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P2_11 Drop and give me ten

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Abstract

The press-up is commonly used for strength building purposes. This paper however calculates the amount of energy expended when performing a press-up to determine whether it is an effective exercise for burning calories. By considering the person's centre of mass and the energetics of the system we calculate 342 Joules are required to perform a press-up.

Introduction

Despite not being the newest or most original exercise, the press-up is actually one of the best for increasing your overall upper body strength. They also have the advantage of increasing your metabolism so you can burn extra calories [1]. This paper however, considers the amount of energy required to perform the upward motion of a press-up, to determine whether press-ups are an effective method of directly burning calories.

Theory

Irrespective of how the force is applied to lift the body, work is still required. Therefore we approach this problem using energetics. The magnitude of the energy, E, required to lift a mass M over a distance h, is given by;

$$E = Mg\Delta h, \qquad (1)$$

where g is the acceleration due to gravity [2].

The above equation however, relies upon the mass being a point particle. Consequently we must calculate the centre of mass of a human and then assume the mass of the human to act at solely at the centre of mass. The centre of mass for a series of point particles is described as such [3];

$$x_{CM} = \frac{\sum_{i=1}^{N} m_i x_i}{M}, \qquad (2)$$

where x_{CM}, denotes the centre of mass, m_i and x_i denote the mass and position of each i^{th} particle respectively, M is the total mass of all the particles, and we sum over N particles. Figure 1 illustrates how the positions of each particle are taken from the same reference point, which for this case is the feet position.

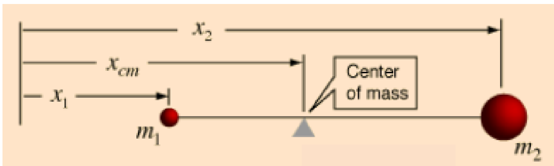

Figure 1 – Centre of mass
http://hyperphysics.phy-astr.gsu.edu/hbase/cm.html

Of course, whilst we recognise that the human body is not a series of point particles to which we can apply equation (2), we assume each limb has constant density, and therefore treat each limb as a point particle. By summing over these resulting discrete point particles we can obtain the centre of mass of the body.

Method and Results

The body is divided into separate sections. We assume the body is reflectively symmetrical in the x-y plane (see figure 2). Therefore, the body can be modelled as a rod, and as we assume each section has uniform density the centre of mass of each section is located at the centre, as shown in red on figure 2.

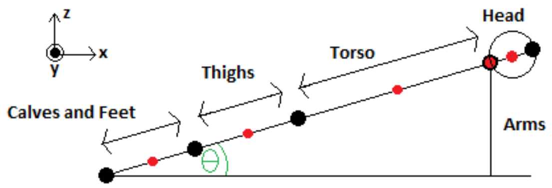

Figure 2 – Schematic diagram - Modelling human as rod

Using the average dimensions of the male's body parts, as tabulated in figure 3, and equation (2) we can calculate the centre of mass of the average male. It should be noted that the arms are not in the same plane as the body. The arms are orientated such that their centre of mass is located at the shoulders, as shown in red in figure 2. To a reasonable approximation, we assume this is also the case when body is laid flat. As such, the length of the arms is irrelevant when calculating the body's centre of mass and don't contribute to the body's total height.

Average Dimensions of Male Human		
Body section	**Length (m)**	**Mass (kg)**
Calf and Foot	0.45 [4]	3.970 [5]
Thigh	0.485 [4]	7.165 [5]
Torso	0.57 [4]	29.608 [5]
Arm	0.79 [4]	3.770 [5]
Head	0.24 [5]	4.555 [5]
Total	1.745	63.973

Figure 3 – Average Dimensions of Male

Recalling that the body is reflectively symmetrical in the x-y plane, when considering the calf and foot section for example, the section is simply regarded as 0.45m long. The mass of the section however is two times the mass stated in the figure 3, as there are two legs. Essentially, the rod-like approximation transforms our body into a two-dimensional shape, yet the total mass still remains. By applying our approximations, and using equation (2), the calculated centre of mass is 1.04m. Figure 4 illustrates this centre of mass.

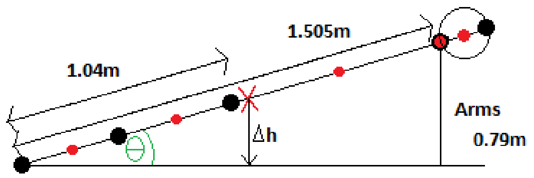

Figure 4 – Representation of centre of mass

Having identified the position of the centre of mass, the total mass can be represented as a point mass acting at this location. To determine the energy required to lift this mass however, it is necessary to obtain the height, Δh over which the 'point mass' moves. This is done using a simple trigonometric calculation. The angle θ to which the average male raises themselves is governed by their arm length, and their height to their shoulders. This forms a right-angled-triangle, hence;

$$\theta = \arcsin\left(\frac{0.79}{1.505}\right) = 31.66^{\circ}. \tag{3}$$

From figure 4 we can clearly see that $\Delta h = 1.04 \times sin\theta$, hence substituting into equation (1), and using the total mass, and the calculated value of θ, we derive the energy required to perform the upwards motion of a press-up; 342 Joules.

Conclusion

The energy required to perform the upwards motion of a press-up for an average male is 342 Joules. In kilocalories, the unit of energy that most athletes will be familiar with, this equates to a mere 0.0818 kcal. In reality however, the number of calories burnt is likely to be more. This is due to the additional downward motion, which will still require work, and because we have of course assumed the human body is 100% efficient. To factor in these components however are beyond the scope of this paper, yet could be considered by future groups as further study. Nevertheless, if the athlete in question was concerned with using press-ups to burn calories, they would be required to 'Drop and give me' approximately ten *thousand* press-ups to burn an equivalent amount of calories during a 15km run [6]. As such we can conclude that press-ups are not an effective method of burning calories, especially as muscle fatigue would cause failure long before the target was ever reached. Instead, we suggest press-ups are best left to the 'big guys' concerned with building strength.

References

[1] http://jonathanfairfield.hubpages.com/hub/The-Best-Bodyweight-Exercises-Push-Ups.

[2] P. Tipler, G. Mosca, *Physics for Scientists and Engineers*, (W.H. Freeman and Company, New York, 2008), 6th edition.

[3] http://hyperphysics.phy-astr.gsu.edu/hbase/cm.html.

[4] http://www.roymech.co.uk/Useful_Tables/Human/Human_sizes.html.

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[6] http://www.runtheplanet.com/resources/tools/calculators/caloriecounter.asp.

All websites accessed 13/11/2013