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Metabolic Cost of Negative Work

A review of the literature on negative work may lead to more confusion than knowledge, primarily because anything written on the subject seems to be guilty of at least four faulty assumptions.

ONE… it has been assumed that human muscles are stronger during negative work, by comparison to their strength during positive work.

TWO… it has been assumed that the metabolic cost of negative work is much lower than the metabolic cost of positive work.

THREE… it has been assumed that negative work has very little effect upon the cardiovascular system.

FOUR… it has been assumed that the ratio of positive metabolic cost to negative metabolic cost changes as the rate of work changes.

Any or all of these four basic assumptions may be true, but they have not been proven. They have been generally accepted, I think, only because they appear to be true on the basis of rather casual observation. But even if they are true, the degree of truth involved is far less than that which has been generally accepted.

All of these four basic assumptions are based upon apparent differences and positive work. However, when several factors that have previously been ignored are considered, it is immediately obvious that the real differences, if any, are far less than the apparent differences.

ONE, a difference in strength. While it is certainly true that an exerciser can lower more weight than he can lift, it does not necessarily follow that his muscles are actually stronger during negative work than they are during positive work.

The muscles may be stronger; but even if so, they are not as much stronger as they appear to be. The apparent gross difference in strength is, I think, primarily a result of friction… internal muscular friction.

While lifting a weight, the muscles must contract with sufficient force to move the imposed resistance… but they also have to overcome their own internal friction. Thus, doing positive work, friction is working against the muscles.

Whereas, during negative work, friction is working for the muscles instead of against them.

Therefore, an exerciser's usable strength during positive work is equal to the force provided by his muscles, minus friction… and his usable strength during negative work is equal to the force provided by his muscles during negative work.

It may well be that all of the difference in usable strength cannot be accounted for by friction; but even if not, it still remains that at least part of the difference is a result of friction… thus the actual difference is certainly less than the apparent difference.

At the moment, we are conducting careful tests in an effort to determine exactly what part friction plays in the matter.

TWO, a difference in metabolic costs. A great deal of confusion exists on this point because of attempts to compare metabolic work with mechanical work, and, secondly, because of a failure to consider several related factors.

By definition, work require movement… no movement means no work; and while this is undoubtedly true in regard to mechanical work, it certain is not true in relation to metabolic work.

Muscles produce force, and it is easily possible for a muscle to produce a high level of force without producing movement; logically, it appears that the metabolic cost of muscular force production would be related to the level of force produced and the time that the force is maintained… rather than the amount of mechanical work performed.

If, for example, a 100-pound barbell is held motionless at the halfway position of a curling exercise, then the muscles will be required to produce a certain level of force to prevent the downward movement of the barbell. Providing that force will certainly entail metabolic cost… yet no work is involved.

Slowly, curling a 100-pound barbell also requires a greater metabolic cost than curling the same barbell at a more rapid pace; even though the amount of mechanical work involved is exactly the same in both cases.

Many other examples could be given to illustrate the same point, but it should now be obvious that attempts to relate metabolic cost to mechanical work are doomed to failure.. there is no meaningful relationship. We must have another standard for comparison.

The only meaningful standard, I can think of is force/time… the amount of force produced by the muscles multiplied by the time that the force is maintained.

But again, attempts to measure force/time will be meaningless if we fail to consider friction… and will be very difficult in situations involving movement. At the moment we are working on the development of a practical means to measure accurately force/time in situations involving movement... but until and unless such equipment is produced, force/time can probably be measured accurately only in static situations.

It should be reasonably simple to determine the metabolic costs of force/time in static situations… and if this is done accurately, I think it will then be shown that a very close relationship exists between force/time and metabolic cost. Perhaps an exact relationship will be established… and if so, then we will have a standard for comparison. But in the meantime, no such standard exists; the attempt to use mechanical work as a standard for determining metabolic cost has led to widespread confusion.

When and if it becomes possible to compare the metabolic cost of negative work with that of positive work on the basis of a meaningful standard, it may well be shown that the metabolic costs is in fact exactly the same in both cases; but even if not, it will certainly be shown that the difference, if any, is far less than it is now generally assumed to be.

THREE, a difference in cardiovascular effects. When it becomes possible to determine accurately the difference, if any, between the metabolic cost of positive work and that of negative work… then, and only then, will it also be possible to make meaningful comparisons between the cardiovascular effects of positive work and those of negative work. In the meantime, any attempt to make a meaningful comparison is limited by lack of a standard for comparison.

FOUR, changing ratios of metabolic costs as a result of changes in rate of work. It is generally believed that a faster rate of work produces a high ratio of metabolic cost, and vice versa.

If, for example, two subjects are seated in the same leg press machine, in such a manner that one subject performs all of the positive work, the lifting part of the exercise, while the other subject performs all of the negative work, the lowering part of all exercise… then, at a slow rate of work, the man performing positive work might be required to pay a metabolic cost that is twice as high as the metabolic cost required of the man performing negative work.

But it does not follow that the actual metabolic cost is different to that degree… or even that there is any difference at all. Because the force/time factor is different… even though the speed of movement may be exactly the same with both subjects.

Remember, the man doing the positive work is lifting the resistance while also working against friction… and the man doing the negative work is lowering the resistance while being helped by friction. Thus, it could easily be possible that the man performing the positive part of the work was actually producing twice as much force/time as the other man.

But, in any case, it is obvious that the muscular work (as opposed to mechanical work) is certainly not equal… so, it is only natural that the metabolic cost would also be different.

Then, if the rate of work is increased, the apparent ratio between the metabolic cost of positive and negative work will also be changed. If, for example, the rate of work is doubled, then the apparent ratio may change from a ratio of two-to-one to a ratio of three-to-one. And again, I think that any such apparent change in ratio is an illusion resulting from a failure to consider all of the involved factors.

If, for example, a rate of work is increased by increasing the speed of movement, then a point is eventually reached where the amount of negative work involved becomes literally zero. This occurs when the downward movement of the weight is occurring at a speed equal to the normal acceleration produced by gravity, in effect, when the weight is simply dropped.

In such a situation one man would be lifting the weight fairly rapidly… while the other man would be simply dropping it, making no attempt to stop or delay the normal acceleration resulting from gravity. Obviously, then, the man doing the positive part of the work would be working… while the other man would be doing literally nothing.

Even more confusion on this point has resulted from a failure to consider basic metabolic requirements. A man at rest is constantly paying a certain metabolic cost merely to stay alive… thus, in order to determine the actual metabolic cost of any particular activity, we must first subtract the basic metabolic cost from the total metabolic cost, any resulting difference then being the metabolic cost of that activity.

If, for example, an individual's basic metabolic cost while resting was 100 units per minute… and if his total metabolic cost increased to 150 units per minute while walking slowly on level ground… then the metabolic cost of walking at that pace under those conditions was 50 units per minute.

Unfortunately, when attempts have been made to determine the metabolic cost of positive work as compared to the metabolic cost of negative work, it appears that the basic metabolic cost was not subtracted from the totals. Instead, the meaningful comparison, the net metabolic costs, should have been compared.

At this point in time, I do not know just what the exact results of careful tests on this subject will be… but it appears that many of the tests conducted in the past, left a great deal to be desired, and that the conclusions based on those tests are in error.

People who are interested in meaningful areas of research in the broad field of exercise physiology might find it very fruitful to conduct careful tests in connection with the points raised in this chapter; in the meantime, we are conducting our own tests… which will be published in due course.