Economy and Skiing Technique(s)

Now we come to another unique aspect of XC skiing. There are Many different ways to go from Point A to Point B, even on the flats: **Diagonal stride, kick double-pole, double pole, marathon skate, V1 skate, double skate with-out poling, to name just the flat ground techniques.** There is no simple answer to questions about skiing economy differences among competitors.

Skating vs Classic

The reason we now have "freestyle" races and "classic" races is that without this distinction, everyone would be skating every race, and classic skiing would eventually dissappear into the ranks of the wilderness trail blazers, Skating is faster, plain and simple. Depending on temperature and snow conditions, skating races are 5-15% faster over the same distance. In very wet snow or extreme cold conditions, the difference in speed between skating and classic decreases. As a rule of thumb, we can say that skating is 10% faster for a given group of athletes. Why?

There have been several hypotheses presented and tested:

1. Skating allows the athlete to achieve a higher aerobic capacity compared to classic. In other words, perhaps skating creates a bigger work capacity.

2. Skating allows more of the work output of skiing to be delivered to the skis and forward progress.

3. Skating results in decreased frictional resistance.

Here is what the studies have shown so far. First regarding possibility #1. This is not correct. Several studies have indicated no difference in VO_2 max when measured in the same athlete performing either skating or classic techniques. Of course, this could be a different story if the skier is technically weak in one or the other technique. However, at the top levels, this is never the case. Even as early as 1986, a study of junior world class skiers demonstrated that the race placement in classic and skating races is very similar. Watching the world cup season also indicates the same. The same skiers are dominating the top 10 places in both skating and classic races.

Possiblity #2 seems to play a role. On flat terrain at a constant speed, skating (V1) has been shown to require 10% less oxygen compared to the same speed via the diagonal stride. Heart rate, perceived exertion and lactate accumulation are all lower at similar intensities while skating compared to diagonal striding. One explanation for this seems to be that the velocity changes by the limbs are much smaller in the skating technique. Skating results in a longer force development period for the limbs. Minimizing repetitive acceleration and deceleration of the limbs increases economy.

Finally, regarding #3, the elimination of the grip wax during skating results in a small but significant decrease in friction, and increased speed for the same effort. Since skating results in a slightly lower body position, air resistance may also be a little lower during skating.

There ARE exceptions to the general trend of skating based techniques being more economical than classic techniques. **The classic double pole technique is even more economical than skating on level ground.** (Double poling on ski-skates is the MOST economical technique). However, since double poling involves a smaller muscle mass to generate the work, the strain on the muscles is higher and so is the perceived exertion. If double poling is the most economical, why not use this style all the time? Double poling does not allow the athlete to use his/her maximal work capacity. Being efficient is not effective if too little power is generated! So when push comes to shove, and you are climbing a hill, the prize still goes to the guy with the biggest engine and economy goes out the window!

The LEAST economical style is the classic diagonal stride. A study by Hoffman and Cliffard (1990) measured several physiolgical variables during skiing at a constant speed while using different techniques on level ground. The oxygen cost was 33% higher duing the diagonal stride compared to double poling on classic skis. This isn't hard to believe when you consider how much limb movement is going on for a given amount of forward progress. Consequently, this technique is most frequently seen during hill climbing (in Classic races), when distributing the high workload over the largest muscle mass possible is important. The V1 technique required about 15% more energy than double poling but 15% less than diaginal striding.

Can Technique Decide a Race?

Well, sure it can. My "technique" sure didn't do me any favors during my first race (52 km) after only 3 months on skis! And, there are significant differences in skiing efficincy between the elite and the recreational skier at a given speed. The elite are technically superior. But, who cares about that comparison. The world class guys and gals could ski with no poles and kick our butts (I saw Thomas Alsgaard finish a major relay with one pole and a broken hand. He was still skiing pretty darned fast!). What I am really getting at is "How big are the technique differences among the best skiers?" Again, this is a tough question. Part of racing efficiency probably involves technique selection at different stages in the race. You can't measure that in a lab test. Several studies suggest that you can find national class skiers who are no better technically than good recreational skiers. There is pretty good variation at this level. However, if you just look at international class skiers, the variation gets much smaller (7% in one study). At this level, efficiency is not a strong predictor of performance placing. Inefficient skiers never make it to the international level. Again, we go back to who has the biggest performance engine. A good example of this is Bjorn Daehlie. Among those with discerning eyes for this stuff, they will tell you that he is by no means the smoothest skier on the list. His double poling stands out as frenetic even to the novice. And, he hates to get into a sprint situation, because that is a major weakness for him. However, he rarely NEEDS to sprint at the end, and he WINS and WINS. Why? A 90 ml/min/kg VO_2 max, a love of training, and an unquenchable competitive spirit. When it's all said and done, thats ALL you need to win in World Class Cross country skiing!

XC Endurance Training Theory- Norwegian Style

Borrowing from theoretical physics lingo, I am going to try to present a "Unified Field Theory" if you will of Cross Country ski training, from the standpoint of endurance capacity development. **Unified** because it represents a conceptual blend of my own experience, understanding of the physiology, translations from the Norwegian training literature, and numerous conversations with a national class coach here whose insights I value and trust. **Field** fits too, because I am going to try to talk in terms that make sense out in the field, not just in a lab. Unfortunately, a lot of sport scientists can't think beyond the lab and the "8 week study." **Theory** is also appropriate, because no scientist worth his bodyweight in salt would propose to have the all complexities of physiology and training adaptations nailed down.

I should also point out that this framework does not assume limitations on training time, it is based on the long term development of elite athletes. This is an important point. Much of the research based on untrained or moderately trained individuals doesn't apply to the elite. However, although this material is built up from elite training experience, the basic principles have relevance to us all.

The Big Picture

Below is a training intensity chart, similar perhaps to many you have seen before. It is a closely patterned after the basic intensity classifications for endurance training used by XC skiers and trainers in Norway. When they denote training intensity, this is the language used. I have added another column, lactate concentration. These values are based on several sources including long term studies of elite rowers in Germany. I think rowing and XC are very similar because they are both quadripedal exercise modes.

Intensity Scale	Intensity as a % of HR max *	Lactate Concentration	Training form	Comments
1.0	60-70%	1-2.5 mM	long distance, variable forms	very important- comprises highest volume of total training load
2	70-80%		distance work, uneven conditions	used only as variation. This method gives us the least return for the effort.
LOW Intensity Threshold				
3	80-85%	3-4 mM	Natural intervals	used in a limited way
3-4	85-90%		Medium hard interval training, distance training	very important
HIGH Intensity Threshold				

4	90-95%	4-8 mM	Hard interval training	very important
5	95-100%	Greater than 8 mM	Tempo Training Tests, Short (5-10 k) Races + All max efforts over short time (sprints)	Should comprise only a very small percentage of total training volume!

*** Heart rate is based on the average value at the end of an interval bout or on the top of hills in other training forms.**

**** Explaining the Two Thresholds** I need to write another separate article on this issue of blood lactate and exercise intensity. The basic lactate threshold (also called anaerobic threshold) concept is a useful tool but also over-simplistic. The traditional way of viewing the lactate threshold is that it is the exercise intensity at which the working muscle becomes "anaerobic" and lactic acid production commences. This is wrong, but the idea persists in the popular literature because it is an easy concept to get across.

The reality is this. Even at rest we are producing lactic acid in small quantities. Blood concentrations stay low because this lactic acid that is being produced one place can be taken up and used by another tissue. At low exercise intensities, no or only a very small increase in blood lactate concentration occurs. In fact, we sometimes see blood lactate drop a little from resting values at low exercise intensities, depending on what the athlete just ate. However, if we increase the exercise intensity enough, but not too much, we see blood lactate concentration increase to a new stable concentration. Now we are crossing the **Low Intensity Threshold (LIT)**. At this intensity(s), the blood lactate is not out of control. Lactate removal or clearance can also increase so that a new steady state is achieved. The highest blood lactate concentration that can be maintained during a 30 minute exercise bout corresponds to what we call the Maximal Lactate Steady State or MLSS. This lactate concentration varies with the sport. It is higher in activities that have a smaller active muscle mass like speed skating and cycling (4-6 mM). It is lower in rowing and XC which employ more active muscle mass simultaneosly (3-4 mM). There are also inter-athlete differences, of course. The intensity at which it occurs varies with training status. When the intensity climbs above the MLSS workload, then we have exceeded the **High Intensity Threshold (HIT)** on the chart. At these intensities, lactic acid concentration would continue to climb over time until the concentration becomes high enough to inhibit muscle contraction and causes fatigue. The rate of accumulation will depend on how high above this threshold the intensity is and how effective the body is at clearing blood lactate. We have growing evidence to indicate that the best endurance athletes have higher lactate clearance rates. They get rid of lactic acid faster. So **LIT** represents an intensity at which blood lactate begins to rise. Between LIT and FIT we are working in a range where the increased production is accomodated for by increased clearance by non-working muscles, the heart (a lactic acid lover), the liver etc. **HIT** is the traditional red line, the exercise intensity above which fatigue is just a matter of minutes! How much time can be the difference between winning and losing.

The Basic Recipe

Here are the basic philosophies of the Norwegian system with some explanation and comments along the way:

1. **Build the program around weekly high intensity training/intervals!**

XC country skiing races are won by athletes with VERY high maximal aerobic capacity. This capacity requires both genetics and hard training. The athlete should build the program around TWO hard/interval sessions per week. In general, the emphasis is on long intervals in the 3 to 8 minute range. This 2 hard session/week rule of thumb is a consistent feature from the junior level all the way up to the international class. For example, here is some actual training data for three elite Norwegian skiers when they were juniors (18-19 years old), during the competitive season.

Vegard Ulvang: 1.9 interval/hard training sessions pr week (including competitions)

Anders Eide: 1.6 " "

Anita Moen: 1.9 " "

All three were averaging 8.5 hours/week volume during the racing season at that age (a volume which is significantly reduced from what they do during the preparation period). Interval/hard sessions are part of the training program beginning in August and through the competitive season, which concludes in early April. The only period where we see a deemphasis on high intensity work is during May, June, and July. So, when I get asked the question, "when should I start doing intervals?," I usually reply "two months ago." Hard training bouts at high physiological intensity are an important **part** of the training program most of the time. What will change is the absolute intensity (and duration in some cases) of these bouts as the athlete approaches competitive form.

Similarly, international medal winning athletes like Marit Mikkelsplass and Kristen Skjeldal, who are 10 years older or more and competing at the international level, are still averaging 2 hard sessions per week, according to their coach. So, the **number** of high intensity sessions/week does not increase over the development of the athlete. However, with the improved basic endurance that they develop over years of increasing training volume, the quality of these hard training sessions does improve. This is a fundamental concept of the preparation of XC skiers. High volume, low-intensity work builds the basis for extending the athlete's performance capacity with the hard sessions. The two are complementary. At the elite levels, both are necessary for success.

The interval/hard sessions have the primary effect of stressing the cardiovascular system. We think this is very important for increasing/maintaining a high maximal oxygen consumption. These sessions also are important for stressing the lactate clearance and buffering systems which are stressed during competitions. High intensity interval training IS NOT an ideal method for inducing muscular adaptations such as mitochondrial proliferation and increased capillary density. The adaptations induced by high intensity sessions occur relatively quickly, but are also more quickly lost with inadequate volume of high intensity training.

2. Do (most of) the remainder of the endurance training volume each week at LOW (below the LIT) intensities.

The volume of this work does change and can be quite high, depending on where the skier is in their development. At the extreme, these sessions can be 4-5 hours long in elite athletes who are accumulating 25 hours a week of training volume. The key concept is that the long distance training is also critical but should not diminish the quality of the interval sessions. If something has to be reduced, it is the low intensity volume, not the interval volume or quality. The operative Norwegian word here is "overskudd" or overshoot. We want the athlete to feel psychologically ready and be physically rested to perform those hard, high quality sessions. The low intensity training is vital because it builds the muscular endurance foundation necessary to allow the cardiovascular system and lactate removal systems to be stretched to their limits during the intervals without overstressing the recovery capacity of the athlete.

This "hard core" philosophy is a departure from thinking and practice 10-15 years ago, when the training volume was considered the key element.

The primary adaptation acheived with a high volume of low-moderate intensity training is at the muscular level. Mitochondrial density increases, capillary density increases, and cyctosolic enzymes involved in fat metabolism are enhanced. It appears that these adaptations can take years to be fully realized. It is important to point out a few points here. First, despite the fact that the very best junior skiers have VO2 max values that are similar to the best senior skiers, no junior skier has ever won a world title. The increasing training volume that is adapted to over several years of high level training seems to be important, even after VO2 max has plateaued. Second, an alarming trend that has occurred over the last several years is that top skiers are reaching their peaks later in life. And, junior skiers who take the step up to the World cup level are taking longer to achieve good results. In Norway, it has been suggested that one of the problems is that junior skiers do not put in the training volume they used to. Too many cars and busses. This is a distraction that Kenyan children have avoided so far, to the demise of the western distance running establishment who chases them from a widening distance.

The Progressive Overload Principle In Action

Total training volume increases progressively over the developmental cycle of a cross country skier. Here are some guidelines for yearly training volume (hours of actual training), in relation to age. These numbers come from material presented by current Norwegian men's national team coach Eric Røste.

Annual Training Volume in Relation to Age:

12-13	**250 hours**
14-15	**300**
16	**380**
17-18	**? dependant on maturation**
19	**520**
20	**580**
22	**650**
25	**750**
Upper limit (males)	**approx. 1000**

Keep in mind that this is a progression based on long term development. The late starting athlete is not going to be able to automatically handle those high training loads, just because they are older! When the training is broken down into percentages of hard and "easy" training, it comes out to around 15 to 20% hard and 75-80% "easy" or "steady." Coach Røste also points out that there is some hidden intensive training that occurs during the long steady state bouts (big terrain changes). I hesitate to use the term "easy" this describe this low intensity form of training. The actual Norwegian term used is "langkjøring" or long running. Distance, not time is of the essence here. A 3 hour trail run in the woods, kayak session, or climbing-intensive hike with back pack in the mountains is not "easy" if have only been doing "60 minutes and out" training!

3. In General, Avoid "Middle of The Chart" Intensities.

This should not be taken too dogmatically. Sometimes the intensity climbs during a steady state workout as a function of the terrain, or getting chased by a dog! And even the top skiers say that sometimes it is a nice variation to pick up the pace just a bit on the long tours. However, the main point is important:

"Train too hard on the easy days, and soon you will be training too easy on the hard days!"

Ok, after reading so far, two questions might be swirling about in your brain:

1. "If interval training is so important, why not do more?"

and

2. "Why not do more of the low intensity distance training at higher intensity, or in other words, what is wrong with the "pretty tough" medium intensity workout?" Whatever happened to "No Pain, No Gain?"

I think answering both requires not only a knowledge of muscle and heart physiology, but an understanding of the "whole athlete". Historically, many people have made the mistake of thinking of training one-dimensionally. By this I mean they only think of training as a means to induce the positive physiological changes that result in better performance. This type of thinking rapidly leads to the "more intensity is better" or, more precisely, "more intervals are better" mentality. In the lab, numerous sport scientists have designed short training studies with untrained subjects and demonstrated that those who train at higher intensity improve more in the short run. I have done it myself, having made rats run hard intervals 5 days a week before! Clearly, intensity is a critical determinant of the training response. BUT, pushing intensity too far, too often leads to big problems when we try to extrapolate to the long term development of the elite endurance athlete.

Training must be thought of "two-dimensionally." The first dimension is training as inducer of positive change. The second dimension is training as a stress that does cellular damage, alters brain chemistry, and disturbs hormone levels, negative consequences all in all. When we realize that the training sword cuts both ways, then the "magic" of ensuring the long term progress of the elite athlete can be understood as an exercise in maximizing the "Benefits to Risk ratio," both from week to week and over the long haul.

The answer to both "why not more interval sessions?" and "why so much low intensity steady state work?" is similar I think. I call it avoiding regression towards the mean. If we try to do hard/interval training (read: high lactate accumulation over many minutes) too frequently, we either break down completely or we end up performing many of the interval sessions at inadequate intensity. It can be either the head or the body that cracks, but the result is the same. If we instead try to turn up the intensity on those "long tour sessions," they become too stressful and too limited by glycogen availability, and we shorten them.

As a related point, one of the best ways to end up overtraining is to have too little variation in training intensity (coined "training monotony" in some nice research on speedskaters and cyclists by Dr. Carl Foster). Athletes can eventually handle high workloads if they successfully avoid letting all the workouts drift towards a middle of the road intensity.

Is this training structure unique to XC skiing?

I would have to say YES and NO right now. In general terms, I would say no. This philosophy of training is generally consistent with observations in rowing, cycling and running (though perhaps less so with running as it relates to the Kenyans). It looks very similar to the current pattern in international rowing. However, some might argue that the high volume of low intensity work is particularly evident in rowing and XC skiing. If that is true, I propose that these sports ARE unique in an important way. They require the simultaneous work of all four limbs. This is an exercise situation that humans have evolved away from. The human cardiovascular system was not designed to support the energy demands of quadrapedal movement. We just don't have the big pumps like sled dogs and race-horses. So, when the upper limbs are added to the mix, the sympathetic stress load is higher at any given absolute work load. This may mean that higher volumes of low intensity work are a better way to train the upper limbs and lower limbs simultaneously while avoiding overtraining. Another approach is to spend more time isolating the upper-body during endurance training. This is an issue I will discuss more in other articles!

A SUMMARY of the "UNIFIED FIELD THEORY" for XC ski endurance training.

1. Build the the typical training week around 2 hard/high intensity training sessions.

2. Increase the total volume of training with primarily low intensity work at not more than 70-75% % or so of HR max. Don't view these long, low intensity sessions as valueless, and don't adopt a "harder must be better" approach!

3. Avoid a training condition in which each session begins to take on the same medium intensity.

Walking vs Running as dryland training for XC

It might surprise many of you to know that it is November here on the south coast of Norway, and we still have no snow. It turns out the ocean "warms" the coast a bit and makes the coastline less snow-covered in winter. So, for a Texas transplant who is learning cross country skiing where it all started, I have to do my best to get ready for some skiing without the white stuff for now.

What to do for off-snow training? Certainly roller skiing is an option, but not always a safe one if the conditions are wet, icy, hilly etc. Plus I am a beginner. The next obvious choice is running. This is sensible. You are on your legs doing the same "basic" motion as skiing. And then there is walking. Yeah, walking. Now, trust me, I am a hard core, fairly fit guy who would have laughed at anyone that suggested to me that I could train for anything by walking. But after some personal experience, observations and experimentation, I am rethinking. Here is why.

The "make or break" aspect of XC racing is hill climbing. That is when the boys and girls with the really big aerobic capacity show their stuff. So, do we run hills to simulate the hill climbing on skis? No, I think most of us would do better by walking all the long steep ones we can find, fast.

This got started when my wife told me that the women she ran with would often shift to a fast walk during hill climbs. They cold have continued running, but they didn't. They shifted into a style where their arms and legs were moving in the long deliberate movement cycles typical of skiing.

On a motorized treadmill, usually late at night, I have been experimenting on myself. With a heart rate monitor and controls that allow me to change speed or treadmill incline on the fly, I have done some interesting workouts. I like to experiment under well controlled conditions, so the laboratory treadmill is perhaps a workout only a physiology geek could appreciate. I started with walking and slowly increased the "hill" to 14% grade, which is really steep, but just below what over-stretches my Achilles, then I keep increasing the speed until I have to really work to keep up while walking. In fact, if I shift into a jog on the steep climb, the going is actually easier and I feel less fatigue. It turns out that I can achieve a heart rate of 155-160 at this steep incline, upper limit walking pace. This is perfect for me for steady state work. However, I can easily reach the same cardiovascular workload with running if I speed up the treadmill and drop the incline. This is actually more "comfortable" for me and I get less local muscular fatigue. So, why not just run? The really important difference is the muscular work pattern. When I started doing this workout, and at the same time comparing it with running at the same or much faster speeds and lower inclines, it was the walking that made my legs and lower back feel the fatigue pattern I get from skiing. This was true despite the fact that I could maintain the same heart rate over a wide combination of speeds and inclines, including a pretty fast running pace at only a slight grade (I call these my "iso-HR" fartlek sessions). The difference is new to me, but not to the skiing elite and researchers. It turns out that walking more closely simulates skiing (especially the classic stride) than running. This has been quantified using electromyography, a technique that detects the pattern and intensity of electrical activity of active muscles. The ground contact phase for walking is longer and less "ballistic" in walking, just as in skiing. This means there is less vertical motion associated with walking. And, vertical motion is not something we want to create much of in skiing either. Of course, the incline is critical to the whole thing. This is what forces a higher muscular workload at a low horizontal speed and stride frequency. The incline you need will depend on your fitness. However, even the elite guys spend some time "hill walking" during long steady state workouts. And when they run the hills, they employ a hybrid movement style that exaggerates the horizontal component of the movement, while minimizing "bounce". Out on the hilly forest trails they use the poles too, but I don't do that on the lab treadmill!

So, if you are still waiting for snow like me, experiment with some fast walking. If you don't have the really long hills around, then mix the exaggerated walking style in on your runs whenever you come to a short steep hill. This may be just the ticket to help get you ready for the white stuff!

Bjørn Daehlie- Ingredients for Success

If there is an endurance athlete equivalent to Michael Jordan, I think you could make a strong argument for Norwegian cross country skier, Bjørn Dæhlie. In a sport that has been remarkable in exercise physiology circles for its concentration of physiological marvels, NO cross country skier has every dominated the sport the way this 29 year old from Nannestad Skiklub in Norway has. This year he has started the brutally competitive World Cup season with 3 victories in 4 races, and the margins have not even been close, in a sport where the performance differences over 10s of kilometers are frighteningly small. Now, there 60 days or so until the World Championships on "home turf" in Trondheim, Norway. Bjørn Dæhlie is concerned. One might ask, "What is he worried about? He owns the tracks, dude."

Dæhlie has a personal test of his physical capacity that he has been performing for years. It is basically a 6 minute all out effort on the skis, on his own standard course. Every year for 10 years he has improved , until this year. "In the six minute test this Fall, I am 2 or 3 seconds behind my best effort." This evidence tells him that the gold medals from Trondheim are not automatically going to be hung around his neck. Four previous Olympic golds and two silvers, 6 world championship golds and 3 silvers, and 4 World Cup points championships are one thing. February, 1997 in front of the home crowd, is something different.

In his own eyes, he is not the "reigning world champion". That is something he aspires to be. The ability to forget the glory of past successes, but remember how they are produced; this is what helps him get through the two training sessions per day, 3 hour training trips, intervals and strength training that await him between now and February 21.

What is So Special about Dæhlie?

I am a physiologist and a sports scientist. So, when I watch him on the television (which is fortunately often here in Norway), I am thinking about him as a machine and trying to grasp what this machine has that the others don't. After some help from those who have been around him, I realize that this view can only take me so far.

Bjørn Dæhlie IS a physiological marvel, make no mistake. He is on top of the VO_2 max list among the Norwegian skiers, at or near 90 ml/min/kg! His technique is excellent. His fiber composition is ideal. However, when I asked my colleague if there was anything he could detect from the testing that clearly separated Dæhlie from others that are also so very gifted, the answer was not a physiological one. There have been in Norway, and are in other countries, other skiers with similar V02 max values. But they never won 33 world cup victories.

The Killer Instinct

When the other skiers face a treadmill test, they generally pre-determine a value that they expect to achieve, something inhuman like 84 ml/min/kg. When and if they reach that improbably high value, they are FINISHED. Daehlie sets no such limits. "I have watched him during a test, when the going was getting really tough. He might plateau at 85 ml/min/kg for 2 or 3, 20 second readings (on a treadmill at a steep 10% slope). Everyone else stops at that point. Dæhlie keeps running, and amazingly, the values climb some more, to 86, 87, 88 ml/min/kg. When he is finally finished we have had to hit the emergency stop so we could collect him from the back end of the treadmill, where his shoulder was being rubbed raw by the belt sliding below his exhausted body." The Dæhlie difference is his absolute killer instinct. He never backs down. Whe you see Dæhlie fling his body across the finish line and collapse in a heap, that isn't theatrics. It is the only way he knows how to race. Combine that ability to maximally extend himself with his genetic gifts and years and years of training, then you have most of the ingredients for the most successful XC skier ever. But there are two others.

Part of a Great Team

"This entire winter, I have had great skis", says Daehlie "There is a system around the skis that functions very well". The men who take care of the skis, Magner Dahlen, and Per Knut Aaland, were in the spotlight on December 16 in Oberdsdorf, Germany. There, Daehlie won the 30k classic race and was followed by seven other Norwegian men in the top 10. The first 4 women across the line were Norwegians. I watched the race in amazement on TV. It might as well have been a Norwegian national championship event. Why were the Norwegians so much better? The difference was the skis. When a sudden weather change brought early morning rain on race day, the Norwegian support team had been up all night preparing for that eventuality. They figured out a klister blend that made a difference. The had retired racers out testing the skis with their still elite level technique. When Daehlie warmed up he had not one set of skis, but two, with different "recipes" from which to choose. He chose the ones with a more secure grip instead of the ones with the best glide. He chose right. The skis matter. And Dæhlie is surrounded by guys that make sure they get them right. "If I had to take care of the skis myself, they would just sit in the bag until the next race."

The Final Ingredient

Bjørn Dæhlie trains often and he trains hard. Thirty hours a week or more is usual during the late Fall. However, as much as that is, he is not alone. All the top skiers put in the hours, and they never shy away from hard work. One thing that seems to distinguish great XC skiers is that they love being outside, in the terrain. The best seem to always come from remote little places. It is tough to become a great skier if you are a city boy.

The challenge for the world class skier is to find the perfect balance that GETS them to top form and KEEPS them in top form through the several months of frequent racing. Very few manage that. They get ill, they get stale, they overtrain, they peak too soon, or not at all. According to those who have seen him in action, Dæhlie is an absolute master of knowing just how hard and how long to push his body during training.

Dæhlie is in good form now in December, but he doesn't want it to be "great", not yet. He knows that the season is long and the big prize isn't fought for until late February. He also knows that his victories before Christmas are the product of has basic conditioning training in the Fall. So now, he is pushing his basic training phase farther into the season then normal, to avoid peaking and then crashing too soon. "The years I have won gold before, I have gone faster in December and January. Take for example, 1993 in Falun. Then my form fell off immediately after the championships. Fortunately others had the same problem as me. By the time the championships come, it is too long since we have done our basic (high volume) training."

The Dæhlie Decade-In review

Here are some details about his rise to dominance. The story is always the same, the great performers take years to reach their peak.

- **Spring 1987**- At age 19, he gets his first start in a world cup race, of all places in the demanding 50k Holmenkollen race. He was awarded the start because he had won the junior championship in Norway by more than 20 seconds. He finished 25th that year. Daehlie remarked that he was so happy to be part of the world cup that he nearly cried with joy. By this age, he was already known for his joy of training. "What distinguished me as a teenager was that I was unusually willing to train, Summer or winter. Alone, in the dark, with a headlamp, in the rain, I would do intervals on the steep hills in Maura." His results in other races in 1987-88 were: 41st, 65th, 24th, and 29th.
- **1988-89 Season-** A fourth place, a sixth place were the highlights. The other races looked like this: 23rd, 28th, 19th, 10th, 13th, 20, 12th (Worlds), and 15th.
- **1989-90 The Breakthrough** He won his first World Cup race in December 1989 in Salt Lake City, Utah, then won two more after January. He competed in a total of 9 events that year.
- **1990-1991 More Development** Two victories and a 2nd in 1990, but also 5 races outside the top 10.
- **1991-92 First Olympic Golds-** Four World Cup wins plus 2 Olympic golds and one silver in 12 starts.
- **1992-93** Two World championships plus 4 other World cip victories
- **1993-94** Two Olympic Golds and a silver

- **1994-95** Six World Cup wins, plus 3 silvers in the World Championships. Also one 48th place and a 31st place, proving that even the legeneds have off days.....Sometimes.
- **1995-96** Six World Cup victories and four 2nds in 14 starts.
- **1996-1997 ?????** Three world Cup wins as of December 20th, in 4 starts.

Folks, watch this guy ski every chance you get. The day is not so far away when he will hang up the skis and complete the trasition to his new career of selling his own new line of ski clothes. Even he admits that it is getting really tough to keep suffering through the training every year. I am sure the clothes he sells will be great. Unfortunately, what he can't sell is his unique talent, training savvy and dedication. Well maybe that is a good thing. I would hate to see a bunch of middle aged men with love-handles going fast on skis, just because they were rich!

UPDATE: Feb 4, 1997

When I wrote this article in December, Dæhlie was clearly on top of his form. The big question in his mind and others was, could he hold top form until February. That question remains at the forefront of eveyone's minds here in Norway with two weeks until the Worlds. Dæhlie has slipped. He has been attacked from within by colds and flu. He has been attacked from outside by the entire altitude training controversy that raged here in Norway during January. Is altitude training unethical? Are high altitude simulation houses unethical even if not considered illegal. Does Dæhlie win because of altitude houses and camping wagons equipped to function as "the Alps in a Winnebago"? The press in Norway are not so different from the US or British press; the will work a story to death, and wear down even the most patient athlete with their pursuit. Dæhlie is not a World Cup champion because of altitude houses. If that was enough, there would be champions from Sweden, Finland, Italy and other countries were specialized altitude training methods are used. He is champion because of natural talent and an accumulated 10,000 + hours of consistent, intelligent, hard training. I say that not as a Norwegian loyalist (I am from Texas), but as a physiologist. To be honest, I think the psychological pressure has brought on the physical decline more than a training mistake. Dæhlie has responded by dropping out of several races, including the Norwegian National championships, in order to return to a comfortable training environment, and give his body a chance to recover. Because the drop-off occurred over a month before the Worlds, there is still good reason to believe he will regain top form and fight for gold in Trondheim. This is the supreme test of Dæhlie's personal sense of what his body needs in training and when.

Meanwhile, another Norwegian athlete who has been at rock bottom this season is climbing back to the top. Thomas Alsgaard is back. There was no medical or physical explanation for his collapse at the beginning of the season (In one early season race he actually came to a stop on a hill). In his own words, his training had gone well. Repeated trips to the doctor failed to reveal anything substantive. Perhaps Thomas was also the victim of physical decline due to psychological pressures. He lost his father suddenly last Spring. His father had guided him as a trainer and as a friend for his whole carreer. You can't measure the impact of such a loss on a treadmill. The good news is that the tall smooth skier is climbing back on top. He recently dominated the Norwegian national championships (with Dæhlie absent), sending a message to those who had written him off as a threat this season. He says that he still needed excellent training over the final three weeks before Worlds to compete for a medal. Don't count him out. From my seat here in Norway, the race for Gold(s) is wide open!

The Search For Speed in Cross-Country Skiing

Here is a sport science trivia question for you. What "transportation" sport has experienced the greatest average improvement in performance over the last 75 years? Despite the awesome spectacle of the sub-27 minute 10ks of late, at 10-13%, it is definitely not distance running. Ditto sprint performances in running. Sebastion Coe's 1:41.73 800 record still stands after 16 years and is only 8% faster than the record in 1926. Speed skaters are going 20-25% faster than in 1920. Swimmers have improved far more, about 40%. But these events are advancing at a snail's pace compared to the event contested most passionately in the cold climes of Scandinavia. The average velocity of international elite cross-country skiers has roughly doubled in the last 75 years! Male skiers now cover 50km in roughly 2 hours compared to 4 hours back in 1920. In the shorter events, the improvement is not as great, but still 50% or more. Every aspect of XC skiing has changed; courses, equipment, technique, and the physical capacity of the skiers. Most of the really significant breakthroughs in skiing have occurred in the last 30 years. Here is a survey of the events that have helped skiers to keep pushing back the speed barriers, and a look into concerns for the future.

Making Tracks

XC ski races are contested "across country." Before 1960, course preparation was crude at best. Courses generally followed existing paths, with little additional preparation. The military of the host nation in major races was often called out to tramp down the course on skies. Despite their efforts, early skiers on a race course were forced to "blaze a trail" through untracked snow, and following skiers had to contend with the uneven ruts. Then, a a course preparation machine was introduced for the 1960 Olympics in Squaw valley, and within a few years became standard equipment around the world. The machine laid out perfectly parallel pairs of "tracks" for the skiers to stride in. Today the courses are just as physically demanding, but now each skier in the time-trial format faces the same course conditions (unless the weather suddenly changes during a race) and all the skiers expend less energy fighting the friction of an unprepared course and more energy going forward. In addition, track preparing machines have led to a wider prepared area for the racers to maneuver in. This change was one important ingredient that catalyzed radical technique changes that began in the late 70s and early 80s.

Lighter, Faster, Stronger

A world cup cross-country ski race presents a rather anachronistic visual spectacle. The modern race sites are little changed after many decades. Races are battled in and around quiet forest areas that might at other times serve just as well the winter activities of the resident moose population. But on race day, a kaleidoscope of form fitting lycra, carbon fiber and kevlar is super-imposed on this pristine scenery. Drawings discovered in ancient caves suggest that humans have moved on skies for 4000 years. One can only wonder what a skier from the turn-of-the-century, or better yet the turn-of-this-millenium would think if they could see one of these races.

Lighter, faster and stronger sums up the changes in the skiers' interface with the snow, the specialized cross-country skies. As in rowing, kayakking, pole-vaulting etc, the basic building material of skies has evolved from wood to multi-layer composites made from carbon fiber, kevlar, and fiberglass. The last World Cup winner to use wooden skis competed in 1974. The shift to composites has resulted in lighter (about 500g each) skis that are more precisely tuned to a skier's weight and force production. They are also shorter and narrower (by about 1 meter and 6 cm respectively in comparison to skis of old), and more "slippery" due to micro-engineering of the undersurface structure. To make things more interesting, ski surface optimization is highly dependent on temperature and snow conditions. Choose the wrong ski (or the wrong ski sponser) on a given day and you lose valuable fractions in efficiency and find yourself out of the top 20. The matching of ski to conditions can be decisive, as evidenced in last year's Holmenkollen race in Oslo, March 1996. In the 50k race the conditions were borderline "wet" and ski and wax choices were highly debated. Ultimately the first three finishers all had the same ski type on. None of the three were among the big favorites. The difference was the skis.

Get a Grip, Then Let it Go

Propelling ones-self on skis without the aid of gravity presents a unique challenge. The low friction of the snow is both friend and fiend. Classic cross-country skis are constructed with a longitudinal arch so that the middle portion of the ski directly under the foot is only in full contact with the snow when all of the skier's weight is transferred to a single ski. The stiffness of this arch must be precisely tuned to the weight of the skier, and the dynamics of their technique. This middle portion (about 25-30% of the total ski surface) is coated with a special "kick wax", dramatically increasing the friction between ski and snow. The jagged edges of the snow crystals "stick" in the grip wax when under pressure and allow a brief, forceful push against the snow surface to accompany each stride cycle. Then, when the skier's weight is distributed between the two skis during the glide phase, the gripping center surface is slightly elevated and only the outer portions of the skis "glide" on the surface, this time aided by a different type of wax that **reduces** drag. Both wax types are specific to the snow temperature and the crystalline structure of the snow, which in turn is affected by the snow's "age". Research on the ideal matching of wax composition to weather and snow conditions has been performed throughout Scandinavia and is at times guarded like national security secrets. The net effect is more precise matching of wax characteristics to conditions, better grip during the pushoff phase and less speed sapping friction duing each glide phase. One centimeter more glide per stride can be decisive.

If Dick Fosbury had been a skier

In the 60s, track preparation was revolutionized. In the 70s, the skis were revolutionized. Still, the elegant diagonal stride technique that all associate with XC skiing was principally unchanged for many decades. Then something extraordinary happened in skiing in the early 80s. A new technique was introduced that produced such marked improvement that an entirely new discipline had to be created, or else the elegant classic style would have become extinct. Skiers began to skate.

Perhaps it is an oversimplification to suggest that skiers "discovered" skating only in the 80s. The rare skating stride was detected in old competition photos dating back to at least the 30s, usually during a change of direction or when changing to a different set of tracks. It is clear though that even if skating on skis had already been discovered, it had definitely not been exploited. Why not? Complacency may have played a role. Reading off the medalists from early Olympics and world championships explained a lot. Norway, Finland, Sweden. Sweden, Finland, Norway. Choose a country among these three and you couldn't miss. The Scandinavian powers in international skiing were dominant and conservative. Change was not encouraged by this close-knit triad of competing winter-sport giants. Then in the 60s and 70s, middle Europe began to periodically compete for spots on the medal podium. To make matters worse for the Scandinavian triad, in 1976, American Bill Koch won a silver in the Olympic 30km. These upstarts were hungry to catch up with the traditional powers and willing to be technically open-minded. In 1971, 62 competitors started the 50km Homenkollen race in Oslo. Over half of them abandoned the race due to miserable conditions that were bad at the start of the race and changed for the worse as it progressed. A German named Gerhard Grimmer outclassed the field on that day. While other skiers had to stop during the race to rewax their skis, Grimmer found new solutions. He displayed a one-legged skating technique on the flats and some modified two-legged skating on steep hills. These techniques were improvisations made necessary by the poor grip achieved by the kick wax, but they were a glimpse of the future.

The new fiberglass skis introduced in the 70s played a passive role in the technique revolution to follow because they resulted in ski surfaces with lower friction. The track machines also helped because the prepared areas were now wide enough for the skating technique to evolve. But the courses were wider for 15 years before skating took hold. The change came from innovative skiers. Initially most of them were long distance specialists. In 1975 a skier won the Engadin marathon (42k) with unwaxed skis. He double poled most of the way. With no grip wax beneath his skis, he gave up the ability to perform the leg kick, but he also gave up some speed-damping friction. Then when American Bill Koch got passed during a race in 1977 by a skier employing skating strokes on a flat segment, he got an idea and began experimenting. In 1981 he won the Engadin marathon on unwaxed (no grip wax) skis. The big breakthrough came in 1982. Koch won the world cup series primarily because he had now mastered the marathon skate technique. The United States has never been a power in XC. But even in Norway, "Bill Koch" is a name spoken with great respect by those who know skiing. His forerunner of true skating on skis employed one ski in the track while the other ski was used like a skate with a lateral pushoff. The ski federation powers, mostly from Scandinavia, were caught sleeping by the innovations and responded defensively, trying to outlaw the new techniques. In 1984 during a 30km race, Ove Aunli stormed into victory and history's fastest time with unwaxed skis and a skating technique. He managed this despite the fact that barriers had been strategically placed by race organizers to hinder skating. The skiing mileau was in toal chaos one month before the worlds in 1985. Norwegian newspapers reported that skating was "hazardous to the health" for women due to the "unnatural" movement style. Another headline predicted skiers would soon look like bodybuilders, associating skating style with the large thighs of sprint speed skaters. Scandinavia wanted to retain the staus quo, and many pushed to forbid skating, but nothing was finalized. That year all three medal winners in the 30km race skied with no kick wax on their skis and used skating techniques throught the race. FIS made a last stand against skating in 1985 by establishing zones in the race course through which skating was forbid and basically impossible. To negotiate these zones, skiers had to wax their skates traditionally and use the classic style. With grip-waxed skies, skating would then be ineffective, even if possible throughout the remainder of the course. A young Swede named Thomas Wassberg beat the system by using tape under the middle of his skies, with grip wax placed on top. After passing through the "skate-free" zones, he ripped off the tape and skated on smooth skis to victory. Among others, he defeated the great Gunde Svan of Sweden that day. Cross country skiing was irrevocably altered. The Scandinavians woke up.

Since 1985, cross-country skiing consists of two distinct disciplines, classic style and "freestyle" which means skating. The world cup season is divided equally between the two disciplines and over the last decade there has been little difference in the top 10 performers list between the two. The guys with he biggest engines still win. However, as the techniques are refined, specialization is happening. In the World cup season 1996/97 it has been reported that the Norwegian team will consider developing separate "teams" for classic and skating events, in order to more optimally prepare for the home-field Worlds in Trondheim.

Why is Skating Faster?

Skating is 5-15% faster than classic style skiing, depending on the specific snow and temperature conditions. The athletes are responsible for discovering and perfecting the technique changes. The sport scientists have now come in and tried to explain why they make a difference. Three theories were intially posited.

- **Skating allows a greater physical work capacity to be achieved.** Is it possible that skating results in an even higher maximal oxygen consumption and total work capacity?
- **Skating develops greater power in the forward direction for a given metabolic power**, despite the visual incongruity of this possibility, given skating's lateral force vectors.
- **Skating results in decreased total frictional resistance.**

The first possibiltiy is false. Peak oxygen consumption is not different between classic and skating styles when employed for maximal uphill skiing (Bergh and Forsberg, 1992). Work capacity is unchanged. In fact, unless balance and technique is optimal and upper-body strength is sufficient, the V skate may under-utilize maximal work capacity (Forsberg et al, 1988). That brings us to possibility #2. There is good evidence to show that skating, in its numerous subtle variations, is more economical than any other technique employing the legs. Double poling with upper-body only is the most economical technique, but muscle-mass limited (Zupan et al., 1988; Hoffman et al., 1990) and therefore employed primarily during flat course segments. On flat terrain at a constant speed, skating (V1 style) requires 10% less oxygen compared to the same speed via the diagonal stride (Zupan et al., 1988). Heart rate, perceived exertion and lactate accumulation are all lower at similar sub-maximal intensities while skating compared to diagonal striding (Nilson & Lofstedt, 1984). One explanation for this greater economy seems to be that the velocity changes by the limbs are much smaller in the skating technique. The skating technique alters the relative contribution of peak force and force development period to impulse. At race velocity in the diagonal stride, the force production phase of the leg drive is approximately 0.15 seconds, compared to as much as 0.6 seconds with skating (unpublished data from Vogel, presented in Skard, 1986.) Despite a smaller horizontal force component, the longer force development period made possible by the skating style reduces the metabolic cost of skiing by producing smaller increases in kinetic energy. Acceleration and deceleration of the limbs is reduced. The work against gravity during a step cycle may also be lower, since the vertical displacement/step cycle, as well as the cycle frequency, appears to be lower (Berg and Forsberg, in Shephard and Åstrand, 1992)

Finally, regarding #3, the elimination of the grip wax during skating results in a small decrease in friction between ski and snow, and increased speed for the same effort. Since skating results in a lower body position, air resistance may also be reduced marginally, but this has not been measured to the author's knowledge. The more "open" posture of the legs created by the skating technique may offset any drag reducing effect of a more "aero" upper body position. Overall, reduced friction seems to play a small but contributing role.

It should be mentioned that the development of the new skating techniques by skiers was followed rapidly by reciprocal changes in the skis, poles and bindings. The skis used in skating are slightly shorter. The poles are 10-20cm longer and stiffer, to accomodate the longer impulse period and greater forces generated by the upper-body. The ski boots are higher, ad stiffer to support the ankle. The bindings are modified to better transfer the greater lateral forces generated at the foot to the ski. In addition, the binding system used for skating is slightly canted relative to the ski planar surface to facilitate the "edging" required for pushoff.

What is new in the 90s?

Major equipment and technique revolutions have blown through and changed skiing forever. Details continue to be tweeked, but now attention has returned to a fundamental issue for the competitors that is independent of equipment or technique. The focus is back on the physiology.

It is probably not purely coincidence that Scanndinavia has a strong and lengthy tradition in both cross country skiing and exercise physiology. The two pursuits have been interconnected in this region for at least a century. As early as 1897, Henschen used percutaneous percussion to estimate the size of the heart of skiers before a race. He found that the larger the heart, the better the race placing. In 1955 Åstrand published reports of individual skiers with $VO_{2\ max}$ values over 80 ml/kg/min. In their clasic text *Textbook of Work Physiology*, Åstrand from Sweden, and Rodahl from Norway reported individual $VO_{2\ max}$values of national team skiers over 90 ml/kg/min. These tests were performed in the 70s. If we accept that these values were not swelled slightly by Sandinavian pride in their skiers, then it is seems little has changed in the aerobic capacity of the very best performers in 20 years. The talent pool is just deeper. Today current national team testing data from several sources suggest that 85 ml/kg/min represents a reasonable median value (and over 70 for women) for the World Cup top 20 **(although dimensional analysis and empirical data indicates that dividing VO2 by body mass$^{2/3}$ is a more valid expression of aerobic power for skiing).**

Remarkably, 50km cross-country ski races are very often decided by seconds. 30 seconds can separate 10 performers in a 2 hour race. National team relays covering 40km have been decided by photo finishes. While the technicians perfect the skis, and the biomechanists look for tiny opportunities for improvement in technique, the trainers and physiologists are asking **"How do we squeeze out further increases in aerobic capacity and muscular endurance in athletes who are already at the upper limits of what has been measured?"**

With the skating technique development some training emphasis changes were necessitated. The greater demand of skating on upper-body force production has prompted comparisons of the upper and whole-body aerobic capacities. Results from these investigations suggest that individual performance peaking is more closely associated with the attainment of peak upper-body aerobic capacity than whole-body VO2 max during a seasonal build-up (Bilodeau et al., 1995; Mygind et al., 1994; Rundell, 1995).

Increasing total volume of training has been tried, but there are limits to the capacity for restitution. The boundary between optimal and over-trainied is precarious and variable from athlete to athlete, but all the best know it precisely. During the peak preparatory periods, October and November, some athletes are training 30-35 hours per week. Annual training volume is aleady about 850-1100 hours for males. So, with total volume of training already limited by recovery capacity, skiers have sought to increase the potency of the training stimulus.

Altitude training, despite all the controveries regarding its effectiveness, is standard procedure. This has been true for decades, but recently the approach has become more sophisticated. A single three-week altitude camp in the early Fall has been replaced by repeated excursions to altitude lasting 7-21 days interspersed throughout the world cup schedule. It gets more complicated. The hypoxic conditions generated by training at altitude stimulates erythropoetin production and an increase in hemoglobin concentration. But, if you train very high, the absolute work intensity is compromised and the muscular system may become relatively detrained. So, now the athletes "live high and train low", or at least come down the mountain enough during a camp to do high-intensity training bouts under near normal oxygen partial pressures. But this travelling from country to country in search of early season snow and thin air, and then up and down the mountain regularly when you get there, is both expensive and stressful. So, "altitude houses" have emerged to bring the mountains to the athletes. Then this year, in Norway, the altitude house was given a set of wheels. Two camping trailors were custom outfitted with oxygen and CO2 scrubbing sytems, plus humidity and temperature controls to "put the Alps inside a Winnebago". Inside, "chosen" athletes can eat and sleep at an effective altitude of 3,500 meters. Do everything right, and you can end up in peak condition and with a "supernormal" 16.5 to, in rare cases, 17+ grams of oxygen carrying hemoglobin in every 100 milliliters of blood (15.5 to 16 g/dl for the females). The result is perhaps 2-3 ml/min/kg higher $VO_{2\ max}$ in the positve responders, a slightly higher pH buffering capacity, and crucial 10s of seconds in a 10 k race. There are some skiers who are looking for even more. Beginning at the world championships in 1989 and continuing through to the "trial worlds" in Trondheim, Norway in February 1996, the

International Ski Federation began randomly drawing blood samples from male and female skiers to monitor hemoglobin levels. In 89, the average values were actually just under normal population levels (15g/dl). By 1996 they were far over normal levels. The athletes could have pointed defensively to better use of altitude training except for a more alarming finding. Some individual measurements revealed hemoglobin concentrations of over 19 g/dl, even in femles! A few skiers were walking around with a combination of extreme training induced bradycardia and ultra-high hematocrit that was unnatural by any definition and deemed "deadly" due to the resulting risk of embolism. This same pattern has been implicated in the deaths of dozens of professional cyclists over the last decade. Altitude training is not potent enough to induce these changes. The problem is DNA-recombinant erythropoetin (RhEPO). The athletes are clever, but they didn't discover this on their own. They got help from the field of medicine and from "medical support" who choose to give athletes drugs.

Recombinant erythropoetin became available in 1985, and is used to treat patients with impaired Epo production. Benefactors of this breakthrough included patients with renal disease who suffer from Epo deficient anemia. Shortly after, it was demonstrated the Epo administration to healthy subjects for 6-8 weeks resulted in increased $VO_{2\ max}$ and performance time to exhaustion. RhEPO was immediately recognized as a threat to fair competition in endurance sports. It was quickly classified as a doping substance by the International Ski Federation in 1988 and by the IOC in 1990. This ban was made despite the fact that no methods for precise detection of rhEPO in blood or urine had been developed. With no way to inforce the ban, all FIS could do was measure the drug's impact.

In October of this year, the conservative FIS made a very aggressive decision. Beginning during the 96/97 Word Cup season male and female skiers will be subject to blood testing. Based on medical data and the six years of testing, it was determined that hemoglobin levels of 16.5 g/dl for women and 18.5 g/dl were upper-limit legal levels. Was this decision premature? Initially, athletes testing over the legal limit **before** the race would be disqualified from race participation. Then FIS changed their mind and decided to test **after** races and disqualify the results of positive tested skiers. Other punative actions are unknown. FIS has presumably acted in the interest of safety and fair-play. But are the new rules doomed to result in further controversy? I think so, and here is why.

First, altitude training can, in rare cases push male hemoglobin levels into the low 17s to according to unpublished measurements from elite athletes trained at 2000 meters. Some females have been measured at 15.8 to 16 g/dl after altitude exposure. If FIS tests immediately after a race, could the dehydration induced plasma volume reduction result in sufficient transient hemoconcentration to push a "clean" altitude trained skier over the arbitrary limit of 18.5, or 16.5? It seems possible. The mere fact that they want to test after races suggests they haven't thought about this issue. Second, methods for detection of RhEpo have been recently developed (Wide et al., 1995) that could prove more definitive. These investigators suggest that since Epo treatment requires 6-8 weeks for effectiveness, but becomes undetectable after a week, out-of competition doping controls administered weeks before a competition might prove more effective and more decisive. Finally, given that altitude training in all its artificial varieties is not considered "doping", safety must be the overiding issue driving the FIS rules. The International Skiing Federation does not want to share the black cloud of sudden deaths attributed to rhEPO use that hangs over professional cycling. Yet if safety is the key, then why is it "unsafe" for a women to have hemoglobin levels of 16.5, a value commonly observed in altitude trained men, but "safe" for a male to come in at 18.4?

Progress at any Cost?

In many ways cross-country skiing and sport science have grown up together in the last 30 years. We have much in common and we have learned from each other. Both have seen sweeping progress in biomechanics, physiology, and nutrition to name just three areas. And, as in the past, both will depend on creativity, innovation, and cooperation to continue moving forward. Sadly, both the sport of XC skiing and the science of "sport" are threatened and damaged by the cancer of drug use. In the end, we both lose when sport becomes a hazard to an athlete's health instead of a extension of it. Sports scientists are contributing to both the cancer and the cure.