Shin Angle Myths

Dick Taylor

Emphasis on a pronounced shin angle, in both skating and classic ski technique, has become an article of faith in recent years. It has been widely presented in training camps and clinics, from USST camps down, as fundamental to effective movement and explained with "more is better" zeal. Speed of movement as key to the generation of power is noted but extended presence of that angle is described and the suggestion that it must deepen if you want more power. Joe Bouscaren's recent article, "The Third Dimension of Skating " in *Master Skier,* gathers the points of shin angle often prescribed, but the prescription is so flawed that further discussion needs to clear the air. Certainly not all coaches share similar views of technique, but discussing them can enhance how we understand movement and teach our skiers.

"Set the ski down with a steeper shin angle." First, the response of the legs to the ski touching the snow, softly, smoothly, is similar to that of a supple spring which cushions the shift of weight onto a new point of balance, minimizing pressure and agitation. It is the sensation of a smooth touch down in an airplane, almost without feeling at all, without bump or bounce. Initially the leg flexes a little, but optimum balance and glide are achieved to the extent center of mass is vertical to the ski. Thus it immediately but smoothly opens to ride the ski, which has touched the snow softly and already moving. If there is anything characteristic about the best European skiers, it is the ride on top of their skis, not the drive. Their movements are seamless, fast but not forced. And the shin angle they display is not severe; it is the same among them and natural to the movement. It is not "technique;" it is merely the human response to the terrain, speed at hand and the impulse to glide.

The transition from gliding to kicking, as Stefan Lindinger notes (in *Analysis of Skating Techniques*, 2006, in German), "requires a very high level of coordination in order to lower the center of mass plumb to the ski and to maintain the whole system in balance." (p. 284) If the shin angle stays or is deepened, particularly with the hips too far forward, or with "knee drive," more pressure on the forebody of the ski will make it plow. There is also the cost of increased muscle stress in the lower legs. The Norwegians, among others, recognized this danger early in their studies of skating, both in flexing too deeply ("Many skiers have built up a lot of lactic acid by going too deep...") or too long ("If we don't get the right timing, this will lead to stop phases in the movment and often static phases in the muscles. Technical solutions that cause static phases for the muscles that last longer than necessary will pinch off circulation and thus reduce the muscles' access to O2.")(*Skisport*, 2001)

Lindinger also makes the point of straining too much forward: "Mistaken pushing -off can have its beginnings when the system center of mass cannot be dropped plumb to the ski (plane of the ground) because a forward leaning position has already been taken." (p. 281) Only when the kick is initiated does the body again drop quickly and push off (.3-.8 seconds), and this is the fleeting moment that a steeper shin angle appears.....and is gone. It does sharpen, of course, when the athlete, runner or skier, encounters a hill. Hills do that to humans going up them, just like hills "tell them" to widen their stance to varying degrees, not because the wider stance is inherently more stable or powerful but because the glide time is shortened enough that the legs do not have time to completely get back underneath the body's center of mass. The resultant increase in stride frequency in climbs (V1) also requires a natural reduction in moment of inertia (as, for example, in the case of sprinting), which means that the skier must shrink the radius of movements in order to "keep up" with the need for higher frequency, more frequent kicks. There is a cost, however: a wider stance and deeper knee bend bring a loss of mechanical advantage and speed of opening. That is exacerbated by earlier edging and attendant loss of glide.

A variant solution avoids this. Remaining as "tall" as possible with the feet closer underneath facilitates the faster opening from a more shallow knee joint. The turn-over rate is a little higher but the cost is lower. The push-off platform underneath is also flatter and firmer and there less pronounced edging. Among the skiers both movement solutions can be seen. European coaches whom I read (principally Italian and German) look for such a "narrow directioning" of the skis as possible, avoiding too broad (sideways) a stance because it risks sacrificing forward momentum. Recent YouTube videos of the World Cup Skate race in Davos provide ample examples of that priority. I see Vittoz and Freeman tending wide, Hellner, Heikkinen and, particularly Magnificat narrower and lighter in the feet.

We can generalize: all good skiers shift gears responsively, including kids and World Cup skiers, and they are natural responses. It is the human body responding to terrain, glide direction of the ski, speed and its own physical conditions. It is action itself, interaction with the momentary environment, which is the decisive source of information which brain and body use to create movement patterns and optimal trajectories.(Berthoz, *The Brain's Sense of Movement,*p. 76) Stable, static positions are not reliably informative.

The biomechanical basis for advising greater shin angle and duration is also incorrect: "A steeper shin angle would increase the propulsive force which is directed down the track" because "it pushes through a greater range of motion for a longer period of time."(Bouscaren) The assertion does not hold up on two counts. First, drop jump research has demonstrated that conscious effort to deepen leg angles in order to increase lift off power do not work. What does prove optimal is the natural (more shallow) flexion of the legs/ankles in response to height of take-off and the goal of the spring-up. This is because increasing angles past a certain natural point feels more powerful but actually causes of loss of mechanical advantage and with that *less* power/speed of opening. This research was reported in 1987 and appears in my book from 2002, p. 238f. As with accentuating knee drive, the deeper angle results in ground reaction forces (the spring effect) being "soaked up" by the joint rather than converting into elastic lift-off force. The key here is the role of "limb stiffness." It is the instinctive response of the antagonist muscles in resisting further flexion in order to take advantage of ground reaction forces through a combination of eccentric loading and "stiffness." This describes the mechanism behind the principle that velocity is inversely proportional to the time of standing still on the support leg, or on skis during pushing off. The absence of a necessarily sharper lever angle as the mechanism for increasing speed is further observed by Bellizi, et al.(*J.Appl Physiol*. 1998): "Although muscular activity likely varied with skiing mode, it appears that the musculoskeletal system meets the mechanical requirements of increasing skiing speed through equivalent muscular activity simply by modulating the recruited muscle to perform the task more rapidly." This is an example of how adaptation to higher speeds is predominantly neuromuscular rather than a matter of purely mechanical muscle/leverage.

The phenomenon of limb stiffness and its role in the development of speed is an important one for skiers, and it is characteristic of a fundamental way in which biomechanics (animate creatures) differs from Newtonian mechanics (inanimate objects). It is the latter set of principles that so much of ski science (including Smith's long article on biomechanics to which Bouscaren, and many of us, have referred) has labored under over the years, unproductively and inaccurately, in my view.

A line of thought begins with simple running. In 2001 Kyrolainen, Belli and Komi pointed out that "A short and rapid stretch with a short coupling time and a high force at the end of prestretch creates a good precondition for utilizing tendomuscular elasticity.....stiffer muscles around the ankle and knee joint in the braking phase caused further potentiation in the push-off phase, when less increase in chemical energy expenditure among the better runners may be observed." (*Medicine & Science in Sports and Exercise* (*MSSE)*, 33/8, p. 1335) In a related study Chelly and Denis noticed that "The eventual beneficial effect of the leg stiffness on maximal running velocity is a new finding in teenage runners....This reactive power is involved in each stride to maintain high running velocity." (*MSSE* 33/2, p.330f.) Arampatzis, Bruggemann and Klapsing add: "Leg stiffness influenced the vertical ground reaction force as well as the vertical lowering of the subject's center of mass. .... High leg stiffness values caused an increase in the amount of energy transmitted to the sprung surface. Conversely, an increase in leg stiffness caused a decrease in the energy absorbed by the subjects during the negative phase of the drop jumps."(*MSSE* 33/6, p.927-8) Here is a key factor in biomechanical efficiency: the down (negative) movement of the motion is converted via stiffness/elasticity – like a shock absorber – into lift off rather than being absorbed/soaked up/lost by the athlete's limb, in skiing by a consciously more bent knee or ankle. (I have cited the Norwegian article in which knee drive is questioned.) Finally, a conclusion worthy of our attention: "The highest mechanical power values are not achieved by a maximal activation of the leg muscles."(*MSSE* 33/6, p.930) In other words, efficiency/ effective force results from optimal execution, the best in the shortest time, not maximal force accumulation.

Here then we also have the basis for the second error in assuming force applied longer will produce greater power/speed. Force X Distance/Duration = Work. Force divided by Time = Power. In racing time is not a multiplier but rather a divider. You do not go faster by pushing longer and producing greater cumulative force; you gain greater propulsive force by applying the same force faster. As the Finnish physiologist, Heikki Rusko, has observed, most racers have enough strength; they just cannot apply it rapidly enough. Certainly the elementary distinction between work and power is central to any understanding of athletic performance. The time of kicking noted above, roughly the blink of an eye (in classic the time is .1-.2 secs), makes attempts to extend kicking time idle anyway. In 1986 the USST published an analysis of skating which portrayed speed as the result of longer kicking time - the same mistake - which was corrected by a review of basic biomechanics. It is a simple distinction in physics, but one too routinely forgotten.

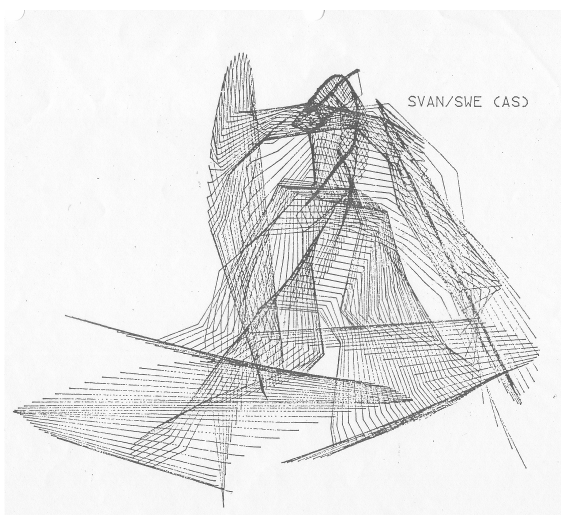
An earlier example yet: in the late 70's the USST discovered the deep shin angle in classical technique. All went to work "developing" it. The net result of these efforts was largely stress and awkwardness. This is not surprising in light of modern systems-dynamic analyses, according to which prescriptions for isolated or part-movements, particularly staying in them, often breaks up the flow/efficiency of the total goal movement configuration (*Modelle der Motorik*, Birklbauer, 2006, p.218; also in *Movement System Variability,* Davids, Bennett, Newell, 2006, p. 81), the distinctive quality Gus Kaeding noticed while skiing behind Bjorn Daehlie ("In the Shadow of a Legend"). At the time of this first "shin angle discovery" I took some video of my 7 year-old son, skiing across the open snow in front of the lodge at Devil's Thumb Ranch in Colorado. There was "the angle," naturally, and he was just headed, sprinting to be sure, for some hot chocolate.

Here is another such comparison from this year.

Andrew Siegel, age 11

Tobias Angerer, Olympic medal winner

At the root of our task is the sheer complexity of human movement, which has so resisted reduction to simple inanimate mechanics. I bemoaned the shortcomings of American research in a chapter in my book of 2002. Here is a way of visualizing the problem perhaps, with a digitized diagram of Gunde Svan skating, from the 1989 Penn State University study.



Which angles or vectors would you pick out as the decisive ones to learn, keeping in mind the age-old nursery rhyme?

The centipede was happy quite
Until the toad, in fun,
Said, “Pray which leg goes after which?”
Which worked his mind to such a pitch,
He lay distracted in a ditch,
Considering how to run.

What is abundantly clear is that isolating or maintaining a given position is contrary to movement itself. There are orders of coordination for whole movements, dynamic configurations sustained through balance and spontaneous response to terrain and speed ("self-organization", as systems-dynamic researchers call it), but no pre-set normative angles or positions, or summations of vectors of force. (As the biomechanist E.C. Fredericke stated in 1985, kinetic energy is not a vector quality.) The mechanical approach assumed that a set of static positions would govern the transitions between them, whereas modern motor learning has long since found that precisely the opposite is true: movement creates the positions, as trajectories, configurations. The whole determines its functional parts dynamically, underway. And the dynamic configuration of a movement is, in fact, supra-summative, both more and different than the sum of its parts. As with a chord of music, you cannot practice single notes, or add them up, and get the tone quality of the chord. What happens if a position is accentuated in the belief that will achieve a better movement is that an optimal trajectory is compromised, whole-body glide hindered. The sensation of tension is bravely interpreted as power, even though the speed remains too slow. That is because, as research has shown, emphasizing a partial movement too often teaches a movement which is different from the ultimate goal movement. Instead of being seamless and rhythmical, that is to say, efficient, it appears angular and awkward, mechanical and somehow stiff.

What is most disturbing is that this knowledge is not new; it has been with us for close to thirty years without being incorporated into our national coaching methodology. In a 1982 presentation called "Technique – Ideal Norm or Adaptation?" Halldor Skaard (Norway) states: "Another weakness is the tendency to divide the technique into minor units and study each of them so thoroughly that one no longer sees the whole movement." (p.2) "The traditional biomechanical methods therefore do not give a clear picture of the efficiency of a technique."(p.4) At the same conference in Davos, Wolfgang Baumann (Germany) pointed out that "each variation of the movement with the tendency of longer duration or slower segmental movements includes the danger to reduce the effectiveness of the muscular work during the movement." (p. 12f.)

Thirty years ought to suffice for American ski science to get beyond the Newtonian physics of an older model of motor movement and take to the insights, and freedoms, of a more modern model in systems-dynamic theory and research. That requires a very different paradigm of thinking and represents advances in the insights of neuroscience which have been with us too long already for us to ignore.

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