sumoman

Technical Issue

Editorial

This is a collection of articles I've written previously, which seem to fall into the same sort of category, i.e. they are of a technical nature.

The first article is on measuring the density of the body. Typically this is done by dunking someone in a large vat of water whilst they are sitting on a chair. The chair is a weighing device and compares the weight of the person in the air to what they weigh underwater. Fatter people weigh less in water, i.e. they are less dense. The hydrodensiometry method allows the person to 'weigh' themselves in water without the palaver of having a big chair weighing machine.

The second article is about the form of the FV curve which is hyperbolic in shape. This shape actually relates to the microscopic structure of the muscles.

The last article is about how one can simulate the effects of different gravities when lifting weights – this is much cheaper than going to another planet.

Will your increased knowledge help you lift heavier weights? Nope, only lifting heavier weights will do this.

Hydrodensiometry

Unbeknownst to most athletes, skinfold tests are mainly based on density measurements of the body. For example if a researcher used skinfolds to calculate the fat percentages of a bunch of female runners in their twenties, then he would have to use correlation formulae from density measurements on female runners in their twenties. Thus a skinfold in itself

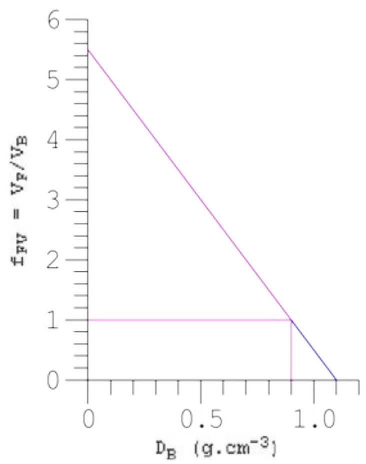


Fig 1 *If bodies had densities ranging from 0.9 to 1.1 g.cm^{-3} then they would range from 100 to 0% fat by volume (blue line).*

is not a measure of fat percentage.

Skinfold conversions to fat percentages are thus population specific - the more specific the better. For example this can be seen when encountering two people with different body masses but with the same skinfold measurements. In such a case we would expect the heavier person to have a smaller fat percentage, however conversion formulae don't take into account body masses so the fat percentages come out the same.

Mortem

The most direct way of getting a person's body fat percentage would be to grind them up into a paste and then boil out the fat.

Failing that, a person's density can be

measured. Bodyfat has a density of 0.9 $g.cm^{-3}$ and fat free mass has a density of 1.1 $g.cm^{-3}$, thus knowing body density allows the percentages of fat and fat free mass to be calculated.

Calculations

$D_B = M_B/V_B = M_B/(M_W/D_W) = M_B/[(M_B - M_{BW})/D_W]$

$D_B = M_B/\{[(M_B - M_{BW})/D_W] - V_A\}$

$M_B \sim M_{BA} \times 1.001224$ (Air density at sea level = 0.001224 $kg.l^{-1}$, body density ~ 1 kg.l-1)

$M_B \sim M_{BA} \times (1 + 0.001224 \times 0.875) = M_{BA} \times 1.001071$ (Metal density of scales ~ 8 $kg.l^{-1}$)

$f_{FV} = V_F/V_B$

Assuming fat is 0.9 $g.cm^{-3}$ and fat free mass is 1.1 $g.cm^{-3}$, as in Fig 7;

$f_{FV} = -1/0.2D_B + c = c - 5D_B = 5.5 - 5D_B$

$f_{FM} = M_F/M_B = V_FD_F/V_BD_B = f_{FV}D_F/D_B = [(5.5 - 5D_B)0.9]/D_B = 4.95/D_B - 4.5$

$\%_{FM} = 495/D_B - 450$ (Siri Equation)

D_B - density of body

M_B - mass of body

V_B - volume of body

M_{BA} - mass of body in air

M_W - mass of water

D_W - density of water

M_{BW} - mass of body in water

V_A - volume of air in lungs

f_{FV} - fraction fat volume

V_F - volume of fat

V_B - volume of body

f_{FM} - fraction fat mass

M_F - mass of fat

M_B - mass of body

V_F - volume of fat

D_F - density of fat

$\%_{FM}$ - percent fat mass

Bottle Buoyancy

To calculate a person's density requires measurement of their mass and volume. Mass is measured on a set of scales. Because air has a buoyancy effect on the body and on the counterbalancing scales a correction factor of about $M_B \sim M_{BA} \times 1.001071$ can be applied, however most simply take $M_{BA} = M_B$.

For volume one could put a person in a large tub of water and note how much the water level rises. For some reason this method isn't used, instead the person is weighed underwater with a special chair. The apparent loss in mass is proportional to the volume of water displaced. Corrections are made for water temperature and for the residual air volume of the lungs.

°C	$g.cm^{-3}$
4	1.00000
10	0.99973
15	0.99913
20	0.99823
25	0.99707
26	0.99681
27	0.99654
28	0.99626
29	0.99596
30	0.99567
31	0.99537
32	0.99505
33	0.99473
34	0.99440
35	0.99406
36	0.99371
37	0.99336
38	0.99299
39	0.99262
40	0.99224

***Fig 2** Change in water density with temperature*

Most people won't have access to a special weighing chair. However a bottle will do just as good a job. Let's say a person weighs 1 kg in the water, to attain neutral buoyancy he would thus need to hold onto a bottle of air of about 1 litre.

This method was first reported by **Katch, F.I., et al** (Reliability and validity of a new method for the measurement of total body volume *Res. Q. Exerc. Sport* 60:286. 1989).

The methodology is actually far simpler than the calculations suggest. I simply gave these calculations to show how the method is derived; however only a couple of equations are actually used.

This is how it would work in practice:

An Example

An accurate set of medical type scales, a normal set of food scales, a thermometer, a swimming pool and a large rigid bottle with a weight taped to it are required.

The subject jumps into the pool and expires as much air as possible whilst holding onto the bottle full of water. The bottle is gradually emptied until neutral buoyancy is attained. The mass of the emptied water being proportional to the water volume displaced by the person and bottle.

The bottle is weighed on the food scales. The amount of water that needs to be added to attain neutral buoyancy of the bottle is weighed - this water weight equals the bottle's (and weight's) weight in water. The purpose of the weight is that some fatter people float so the weight makes them sink.

If $M_{BA} = 45$ kg, $M_{BW} = 2$ kg, $D_W = 0.99567$ g.cm^{-3} (Fig 2) and $V_A = 1$ l.

Then;

$D_B = M_B/\{[(M_B - M_{BW})/D_W] - V_A\} = 45/(43/0.99567 - 1) = 1.067$

$\%_{FM} = 495/D_B - 450 = 14.1\%$

For simplicity M_B is taken to equal M_{BA}.

Errors

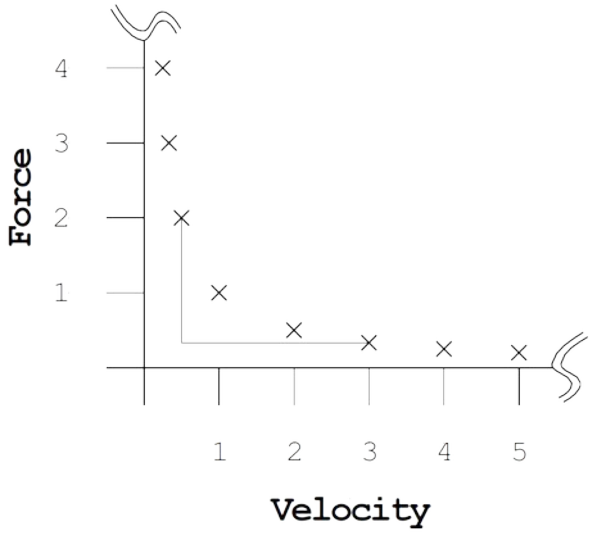
The biggest uncertainty in such a method would be that due to the residual lung volume. It is important that the person expires as much air as possible, this is contrary to what most people want to do underwater so requires some practice. Once achieved it then becomes a matter of estimating how much air is left in the lungs. For a male this is about 1.2 litres and for a female about 1 litre (ages 20-30 years).

Another problem is that there is some argument regarding the exact densities of fat and particularly fat free mass.

Finally some argue that the body cannot be treated as a 2 density compartments model - maybe it contains three or more different ratios of densities... such is science.

The Force-Velocity (FV) Curve

FV curves can be found in books on muscle physiology;



The Hill Equation describes the FV curve;

1. $(F_m + a)(V_m + b) = C = (F_{mm} + a)b$

F_m - maximum force

a - force constant

V_m - maximum velocity

b - velocity constant

C - power constant

F_{mm} - maximum of maximum forces

V_{mm} - maximum of maximum velocities

This is an equation for a hyperbola. It looks complicated so in the diagram I've taken the simplest form of the equation;

2. $FV = 1$

To do this I take a and b to each equal zero and C to equal 1.

The problem with the simplified equation is that it doesn't cross the axes (as a proper FV curve does); instead it never quite gets there, no matter how long the axes are.

What would the equation be if the axes were instead located where the dotted lines are so that the hyperbola crossed at F = 2 and V = 3?

In Equation 2 at F = 2, V = ½ and at V = 3, F = $^1/_3$. Substituting the numbers into Equation 1;

$(2 + ½)(0 + ^1/_3) = ^5/_6$

Thus;

3. $(F_m + ½)(V_m + ^1/_3) = ^5/_6$

A hyperbolic equation indicates that crossbridges and muscles behave in a manner like that indicated in some future article I will write. All Hyperbolae are the same shape (just like all circles) it just that they can look different at different scales. From an infinite distance all hyperbolae look like right angles (all circles would look like dots).

Practical Considerations

The FV curve agrees with common observation. If a heavy dumbbell is grabbed and moved as fast as possible then it doesn't move very fast and takes a lot of force to do so - if the dumbbell is heavy enough it doesn't move at all but just hovers (at F_{mm}, V = 0). The lighter the dumbbell is the faster it can be moved. When the dumbbell weighs nothing (i.e. no dumbbell) then no external force is developed but the hand moves at maximum speed (at V_{mm}, F = 0).

Note that the hyperbolic curve is the force generated and not the weight lifted. Thus a weight of 50% 1RM accelerated as hard as possible may equal about 70% the force of the 1RM's max force. It is the 70% force that is measured.

Follow the Hyperbola

With power training one pretty much follows the hyperbolic curve all the time. Thus an athlete will either try moving as fast or as forcefully as possible - whichever way it is looked at the curve (F_m) is followed.

With slow training, the trainee is always operating in an area well below the hyperbola. According to the SAID (specific adaptation to imposed demands) principle one needs to train in a manner that mimics, in various or all aspects that of the main sporting movement; this is perhaps why slow training is not used by athletes. Occasionally slow trainees will say that if this is the case then they should end up really slow. However the body has natural set points for strength and speed. Whilst one can train slow and improve at moving slow it doesn't mean that one will get slower. It can of course be very effective for the movement impaired (where the FV curve is small) thus in rehabilitative settings (old or injured people for example) it can be used.

If the athletically inclined want to move faster or more forcefully than their set points then the best way is to follow the hyperbola... and to work along it rather than sticking at one point. This is why I sometimes say,

"Demonstrate strength, to train strength."

Small Cams & Rubber Tubes

Small Cams

If you happen to have a look at some exercise machines you might notice that some have very small cams. At first site this may seem a design flaw because if a machine had big cams then the weight stack wouldn't need to be so big.

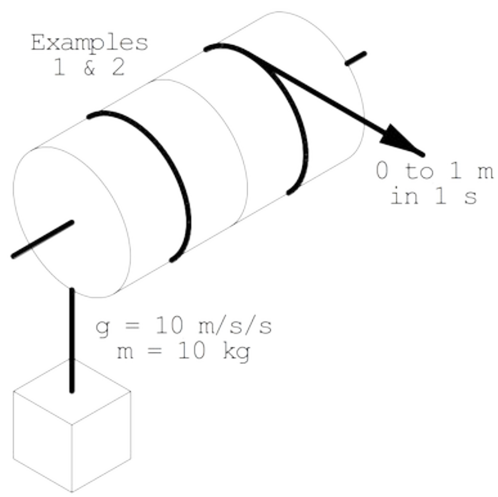
The reason for the small cams is that they allow a large mass to be accelerated at a low velocity thus reducing the squared effect of kinetic energy and so reducing acceleration forces.

- Imagine the following scenario wherein the lifter pulls a cable from zero distance to 1 m in 1s thus acceleration (a) at the cable is 2 m.s $^{-2}$;

  gravity = 10 m.s $^{-2}$, mass = 10 kg

  Force = m(g + a) = 10(10 + 2) = 120 Newtons

  Work = mgh + ½mv² = (10 × 10 × 1) + (½ × 10 × 2²) = 120 Joules



- If the cable ran over a double pulley of 1:1 ratio then the figures would be exactly the same;

  g = 10 m.s $^{-2}$, m = 10 kg

  F = m(g + a) = 10(10 + 2) = 120 N

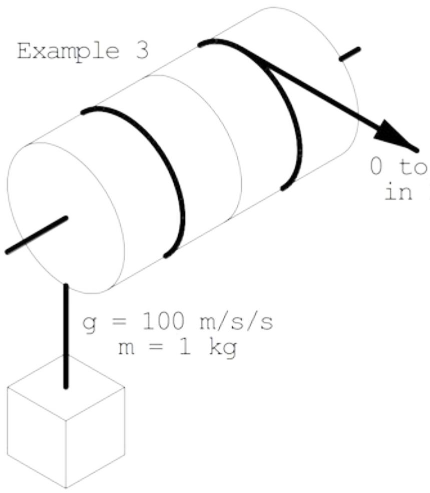
$W = mgh + ½mv^2 = (10 \times 10 \times 1) + (½ \times 10 \times 2^2) = 120$ J

- Now imagine the following scenario wherein the lifter pulls a cable from zero distance to 1 m in 1s thus acceleration at the cable is 2 $m.s^{-2}$ but he is on a planet where the gravity is 10 times higher;

  $g = 100\ m.s^{-1}$, $m = 1$ kg

  $F = m(g + a) = 1(100 + 2) = 102$ N

  $W = mgh + ½mv^2 = (1 \times 100 \times 1) + (½ \times 1 \times 2^2) = 102$ J



  Note that as the gravity is 10 times higher he thus uses $^1/_{10}$ the mass; thus acceleration force and kinetic energy are also a tenth (2 instead of 20).

- He now returns to Earth but wants to simulate what he did on the high gravity planet, so he gets a double cam with a 10:1 ratio in diameter;

  $g = 10\ m.s^{-2}$, $m = 100$ kg

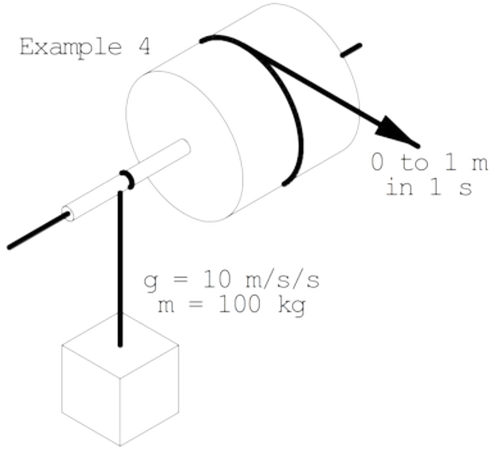
  $F = m(g + a) = 100(10 + 0.2) = 102$ N

  $W = mgh + ½mv^2 = (100 \times 10 \times 0.1) + (½ \times 100 \times 0.2^2) = 102$ J

In all cases he lifts the same weight of 100 Newtons (F = mg) i.e.

1. $10 \times 10 = 100$ N
2. $10 \times 10 = 100$ N
3. $100 \times 1 = 100$ N
4. $100 \times 10/10 = 100$ N

However by either going on another planet or using different sized cams the acceleration forces and kinetic energies can be reduced. Certain companies like MedX do this so that speed variances make less of a difference to the resistance



the machine is designed to give to the trainee. Also it is done to make the machine 'safer' because fast moves cause less change in the acceleration forces.

Rubber Tubes

As it happens the same thing can be gained by using elastic resistance attached to free weights.

However this isn't done for the purposes of safety, there are instead two different reasons:

The elastic provides accommodating resistance. For example in Fig 3 the bar gets heavier the closer toward the lockout. With a speed bench one would normally have to make the bar accelerate all the way to lockout to achieve this - which would mean that the bar would start slow and get faster and faster thus using different parts of the FV curve (see The FV Curve). With some elastic resistance the bar velocity can be made more constant.

High Gravity

The second effect is that, like small cams, the elastic in effect increases the rate of gravitational acceleration. In other words the bar's resistance snaps back with greater immediacy;

$a = F/m = 850/55 = 15.5\ m.s^{-2}$ at bottom

$a = F/m = 1050/55 = 19.1\ m.s^{-2}$ at top

Given that gravity is 10 $m.s^{-2}$ ($a = F/m = 550/55$) the greater acceleration is quite noticeable. Higher gravity inhabitants would need quicker reflexes (to stop falling over) and this may lead to a possible side benefit of training with elastics... that of a quicker nervous system

Tube Bench

Fig 2 55 kg, 320 mm height, grip 1000 mm, 30 to 50 kg tubes, 18th May 2005

Simulating a high gravity environment on Earth.

(in the particular lift).

This doesn't mean that iron should replace rubber. Elastic resistance is instead a low inertia approach to increase strength.

Low Gravity

With Reverse tubes the effect is like working in a low gravity field, everything becomes inertia like and slow motion;

$a = F/m = 750/130 = 5.8\ m.s^{-2}$ at bottom

$a = F/m = 1250/130 = 9.6\ m.s^{-2}$ at top

Given that gravity is $10\ m.s^{-2}$ ($a = F/m = 1300/130$) the lower acceleration is quite noticeable. The same effect could be mimicked by having large cams instead of small cams

Reverse Tube Bench

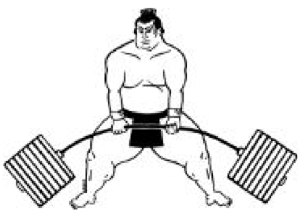
Fig 3 130 kg, 320 mm height, grip 1000 mm, -55 to -5 kg tubes, 17th June 2005

Simulating a low gravity environment on Earth.

A Rubber Note

Rubber absorbs energy and loses it as heat, so each time it is stretched it ends up slightly longer and thus at any particular length gives out less and less resistance with each rep - thus rubber loses its resilience.

Fortunately an inexhaustible supply of used tubes is to be had from the local bicycle shop. Combinations of tubes can be used. For example a couple of doubled over mountain bike tubes provide 300 lbs or so of resistance.✎



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