PEOPLE AND SKIS

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Skiing in Russia and in Scandinavia is a very big thing. But if in Norway the top of the winter sports popularity list undoubtedly belongs to the cross country skiing, in Sweden and in Russia it is skiing plus mountains, with alpine skiing at the very top. Snowboarding, which increasingly grows in popularity (especially among the youngsters) still cannot even "shake" the positions of the mountain skiing disciplines.

Today it is the best time to talk about some interesting research and development in the winter sports technology, skiing in particular. 2006 is the year of the Winter Olympics in Torino (Italy) and in 2007 the Alpine World Championships will be held in Åre (Sweden), only 100 kilometers from Östersund, where the Department of Sports Technology of the Mid-Sweden University is situated. Below we talk about some research results and about the people working here

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Skiing (and especially alpine skiing) in Sweden is more than just a sport, it is a way of living. It is something close to the heart of almost all Swedish people since childhood, and it does not know any age limits. So it is not a coincidence that one of the spring holiday weeks in Sweden is commonly referred to as "the skiing week".

Children in Sweden often learn to ski almost along with learning to walk. One can meet on the ski slopes both kids (as young as two or three years old) and people well into the retirement age (it is hardly possible to call them "old" so fit and sporty they are). On the slopes of small, cozy Swedish family ski resorts one can often see toddlers rushing downhill "restrained" by something looking much like a leash in the hands of a parent. But one should pay the highest credit to the Swedish attitude "safety first": kids are always wearing helmets and goggles. In spring, slopes are often brightened with a more exotic sight of skiing young well sun-tanned mothers with a "leash", restraining her tiny heir skiing in front (tiny skis, bright colored boots, helmet, but traditionally — no ski poles), and chatting non-stop on the mobile phone. Swedish achievements in the alpine and downhill skiing disciplines owe a lot to this universal and widespread love. One can just mention such names as Ingemar Stenmark, who won 87 (!) World Cup events in 10 yeas, including 13 victories in a single season, and the young stars of today such as Anja Pärson (holder of the Big Crystal Globe and the golden medalist of the 2006 Winter Olympics)

Science and Sports

Most probably, sports and scientific research would not be immediately associated for the majority of readers. First, because proper high-class research in this area is very hard to conduct. Second, there are not too many specialized research institutions over the world specializing in the sports technology. And last but not the least, there are not too many high schools having their learning programs in this specific area. At the same time sports and recreation-related industry have an enormous potential for the development and widest fields for conducting applied research. And the most interesting results here are achieved in the areas where science "meets" industry.

Because of its strategic location (Central Sweden) and historic traditions, the Mid-Sweden University became a distinguished center both for education and research in "adventure technology" and sport science, and for winter sport activities. Research projects here are performed in close cooperation with the National Winter Sports Centre in Östersund, the Swedish national cross country and alpine skiing teams and Swedish Olympic Committee.

Research teams in Sports Technology are multidisciplinary, with the team member qualifications ranging from mechanical engineering, materials engineering, electrical engineering, design, product development, manufacturing engineering, software and computer engineering, sports technology to physiology, medicine and surgery. Many of the researchers are active athletes themselves. The research is focused on solving practical problems with design and innovations in mind, which also helps in developing regional business opportunities, where small and medium-size enterprises dominate. Success of many local companies involved in sports and tourism is, to a great extent, determined by high competence of graduates and Mid-Sweden University's expertise and advances in winter sports research. This also significantly contributes to the success of Swedish athletes in winter sports, especially in skiing disciplines.

Sports science is forced to deal with extremely complex dynamic interactions between the human body and the gear at changing external conditions. The human body as such is not an easy subject of investigation for such traditional disciplines as anatomy, physiology and medicine. Properties of materials and mechanisms are also subjects of studies in multiple disciplines such as chemistry, material science, engineering and mechanics, etc. These research areas are big and complex enough by themselves, and as the research in sports technology is carried out at the frontiers of many disciplines, it must be multidisciplinary, and it demands specifically "tailored" specialists. Russia and Sweden are taking the science and technology of sports very seriously, and significant resources are channeled there. It is particularly true with winter sports, where both countries have very long historic traditions.

Rock carving in Rödöy (Norway)
is about 4 thousand years old

"Simple" skis

All the above is directly related to winter sports, skiing in particular. Whereas in the early days of skiing skis and poles were made of wood, today ski technology is as complex as the "space" one. Today, in professional ski gear manufacturing wood is almost completely substituted by modern materials, such as plastics, composites and light metals like aluminum and titanium. The resulting product must be lightweight, strong and resistant.

The issues of the ski materials' abrasive resistance may at first seem unimportant, but it is not that simple. Snow fall-

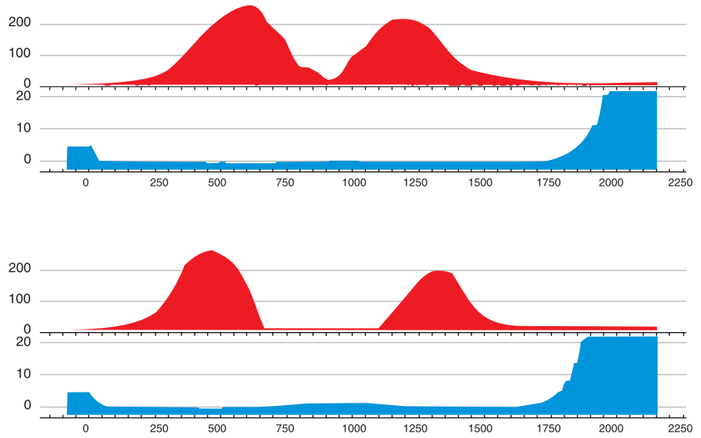
Research Profile in Sports Technology and related educational programs are unique not only for Sweden, but also for the rest of Europe. The scope of research and development activities is very wide and includes the studies of sports gear and its interaction with the athlete's body, optimization of performance of the sports gear and the "main part of sports competitions" — athlete, protection and safety technologies and minimization of injury risks in sports, sports technology for handicapped people etc.
For greater detail, visit the web sites at ***www.miun.se*** *and* ***www.sportstech.se***

ing from the sky may feel soft, but on the slope or on the track, it becomes as hard as concrete at collision. And at high gliding speeds it is as abrasive as sandpaper. So, the ski surface must be resistant and yet glide easily on the snow at all speeds and under different weather conditions.

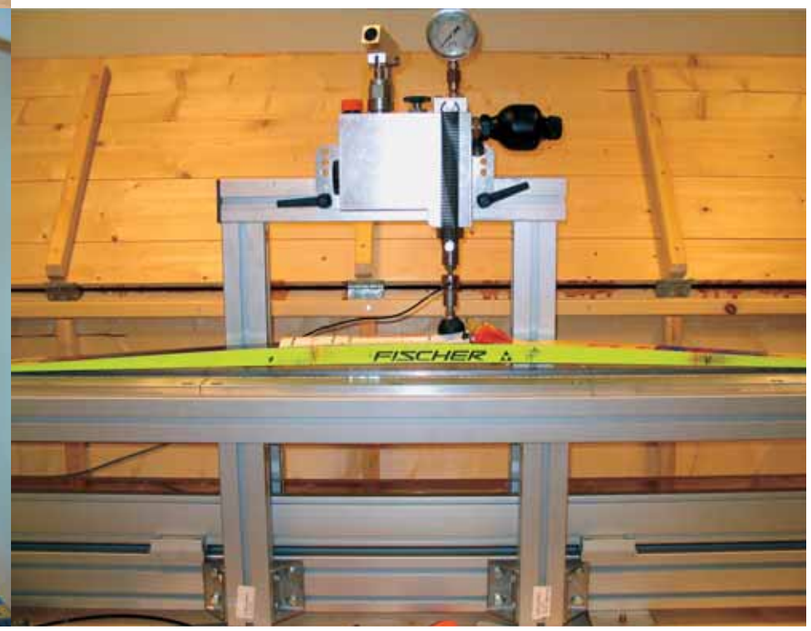
Skis, bindings and poles "at work" are subject to quite significant forces and stress (through vibrations, compression, twisting, bending, etc.). At the same time, they should dump these loads, not transferring them directly to the skier's body; as the human bones, muscles and ligaments will not stand it for long. The bindings must allow a certain flexibility of the "proper" movements of boots and at the same time should restrict the "wrong ones", and also should automatically release in the case of an accident to prevent injuries. These are only a few problems, which are studied by researchers in the field of winter sports technology at the Mid-Sweden University.

Experiments: what to measure and how

A "good" science is always based upon experiments and measurements, and not on unsupported assumptions. Only possessing reliable and testable data, one can gain an understanding of the underlying processes, tendencies and laws so that the main scientific goal of forecasting can be achieved.
It is also undoubtedly true for winter sports science.
But before doing measurements, one should decide what to measure and how. If the measured values are not capable of revealing anything relevant to the study subject, such experimenting becomes an expensive waste of time. And, as in any other applied science, data should be of value to the "end user", that is, to athletes.



Two profiles of pressure distribution along the ski running surface, acquired with the ski parameter measurement setup (the red, upper traces — pressure distribution profile; the blue, lower trace — camber along the ski length). Because of the ski "curvature", pressure upon the track is exerted in two well-defined areas (one at the tip and the other at the tail of the skis); in the pressure profile this shows up as a pair of hills. It is assumed that for the best performance with the wet snow these "hills" can be quite wide, and for the cold dry snow — narrow and pointed



A unique setup for the measurements of cross country ski parameters was developed at the Mid-Sweden University, Östersund. The most important parameters measured are ski stiffness, flexibility and distribution of the pressure exerted upon the snow at different loads. The Mid-Sweden University was asked by the Swedish National ski team not to disclose the information on this setup before the Winter Olympics in February 2006

There are a few types of parameters that are extremely interesting for the skiing athletes and coaches: parameters characterizing *(a)* the equipment; *(b)* the athlete and *(c)* interactions of the athlete, gear and environment in different conditions. Detailed studies of ski parameters are especially valuable for choosing proper of skis.

It is known that even the skis made using a strictly controlled technology by the best manufacturers differ one from another. To improve the athlete's performance, it is necessary to select the best matching pairs, often out of hundreds of supposedly identical skis. Traditionally it is done "by touch" — looking at the skis, twisting and bending, listening to vibrations and resonances, which bears resemblance to a shaman ritual. Using the specialized ski parameter measuring setup it is possible both to select perfectly matching pairs of skis and to choose the pairs fitting best to the style and weight of an individual athlete.

Though the environmental conditions of the "greenhouse" laboratory systems can be kept under good control, some of these parameters cannot be measured indoors.

In this case, researchers are doing field work, on the ski tracks and in the mountains, carrying their equipment with them.

Biomechanics of skiing

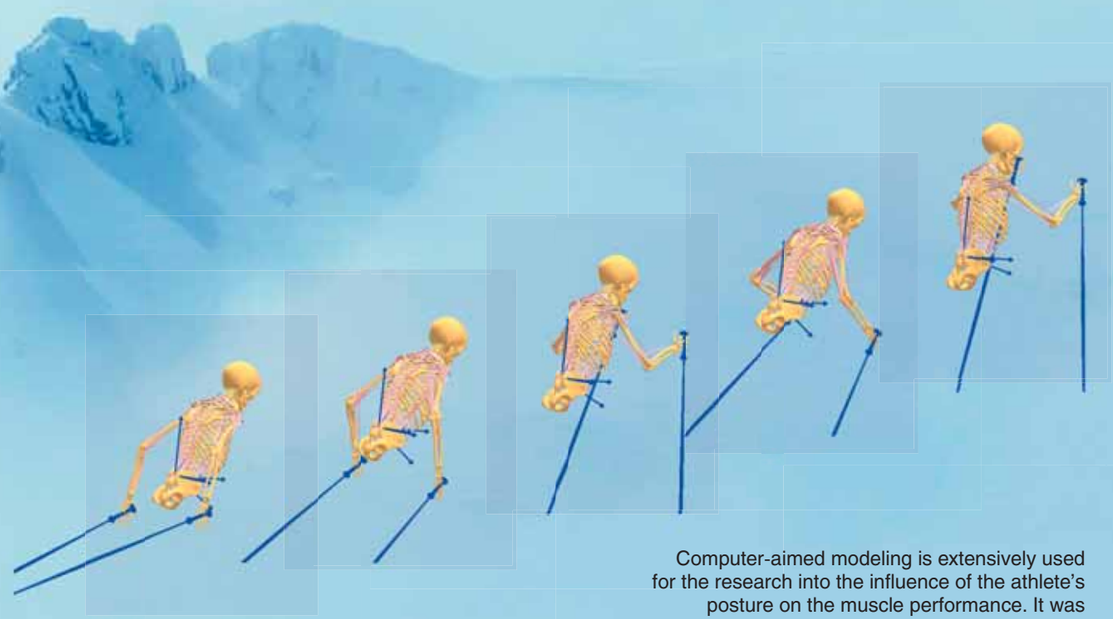
The main task of training and research is the athlete performance enhancement — that is, to become faster, higher, stronger, as the motto goes. Skiing biomechanics studies how the muscles in the athlete's body work; how the body interacts with the skis, boot fixtures and poles; what can be done to make movements more efficient; how to individually adjust the skiing gear, etc. From the athletes' and their coaches' (i.e. end- users) point of view, the biggest interest is when the studies result in practical recommendations on how to improve the athlete's movements for better performance and on how to choose most appropriate skis and poles.

As a matter of fact, experimenting in sports science is quite limited. Moreover, some types of experiments carried out in other practical disciplines are impossible. For example, in other sciences it is common to start studies with the small parts of the whole system, slowly acquiring knowledge and widening research to bigger and bigger "chunks" till the whole system is understood.

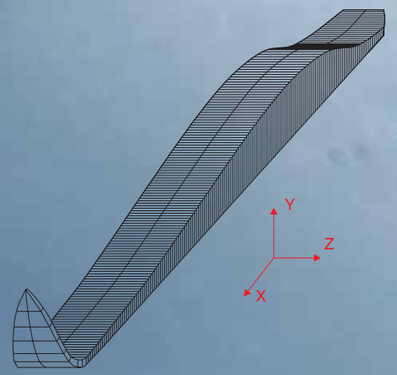
In biomechanics, it is generally impossible to separate an isolated part of a human being.

It is known that the flexion of the upper body at double-poling is quite significant. Because the energy spent by the athlete in such movements is considerable, a reduction of the energy spent for such movements can provide him with certain advantages in competition. Computer-aided modeling allows answering some of the questions. For example, should one keep the elbows close to the body in double-poling, or should the elbows be "put out" at an angle. Unfortunately, we cannot disclose many details of these studies, as they are used privately for the training of the Swedish National skiing team

Skiing is essentially a dynamic activity, so studying and analyzing the athletes' movements is vital. Common video recording of the training and competing athletes is inadequate, as it is very difficult to keep the necessary angle all the time. At the Mid-Sweden University, a special indoors running track is used to make video recordings of the athletes' movements with reflective "markers" attached to the body. Recordings are digitized and used for biomechanical modeling



Computer-aimed modeling is extensively used for the research into the influence of the athlete's posture on the muscle performance. It was assumed that the posture with straight legs was most effective for the athlete at double-poling. Today coaches recommend athletes to use the posture with a slight bent at the knees



It is generally makes no difference for the computer whether one simulates alive or non-alive objects, the question is only whether the model is adequate. Because computers operate with numbers, researchers can extract the necessary parameter values from the simulation results, and compare them with the values measured. These can be both simple physical parameters (like the dynamic forces, exerted by the skier on the poles and skis), and profiles of the skis and poles at varying conditions (loads, temperature, etc.)

The University has three mobile winter sports research Laboratories, based on the Swedish all-terrain vehicles BAE Hägglund BV 206 donated by the Swedish army. But even these agile and robust vehicles cannot take the equipment high into the mountains. In this case, researchers turn into “sherpas” and carry the equipment on their backs. Climbing: Joakim Holmberg, Slottsdalen (Castle Valley), Sylarna mountain range, Jamtland, Sweden

When, for example, one studies how the athlete’s feet and their muscles interact with the boots, bindings and skis, it is impossible to separate parts of the human body from its owner. In such cases, computer modeling and virtual reality provide the necessary assistance. Using a computer model of the system, it becomes possible to answer many questions and to make a successful forecast. But life is life, and all these conclusions eventually are to be proved practically! However modeling can significantly reduce the time and resources spent for the research. But the question which remains to be answered is, ”What is this adequate model, and how to build it?” Actually, this is a big interesting research field by itself, and we will talk about it some other time...

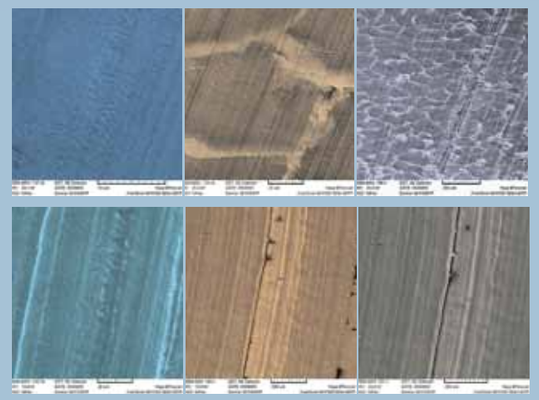
A computer model used at the Department of Sports Technology at the Mid-Sweden University takes into account more than 300 individual muscles and about 50 bones and other anatomical parts of the athlete’s body. This model helps to understand how the load is distributed among the muscles involved in skiing; and how the length, shape and stiffness of the skiing poles, and the rigidity and flexibility of the skis affects the energy spent by the athlete on the track. At the request of the Swedish National skiing team, this model is used for the individual optimization of the cross- country skiing equipment and of the athlete’s movements for enhancing individual performance.

Computer simulations do not only generate the parameter values that are possible to measure but also can generate animated pictures of the moving skier. This is important, for example, in studying the influence of the athlete’s posture upon the performance of the muscles involved. Traditionally it was assumed that the most effective posture at double-poling is the one with straight legs. Today coaches advise athletes to use the posture with a slight bent at the knees. Computer modeling together with studies of digitized videos allows selecting the posture most effective for a particular athlete using individually selected skis and ski poles.

To wax or not to wax?

To wax or not to wax the skis to improve gliding — that is the question... We are sure that an overwhelming majority of skiers (both amateurs and professionals) will answer, “Yes, of course! How can anyone doubt it? Everybody

The special-purpose setup for measuring ski gliding friction under different loads is pulled by snowmobile. Experiments are carried out on a levelled section of the well-profiled skiing track, improving the precision and reproducibility of the measurements



Scanning Electron Microscope microphotographs of the running surface of the modern cross-country skis do not reveal any “pores” that can be closed by the gliding wax

The running surface of the skis with gliding wax, which is constantly applied, picks up particles and other “junk” from the ski track. “Glued” to the running surface, these particles significantly degrade the quality of the running surface, which results in an increase in time friction

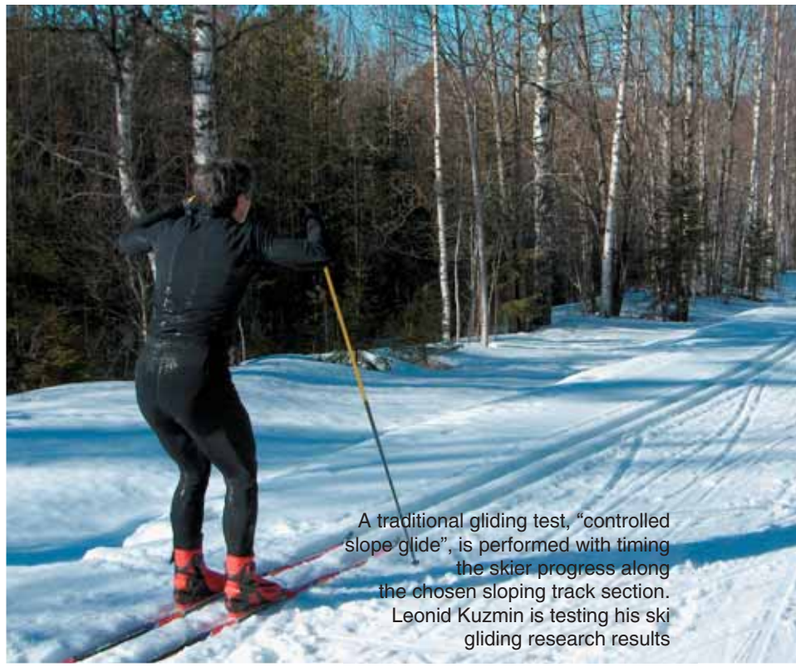
waxed, waxes and will wax skis to improve gliding!”

But this is not as simple as it seems. Traditionally, wax is applied to the running surface of the skis for the classic style skiing in the following way: tip and tail are covered with glide wax to improve gliding, while the cumber part is covered with kick wax to allow the athlete to push, pressing skis to the track. For the skating style skiing all the running surface of the skis is covered with glide wax. In contrast, old-fashioned wooden skis were waxed all the way through with kick wax.

So, the question we have raised in the beginning of this chapter concerns only modern skis with a plastic running surface and glide wax. A lot of people know from experience that in some cases application of the best glide wax does not improve gliding but can slow down the skier. Even though the people who have doubted the generaly accepted things and questioned the application of gliding wax are not many, it is them who advance science. Research must be based on the established facts and relations that have been independently validated, even if the conclusions contradict the generally accepted assumptions. So, the researchers from the Mid-Sweden University together with their colleagues from the Lulee University of Technology initiated the research to evaluate the most essential factors influencing ski gliding.

The technology of ski surface manufacturing is being constantly improved. Materials used to improve the abrasive resistance and gliding properties of the ski running surface have dramatically changed over the last years. With wooden skis, waxing was the only way to improve the running surface of skis and, thus, performance of the skier. Today, a variety of abrasive-resistant plastic materials with good gliding properties is available.

One of the main tasks at the early stages of the research was to choose the best methods for reproducible ski running surface characterization and gliding capability. A special setup and measurement technologies were developed to measure continuously ski friction at different loads. To exclude uncertainty, only glide wax was applied to the plastic running surface of the skis.



A traditional gliding test, “controlled slope glide”, is performed with timing the skier progress along the chosen sloping track section. Leonid Kuzmin is testing his ski gliding research results

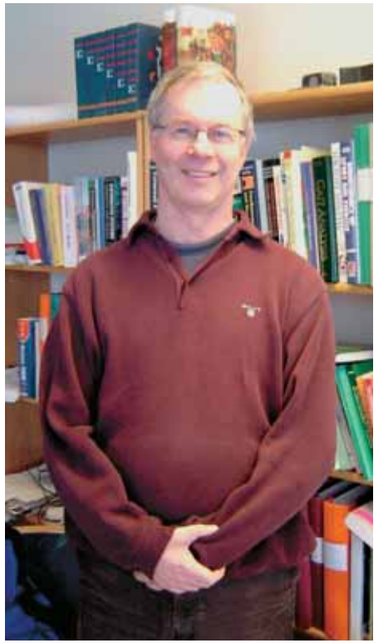
The research results were a surprise. Numerous trails with waxed and unwaxed skis have shown consistent results: waxed skis glide better at first, but the advantage soon disappeared. After some time, unwaxed skis were gliding better than the waxed ones.

The traditional gliding test "controlled slope glide" is performed with timing the skier's progress along a sloping track section. This method does not provide the necessary precision and reliability as it is very difficult to control closely the gliding conditions (such as initial speed of the skier, temperature and humidity of snow, etc.). The distance after which the waxed skis were loosing their advantage varied from several hundred meters to a few kilometers, but the main result was always the same.

After detailed studies it appeared possible to point out the main cause of the effect. It is generally assumed that waxing helps because it "closes the pores" on the ski running surface, making it smoother and providing better gliding. But the running surface of the modern cross-country skis is made predominantly of the Ultra High Molecular Weight Polyethylene, a material with extremely good wear resistance and almost perfect gliding properties. Before competitions, the running surface is also additionally prepared (by scraping with special metal blades). Thus, it is possible to achieve a long-lasting running surface with necessary properties. As for the better gliding of wooden skis, this may be not because of the "pore closing", but due to the hydrophilic surface of the wooden skis, which becomes hydrophobic when waxed properly.

Photo by Kristina Nordenmark

Marie LUND,
PhD. student at the Mid-Sweden University, a member of the Swedish National team in ski orienteering, prize winner at the World Championship in ski orienteering (2003 and 2004). Her interest is modeling in biomechanics of free style skiing.
Her Master's degree Thesis "Biomechanical Study of Cross-country Skiing" is available for free downloading at *http://anybody.auc.dk/pdf/MarieLund.pdf*



Dr. Peter CARLSSON,
PhD. in Computerized Product Development, University Lecturer in the Department of Engineering, Physics and Mathematics. Peter works in the area of sport biomechanics, mechanics and engineering analysis, he is fond of skiing and playing chess

Instead of the conclusion, we would like to point out that scientific research is not necessarily dull. Moreover, enthusiasm and dedication together with a good professional education is often the key to success. Sport science and technologies are among the few areas where the subjects of studies and research may coincide with the hobby, to a great benefit for both activities as well as for the researcher's health and well-being

In this paper we have used the research results and photographs made by young specialists who are simultaneously big sport enthusiasts. Sports Technology Profile (Department of Engineering, Physics and Mathematics, the Mid-Sweden University, Östersund, Sweden)

Joakim HOLMBERG, PhD. student,
is doing research in biomechanics of skiing.
Joakim is fond of alpine skiing and mountaineering

Leonid KUZMIN, PhD. student, graduate of Moscow State Technical University and Moscow State Academy of Physical Education, is doing research on ski surfaces and ski glide. Leonid is the USSR champion in ski orienteering (1989), champion of Moscow in biathlon (1982), and champion of Jamtland in cross-country skiing (2006). His Licentiate Thesis "Investigation of the Most Essential Factors Influencing Ski Glide" (available at *http://epubl.ltu.se/1402-1757/2006/03/LTU-LIC-0603-SE.pdf*) was downloaded up to 2500 (!) times per day