How Does Power Generate Movement? Definitions Can Lead to Different Approaches

or

How we think is how fast we go.

Dick Taylor

The mass-spring paradigm for understanding movement contrasts with traditional classical physics and engineering models.

Ski coaching manuals published by the USST and Nensa, for example, define and explain technique as "applied power," and that suggests force applied to the ground and justifies increases in strength and the presumed resulting capacity to push faster and longer with the arm and leg levers. Trainers educated in the field of strength and conditioning seem particularly to favor this view, as does, let's admit it, our very culture: the solution to a problem depends upon a linear (1:1) relationship between force applied and its effect on a resistance or opposing mass. That principle produces work but not necessarily speed.

It is not unusual or odd to hear echoes of this approach also from some of our top skiers.

In her "Kikkanimal Workout" video Kikkan Randall explains that "If you have greater strength, you can apply more power to the snow." In a sympathetic evaluation of Kikkan's Sochi results, Jessie Diggins seems accurate but perhaps misses an important consideration. The snow at Sochi, she notes, was just too soft for such a powerful skier.

What is made clear here is the fundamental notion that movement is always in dynamic relationship to the environment in which it takes place, and the essence of that environment is its variability. That said, my colleague Jeremy Nellis, points out that the track conditions in top level, and particularly World Cup, racing tend to be uniformly firm, especially with widespread bases of artificial snow, which might seem to favor the force-to-the-ground notion of technique, especially in the sprints.

But that idea also needs qualification, as research suggested.

"Analysis of kinetics and kinematics revealed that it was not exclusively the magnitude of applied forces during skiing, but the timing and proper instant of force application were major factors discriminating between faster and slower skiers….. General strength and power per se seem not to be major determinants of performance in elite skiers, whereas coordination of these capacities within the different and complex skiing movements seems to be the discriminating factor."

"General strength and kinetics: fundamental to sprinting faster in cross-country skiing," Stoeggl, Mueller, Ainegren, Holmberg, *Scan. J. Med. Sci. Sports*, Dec. 2011.

Our top skiers are marvelous athletes. Whether their explanations are accurate for themselves or optimal for everybody (including these top skiers) might productively remain open to alternative approaches, given the availability of more modern system-dynamic movement research. Strength may be the cocoon, but it is not the butterfly. Sometimes they ski "heavy," especially late in the distance races. It is also true that athletes do not often accurately explain how they accomplish the great things they do. Their animal instincts for movement are more reliable than their efforts to analyze. Like other artists, they inspire better than they teach; their bodies are more articulate than their tongues. Research has confirmed that. Some athletes are also surprised when observers describe their movements in terms quite opposite to the cues they (the athletes) were operating with themselves. Visual observation is a fragile, tricky business. That sounds unkind, disrespectful, but it isn't. I just want the most reliable sources of information for our skiers. That means theoretically sound, scientifically validated, and modern. Thinking and experimenting with alternate movement approaches, even momentarily, also almost always has positive affects on human performance. It is called differential or contrast learning and frees movement from the inhibiting effects of position norms and the pitfalls of too much repetition. The goal is movement freedom.

Contrasting Approaches to Technique

Mass-spring theory contrasts with what the USST technique prescriptions suggest. Using one example, mass-spring research, and various physics teachers, conclude that the forward sweep of the whole body (center of mass) over its point of contact with the ground adds to the force of gravity enough to establish the support/grip for continuing strides. That movement is what bends the bow.

The USST and adherents of classical physics and engineering theory prescribe applying the greatest **down**-power to the snow, force **against** the ground, as the formula for speed. Mass-spring research sees **up**-motion in efficient power, reactive spring **release** from the ground and its friction, tension, the bow string let loose.

It seems timely to review how power is generated and organized in humans, as in all animals, and how it expresses itself in movement and technique.

POWER

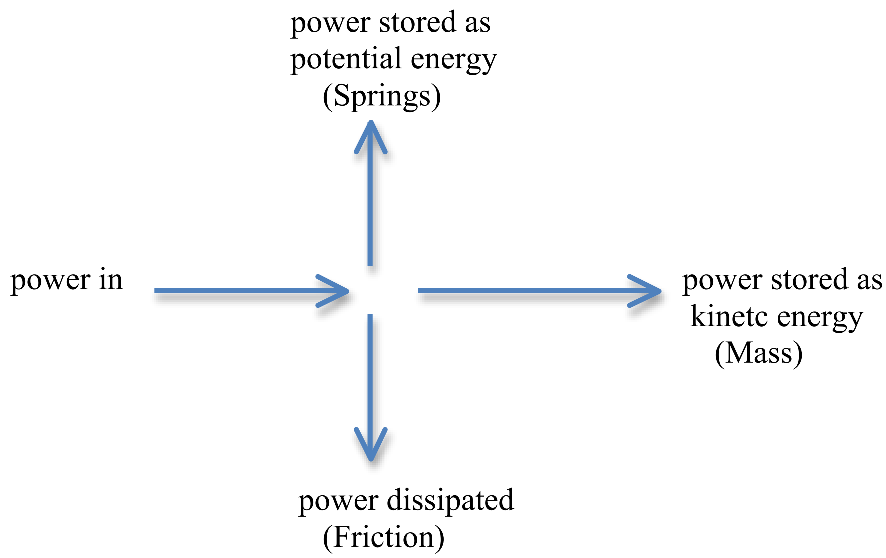
power = (1) force x velocity or (2) force ÷ time

power = rate of energy change (derivative of energy with respect to time)

power applied to a spring or mass is stored as energy – potential energy of a spring, kinetic energy in the velocity of a mass
power applied to a friction element is dissipated as heat

(Derived from www.swarthmore.edu/NatSci/echeeve 1/Class e2 "Work, Energy, Power")

A map of power flows might show something like the following diagram:



(Adapted from www.me.utexas.edu…"Mechanical Translational")

How does this map translate into movement? Mass as kinetic energy becomes movement, inertia, momentum, accelerated by a combination of gravity and the sweep of the center of mass over its point of contact with the ground. Power applied to the body's spring system becomes **potential energy** which only becomes **actual** when it is **released** upward and forward into the trajectory of the stride. Mass as kinetic energy is co-active in compressing the springs; the springs become co-active in releasing or converting the kinetic energy of the mass into flight.

Once this dynamic is underway, initiated in the short acceleration phase by the athlete's intention to move and go faster, the cumulative power is no longer "applied;" it is "liberated in human joints," as a biomechanics text puts it, and goes on to point out that "for a given muscle a faster movement **reduces** the amount of force generated." We have encountered the same idea in the corollary: a muscle does its fastest work **unweighted**.

It is a crucial distinction in how we think about movement. If power is defined as (1) force multiplied by velocity, as the rate of performing work, the assumption arises that power is created by **keeping force constant** and simply **adding** velocity, increasing the rate. Do what you do, just faster. You can drive a loaded truck 5 mph faster and get to your destination, or almost to it, faster, maybe even a few times. But soon the accumulated extra load/speed will overstress the body and begin the splay the wheels. In sport the effects of such thinking are more subtle and gradual but just as detrimental to performance.

Or we can add more force while maintaining a constant velocity. That also results in greater power, and the appearance and sensation of power, but obviously not more speed. Finally, *describing* what we can observe visually simply does not *explain* the dynamics of how power originates in the body to create efficient movement, and the additive equation gets you into trouble with efficiency because it takes for granted that in a mechanical world more energy is the solution. Thinking about going faster by just adding velocity asks for more energy, and we'll tend to ask for more strength in the faith it will make us faster. Doing so, we lose efficiency and "over-ski." We experience greater power but not greater flight.

Not so in the world of cyclical animal movement. In this case, where power is understood as (2) force **divided** by time (the relevant factor in velocity), then **less force** is required to achieve the same speed. Lightness on skis is the result as well, and the body's spring system accomplishes that. After initial acceleration, speed is inversely proportional to stable contact time with the ground. I have used the example previously of an experiment anybody can do on a track. Start a 100m with a normal stride. With that established, halve the time you are in contact with the track. You'll be a half to a full second faster.

I recall Inge Braten's comment while watching Petter Northug skiing at Sognefjell: "He goes so easily." His movements never appear disturbed or troubled in any way. At times they even seem too nonchalant. He is a marvel of efficiency, and it is this quality of his movements which keeps him "light" and helps save "fuel in the tank" for the end of a race.

Technique then is not the simple application of down-power to the ground; that confuses power with force and defines the athlete in an adversary relationship to the terrain, in which dissipation of energy in the friction/tension element grows.

Technique is the up-release patterns of potential (spring-loaded) and kinetic energy in the creation and maintenance of flight, movement over and through and with the terrain, i.e. where speed and efficiency/endurance are achieved not through the greatest pressure applied to the ground but through the most balanced and coordinated energy release, and only what is needed in dynamic harmony with terrain, which itself is subtly "springy." That is what we call "feel for the snow."

The role of strength training is to creates a stronger and more stable overall spring system, critical to raising performance, but it is not the ultimate determining factor in the quality of movement.