THE DEFEAT OF GRAVITY IN WEIGHTLIFTING

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That weightlifting is the art of defeating gravity may seem a statement of the obvious. It is very rewarding however, as in all battles, to consider the nature of the adversary. Its relentless nature means that man can only win for a limited time. As we shall see, the earlier he engages the enemy, the more spectacular is his short-term advantage. A long, drawn-out struggle is to be avoided at all costs. Man, on the other hand, is apt to injure himself when he tries to mobilise his forces too rapidly. Like the battle commander, the weightlifter is presented with a dilemma and the information available about his own strength and resources is inadequate to eliminate the possibility of disaster. We must be thankful that at least the foe, gravity, is an entirely predictable one. These words are a fairly accurate summary of this paper.

As far as the bar is concerned, the effects of both gravity and the jerks that the man exerts conform to the same rules which are known as Newton's Laws of Motion. It does not matter, when applying the rules, that gravity acts continuously and man does not. Both gravity and jerk can be thought to consist of successions of impulses impinging on the weights, as in Fig. 1.

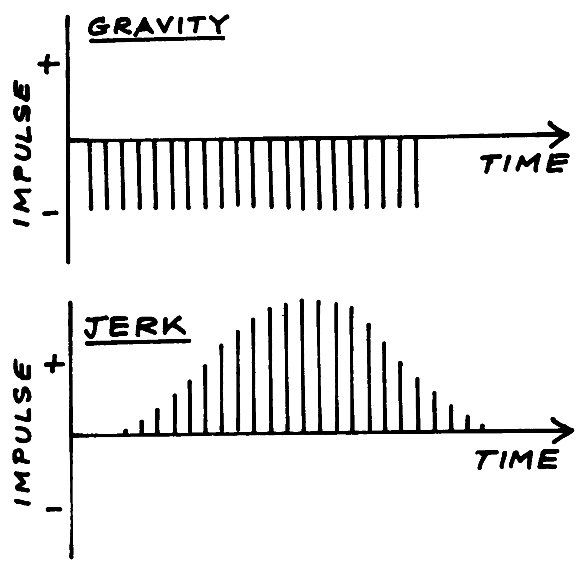

Fig. 1. Forces on the bar depicted as successions of impulses.

In the case of gravity, all the impulses are of the same magnitude whilst those of the jerk successively build up in magnitude and then die away. The impulse is more of a concept than a reality which engineers use to denote a force acting for such a short period of time that the whole event can be called instantaneous.

The product of the force and the time is finite and equals the magnitude of the impulse. Newton's second Law of Motion tells us that when the impulse acts upon a body it changes its momentum by an amount equal to the impulse. (Momentum is the product of mass and velocity). The new velocity will be maintained by the body in perpetuity unless another impulse acts upon the body to change it, which is a statement of Newton's First Law of Motion. The object of weightlifting is to displace the bar, not simply to change its velocity, and a period of time must elapse before the velocity gives rise to displacement (displacement = velocity x time).

Consider a single upwards impulse acting at time T, upon the bar. Suppose that there are no other influences (such as gravity) to complicate the situation. The upwards displacement due to that impulse becomes greater in proportion to the time that elapses. If an equal impulse occurs at time T_2 the effect is added to that of the first, with the net result shown by the dashed line in Fig. 2. The situation in Fig. 2. is unrealistic of course, because gravity would normally be exerting a downwards influence at the same time.

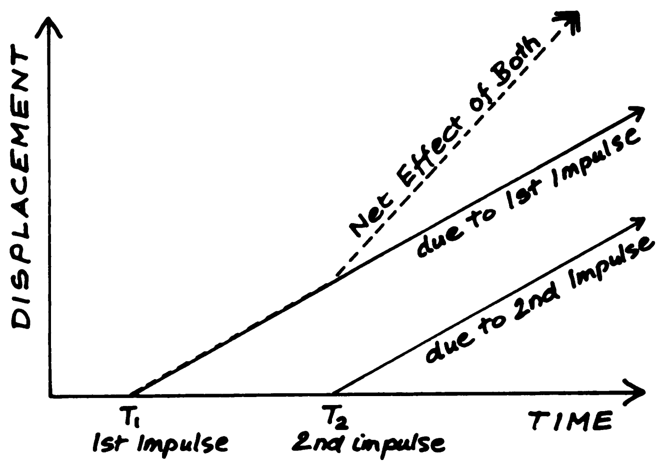

Fig.2.

Effect of two upward impulses on the bar without gravity.

Gravity acts as if there were a continuous succession of equal impulses in a downward direction. Consider the cumulative effect of these in Fig. 3, from the instant that the weights are off the ground and in the absence of any other forces.

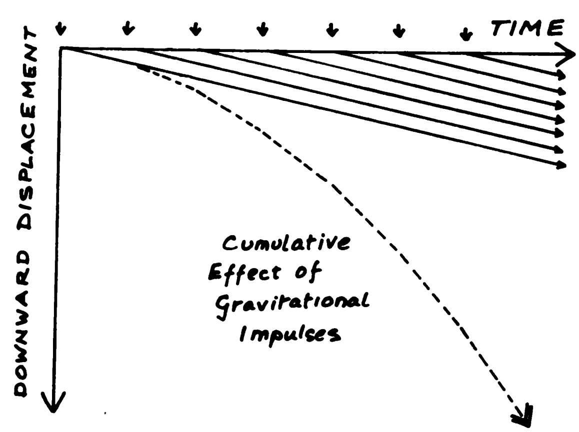

Fig. 3.

Effect of gravity on the bar is cumulative, shown as the net effect of a succession of downward impulses.

TABLE 1

	1st example N Time (sec)		2nd example N Time (sec)		3rd example N Time (sec)		4th example N Time (sec)	
1st impulse	6/10	0	1	0	5/4	0	6/10	0
2nd impulse	1	$1\frac{1}{2}$	6/10	$1\frac{1}{2}$	1	$1\frac{1}{2}$	1	1.1/4
3rd impulse	5/4	1.3/4	5/4	1.3/4	6/10	1.3/4	5/4	1.3/4
Height after 2 sec.	0.4 feet.		19.6 feet.		36.8 feet.		8.4 feet.	

In the first three examples illustrated in Fig. 4 the impulses were given at the start and at $1\frac{1}{2}$ and 1.3/4 sec. afterwards. Exactly the same total impulse is given in each case but the result is dismal in the first case, in which the largest impulses are applied last, and magnificent in the third because the largest impulse was applied first. The fourth example shows that, with the same order of impulses as in the first case, a change of timing of a mere 1/4 second in the second impulse serves to transform the lift. Now the point of the opening remark should be obvious. The earlier the enemy, gravity, is engaged the more spectacular is the short-term advantage.

So far we have talked about individual impulses and it is now time to consider the jerks that the weightlifter exerts. There are an infinite number of different ways in which a load can be lifted. At one extreme the man could exert steady forces very slightly greater than the weight throughout the entire lift. This would take a very long time and be fatiguing. More seriously, the maximum weight would be equal to the upwards strength of his weakest posture.

At the other extreme he could exert an enormous jerk at the start causing the weight to coast up to the desired height while he smartly nips underneath to support it with upstretched arms. All the intermediate postures would be of no importance. I think you will recognise something of both approaches in the techniques of weightlifting, although the reality is a compromise.

The man is unable to develop a force on the load which rises immediately to a peak. This is unfortunate since the resulting lift would be most impressive. However, if he did, he would be unable to repeat it because of torn muscles, rupture tendons and fractures bones! Instead, the force rises over a period of time. The rise may only take one or two tenths of a second but is nevertheless

The net loss of height due to the gravitational impulses builds up as the square of the time. We can express this exactly as an equation in which time is in seconds and heights is in feet, i.e.

$$\text{Height loss} = -(4t)^2 \quad \ldots \quad (1)$$

The gain of height due to an upward impulse produced by the man (as at T_1 in Fig. 2) can also be stated exactly, in the same units of feet and seconds i.e.

$$\text{Height gain} = 32N\ (\text{time since impulse}) \ \ldots \ (2)$$

where N is the size of the impulse (lbf.sec) divided by the weight (not the mass) of the load.

To calculate what the effect of any succession of impulses will have had up to a given time we add the effects of the impulses in the jerks together and subtract the effects of the gravitational impulses from the moment that the weights are off the floor, i.e.

$$\text{Height} = 32[(N_1 \times \text{time since 1st impulse}) + (N_2 \times \text{time since 2nd impulse}) + \text{etc.}] - [4 \times \text{Time since start}]^2 \quad \ldots . \quad (3)$$

A good idea of how the battle against gravity must be fought may be had by working through a few examples. Let us suppose the man is able to exert three impulses for which the values of N are 1.0, 0.6 and 1.25 (e.g. if the load were 200 pounds weight, the impulses would be 200, 120 and 250 lbf.sec. respectively). In each case, the total impulse is 2.85 weight-sec.. We will consider the height reached two seconds from the start with various timings of the impulses, as set out in Table 1. The first result is worked out in full, using our formula (3)

Case 1. 1st impulse N = 6/10 at time zero

2nd " N = 1.0 at $1\frac{1}{2}$ sec.

3rd " N = 5/4 at 1 3/4 sec.

Height = 32 6/10 x 2) + (1 x $\frac{1}{2}$) + (5/4 x 1/4) - $(4 \times 2)^2$ = 0.4 feet

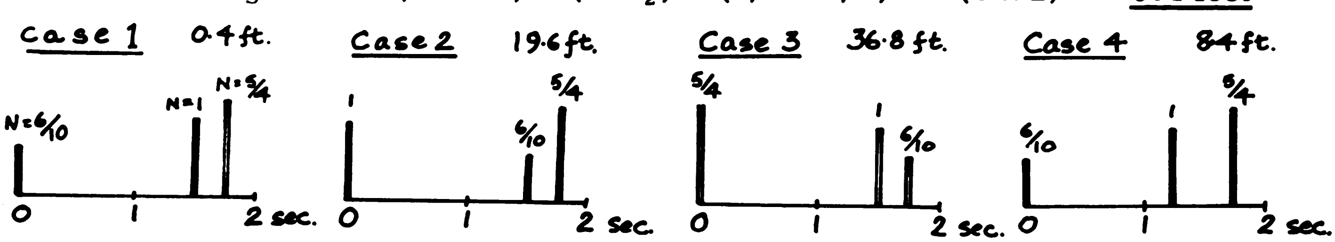

Fig. 4. Effect of timing of three upward impulses upon the bar to produce a gain of height after two seconds, with gravity acting at the same time.

gradual enough to avoid most injuries and unfortunately long enough for gravity to get a grip. From the examples above it is apparent that the exact way that the jerk force builds up and decays is vitally important to the rest. Three force patterns are shown in Fig. 5. The total impulse in each case is the same but

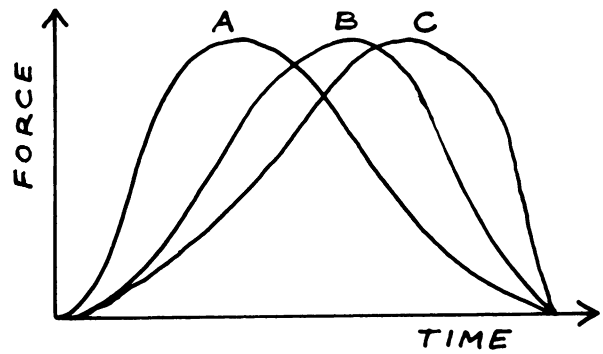

Fig. 5. Three force patterns which impart the same total impulse to the bar. That with the earliest peak is the most effective.

pattern A is better than B and much better than C in achieving height. The important ingredient of a successful lift is an explosive effort as early as possible. This calls for technique which produces the strongest linkage between the trunk and the weight. Generally speaking this arises when the active muscular linkages are being stretched, for example when the trunk is already moving rapidly upwards when the hands lock to the weight. When a situation like this exists, the muscles give more than their isometric tension and the take up of slack in associated structures such as tendons under tension and joint surfaces under compression is more rapid than it would be if the trunk were stationary to begin with. The dilemma for the weightlifter is to know how explosive his connection with the weight can be without causing injury. Our knowledge of the safety factors involved is very meagre. The 'armchair approach' cannot be used to predict, for example a man's safe lifting capability from any measurements that are currently made. Hazarding a guess, I think the effects of training will eventually be judged on more subtle properties of the musculature than its isometric strength which has little relevance to a dynamic lift. In particular one may mention the force-velocity characteristics of the muscle and its elastic properties. Discussion of these properties is outside the scope of the present paper which was designed to show the nature of the problem that gravity poses. We may speculate how the body solves the problem without injuring itself but it would be premature to formulate rules without further research.