulley ratios of 1, 3, 5…



…while arrangements with the ropes starting at the ceiling tend to have pulley ratios of 2, 4, 6…

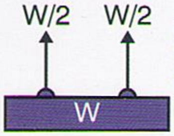
Mechanical advantage II – Friction in pulleys



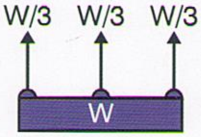
Pulley ratios presume frictionless pulleys. In reality, each pulley adds friction. The rope-on-rope pulleys used in shibari produce a great deal of friction. The actual friction varies with many factors, but even with a conservative 10% friction, the benefit of many pulleys disappears quickly.

Division of load I – Multiple lift points

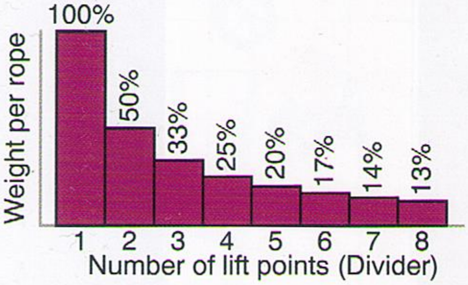
A weight, W, hanging straight down, puts a tension, W, on the rope.



A second rope can divide the tension in two…

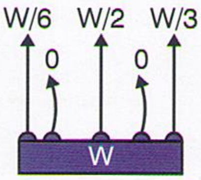


…a third, by three.

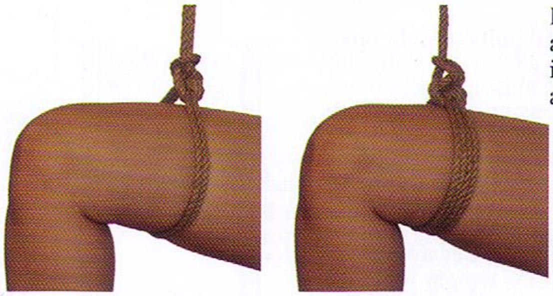


As additional ropes are added, the tension on each rope can be reduced, but by a smaller increment each time, until the difference of adding a rope becomes almost imperceptible.

However, if the ropes don't take tension evenly, additional ropes may do nothing (or reduce the effectiveness of other ropes).



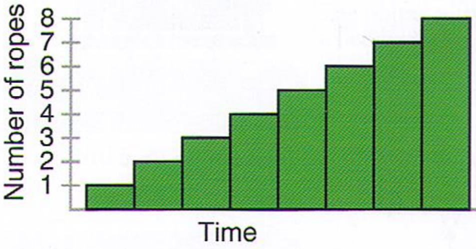
Division of load II – Pressure



Division of load also applies to distributing pressure across an area…

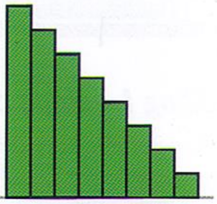
…with the same problems of distributing load evenly.

Division of load III – Time efficiency

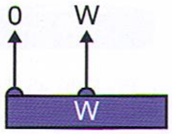


Though each additional rope benefits less and less, it takes roughly the same amount of time to add…

…and remove. So make each rope count!

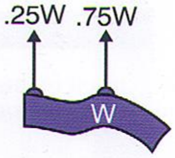


Load distribution I – Flexible bodies

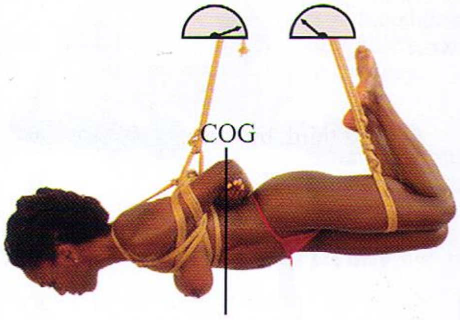


With a rigid structure and inelastic rope, imbalances in loading could mean that a single rope could end up taking the entire load.

Stretchy rope and a flexible body help distribute load more evenly amongst the ropes.

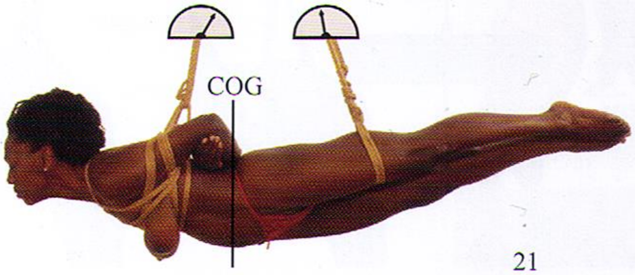


Load distribution II – Counterbalance



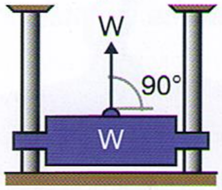
Position affects weight distribution and center of gravity (COG).

In this simple two-point suspension, most of her weight is on her chest harness.



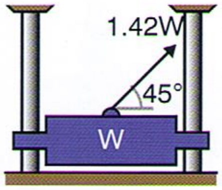
Straightening her legs acts as a counterbalance, reducing the weight supported on the chest harness and increasing the weight on the leg loop.

Angle of pull



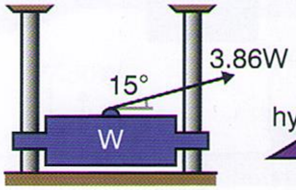
Lifting a weight, W, with a 90° pull (straight up), requires a rope tension, W.

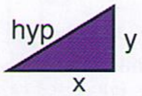
At 45°, the rope tension rises to 1.42W.



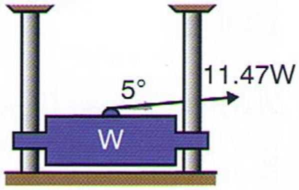
As the direction of pull gets further from the direction of gravity, the rope tension rises dramatically…

…until at 5° (almost a sideways pull), the rope tension to lift the weight is 11.47W!



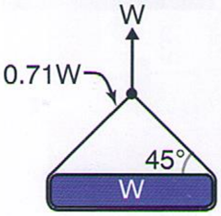


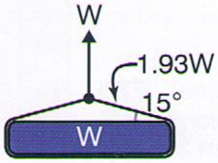
For off-angle pulls, the hypotenuse is the rope tension, but only the *y* component adds vertical lift.

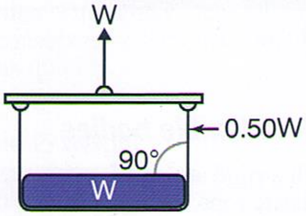


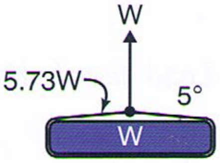
Sling I – Rope cradles

Rope cradles divide the tension in two. However, the ratios are the same as for a single-rope lift.









The tension in the cradle stretches the rope and crushes the suspended object.

In the 5° sling, the object will be compressed as if it's 11.47 times as heavy as the 90° cradle (5.73W instead of 0.50W).

Sling II – Comfort

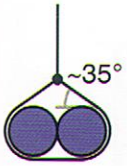
Rope angle is a major predictor of a suspension's comfort.

Comfortable

Less comfortable

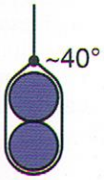
Uncomfortable

Slings III – Orientation of 2 objects

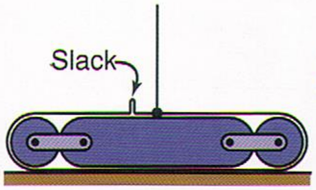


The tension in a sling depends on the orientation of the object within. Two cylinders side-by-side in a sling create more rope tension…

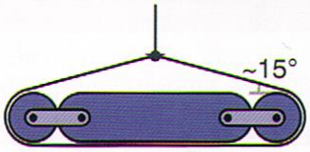
…than two suspended vertically, even though the length of the rope sling is unchanged. The steeper angle predicts that the second arrangement will have less tension. (Note that the *angle* determines tension, not the distance of the rope from the body or the area under the rope.)



Slings IV – Orientation of 3 objects



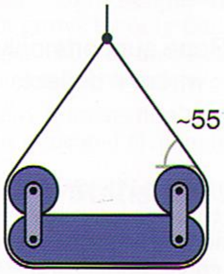
The object within this sling is similar to the upper body when bound in a Box Tie – two arms and a torso.



When suspended, the angle is very shallow, indicating great rope tension.

Rotating the object 90° increases the rope angle (reduces the tension), without changing the sling's rope length. Again, notice how the rope gap isn't a predictor of rope tension (this configuration has very little gap), but rope angle is.

Side suspensions tend to be more comfortable, particularly for tight chest harnesses or broad-shouldered individuals.

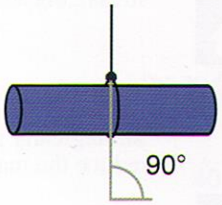


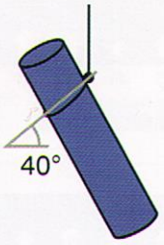
However, if the bottom's arms can rotate back (such as they do for "Hogtie Suspension" on page 80), the tension is reduced dramatically. Small, flexible bottoms are usually best able to do so, though few can move their arms fully out of the way.

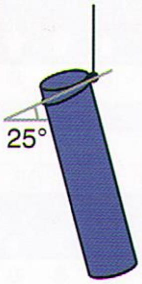
Bundles of objects will tend to stabilize where the tension is lower (and rope angle is greatest).

Slings V – Hanging vertically

Hanging an object vertically in a sling also creates a rope angle that suggests relative tightness.

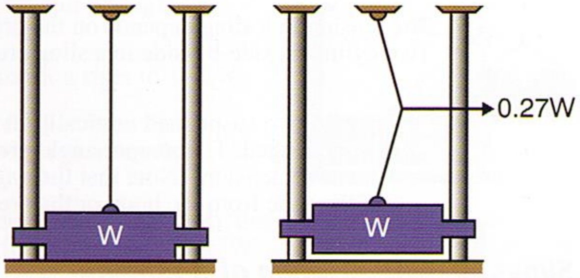






Deflecting rope I – Lifting

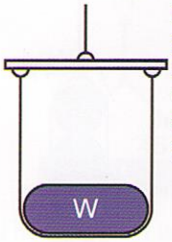
A rope can't withstand even the slightest side load without deflecting (excepting rope stiffness). In fact, it would take an extreme amount of rope tension to prevent deflection. Conversely, slight deflecting force on a rope can lift a heavy weight.



Deflecting rope II – Cinches

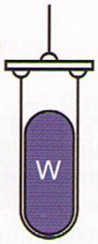
Since cinches pull in the middle of ropes, slight cinch tension can put great tension on a rope. Suspending with a cinch can put extreme tension on rope (and similarly extreme pressure on the body within the rope).

Deflecting rope III – Support area



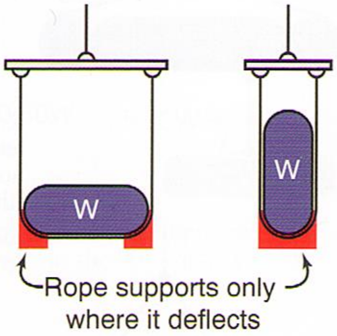
Intuitively, this sling supports the object's weight with half the surface pressure of…

…this one.

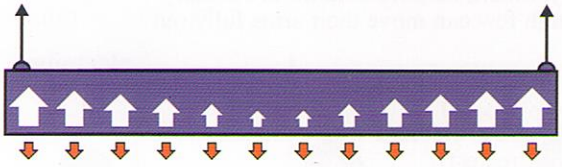


However, horizontal rope can't support a vertical load without deflecting. The rope on the bottom of this (idealized) sling is perfectly horizontal.

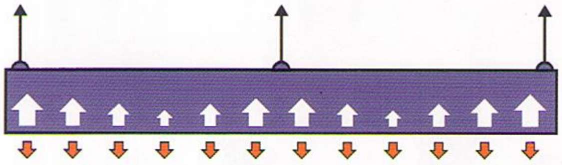
In reality, the vertical lift area (and pressure caused by it) is the same for both slings.



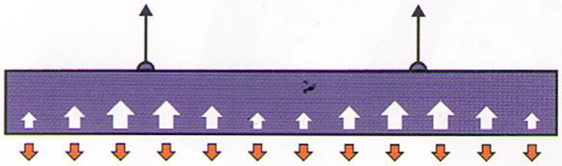
Bending moment I – Long spans



To keep from sagging due to its own weight, a suspended beam generates internal stress. The weight in the middle of the beam must be supported by the ends of the beam, so the bending moment increases with longer spans.

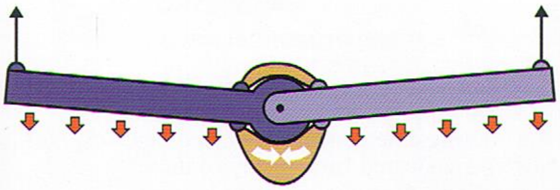


Adding more lift points eliminates long spans, greatly reducing bending moment (and internal stress).



Strategically placing the lift points can also reduce the maximum bending moment.

Bending moment II – Human body



In the human body, muscles produce the torque necessary to rotate bones relative to each other, countering bending moment. Muscles can only contract, but by pulling a lever, they can produce torque.

In this simplified suspension, the stressed muscles will always be on the bottom.

(Muscles used to resist a cantilever effect will be on the top; hyperextended joints don't stress muscles, but risk other types of injuries.)

Scale I – Proportional mass

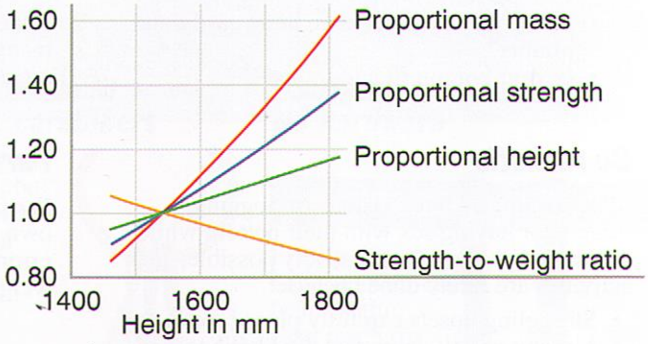
As objects grow, they become proportionally weaker.

For example, mice, humans, and elephants have proportionally similar bone sizes. However, a mouse that fell 3 m would likely scamper away while a human would be at serious risk of a break or a sprain. If an elephant jumped, it would break its leg.

Similarly, whales are so large that without the support of water, their ribs might break; ants can lift ten times their weight because they're very small; if you doubled every dimension of your kitchen table, it would eventually collapse under its own weight.

The reason is scale.

The mass of a proportional object grows by the *cube* of its height, while the strength grows by only the *square* of its height. Thus, as an object grows, it becomes proportionally weaker.



Effect of scale (Baseline person, 1550 mm tall)

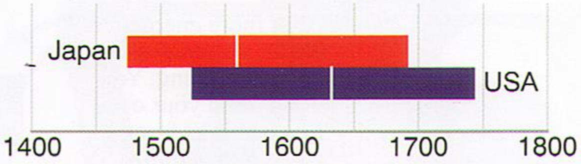
Obviously humans don't have the size range of mice and elephants, but even considering the typical range of human females, the mass can vary by almost a factor of two, for women of the *same shape*.

Note that scale applies to two people of the same proportional shape, not people of different body types. Differences in proportional muscle mass, body fat, limb length, etc., make a major difference in a person's ability to be suspended, independent of scale.

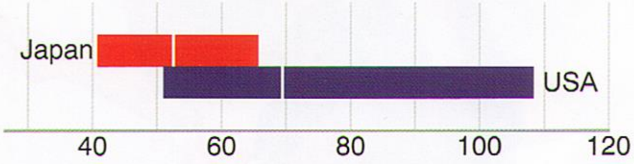
Scale II – Statistical norms

Shibari was originally applied on Japanese women. However, as a population, Japanese women are considerably shorter than American women and, due to scale, weigh dramatically less.

When suspending someone, remember that a few centimeters extra height makes a difference, even if the body shapes are similar.



Range of heights of adult females in mm
(5% to 95%, mean shown)



Range of mass of adult females in kg
(5% to 95%, mean shown)