Technical University of Munich
Departement of Mechanical Engineering
Associate Professorship of Sport Equipment and Sport Materials

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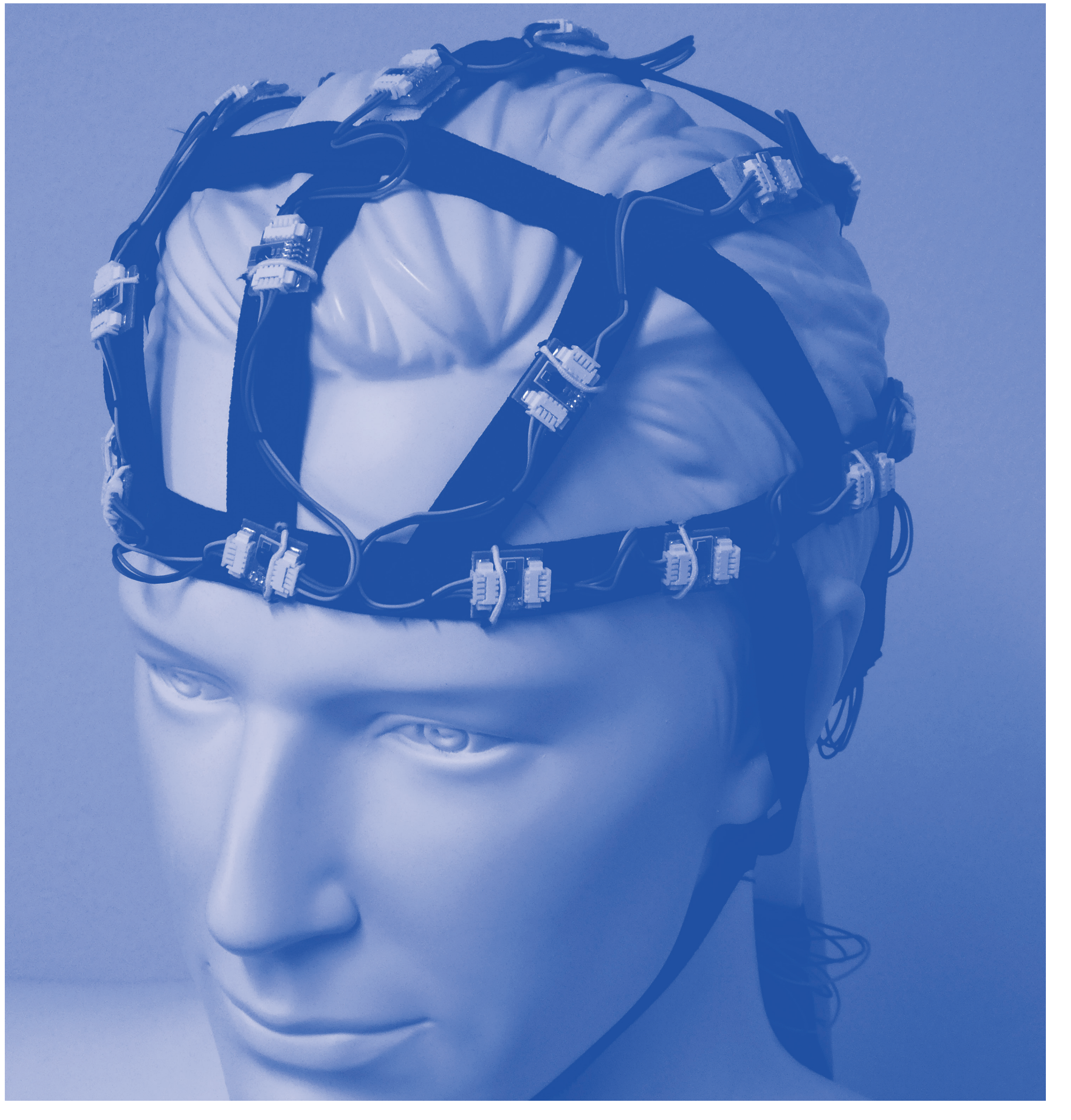
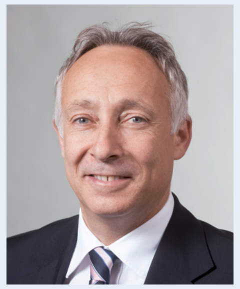
Associate Professorship of Sport Equipment and Sport Materials
TUM Departement of Mechanical Engineering
Technical University of Munich

Annual Report 2019

Jahresbericht 2019



Sport Equipment and Materials



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Dipl.-Ing. Kilian Rauner
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Research Focus
- Performance of sport equipment
- Improved performance of sport equipment
- Safety and protection gear to avoid overloads
- Thermo-physiology in sport garment design
- Footwear – sport surface interaction
- Electric and muscle-powered lightweight vehicles

Competence
- Muscular-skeletal models and simulation
- 3D-motion analysis (optical, inertia, DGPS)
- Electromyography (EMG) and spirometry
- Measurement of external loads and plantar pressure
- Development of physical models (foot and ankle, knee, lower leg)

Infrastructure
- Mobile skin- and core-temperature measurement
- Multi-body simulation software SIMPACK®
- Mobile EMG and spirometry
- Video-based motion analysis (Simi Motion)
- Leg surrogate with loading device
- Instrumented bicycle
- 5-axis fatigue testing device for bicycle frames
- Ski boot flexibility test rig, simulating real ground reaction forces

Courses
- Basic Skills of Science
- Applied Biomechanics
- Sports Technology
- CAD-Basics
- Practical Ergonomics
- Digital Human Modeling
- Advanced Biomechanics
- Sports Engineering
- Field Studies Sport Technology
- Interdisciplinary Research Project

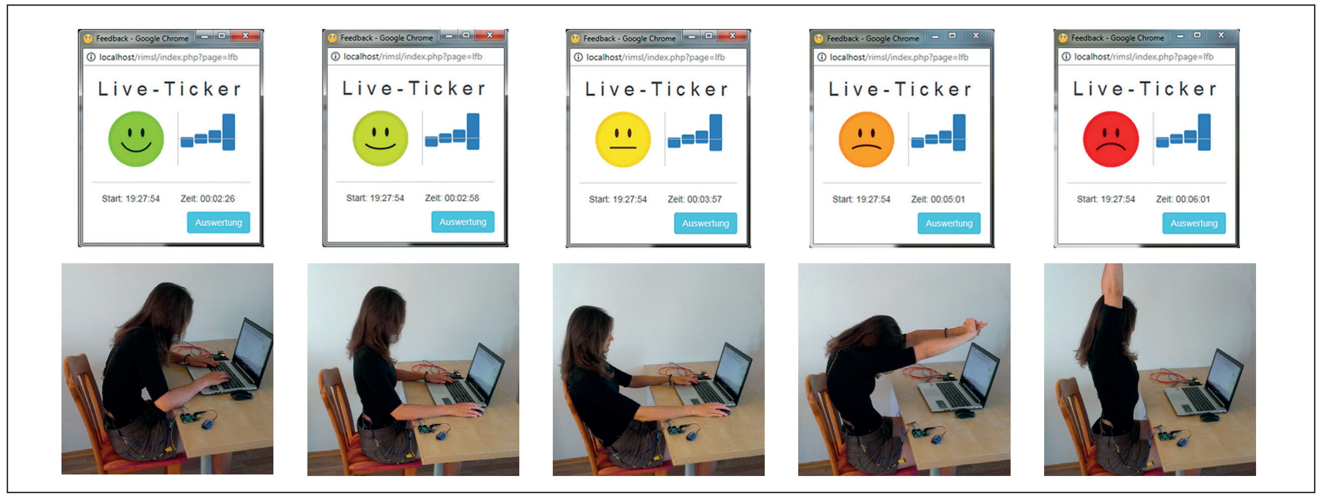
Publications 2017/18 to date
- Brandauer, T., & Senner, V. (2017). The Flow Experience in Alpine Skiing. In E. Müller, J. Kröll, S. Lindinger, J. Pfusterschmied, J. Spörri, & T. Stöggl (Eds.), Science and Skiing VII (VII1st ed., pp. 40-51). Meyer & Meyer Sport (UK) Ltd.
- Link, D., Hermann, A., Lames, M., & Senner, V. (Eds.). (2018). Schriften der Deutschen Vereinigung für Sportwissenschaft: Band 274. Sportinformatik XII: 12. Symposium der dvs-Sektion 'Sportinformatik und Sporttechnologie' vom 05.-07. September 2018 in Garching; [Abstracts]. Hamburg: Feldhaus Edition Czwalina.
- Meyer, D., Körber, M., Senner, V., & Tomizuka, M. (2018). Regulating the Heart Rate of Human-Electric Hybrid Vehicle Riders Under Energy Consumption Constraints Using an Optimal Control Approach. IEEE Transactions on Control Systems Technology, 1-14. https://doi.org/10.1109/TCST.2018.2852743
- Meyer, D., & Senner, V. (2017). Evaluating a heart rate regulation system for human-electric hybrid vehicles. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 232(2), 102-111. https://doi.org/10.1177/1754337117710069
- Senner, V., Lehner, S., Michel, F. I., & Brügger, O. (2019). Modelling and simulation to prevent overloads in snowboarding. In A. Baca & J. Perl (Eds.), Modelling and simulation in sport and exercise (pp. 211-236). London and New York: Routledge/ Taylor & Francis Group.

including a heart tracker, a body core temperature sensor and a micro-climate sensor network between helmet and head add physiological measurements to the biomechanical supervision of the skier. The event was organized by the Deutsche Physikalische Gesellschaft, the Federal Ministry of Education and Research and TU Dortmund University. The exhibition attracted 45,000 visitors.

Health, Wellness and More Fun Through Technical Support

Supporting Dynamic Sitting with Artificial Intelligence
Physical inactivity caused by long hours of computer use leads to musculoskeletal disorders also known as functional backpain. The support of dynamic sitting is regarded as an effective countermeasure. Real-time feedback systems may provide a verifiable improvement of motion behaviour at the computerized workplace.
The purpose of our work was to design an intelligent feedback system that motivates dynamic sitting using real-time visual feedback. This should increase the awareness and the ability to reflect one's own motion behaviour.
Our system consists of a motion capturing unit which feeds an artificial neuronal network (ANN) for the identification of motion patterns plus a graphic representation for visual feedback. Four polymer threads sewed on a functional shirt (see picture to the right) serve as a measuring system. Their data is collected with a microcontroller board.
A smiley presented in the web-browser signals physical inactivity by changing its colour and facial expression. Positive feedback results when the user varies their sitting posture constantly. Moreover, the movement data is analysed with an ANN. This allows the user to check in a histogram, if he or she has an equal use of the six postures the shirt categorizes.

Sensor shirt with measuring fibres (TUM)



Sport Equipment and Materials

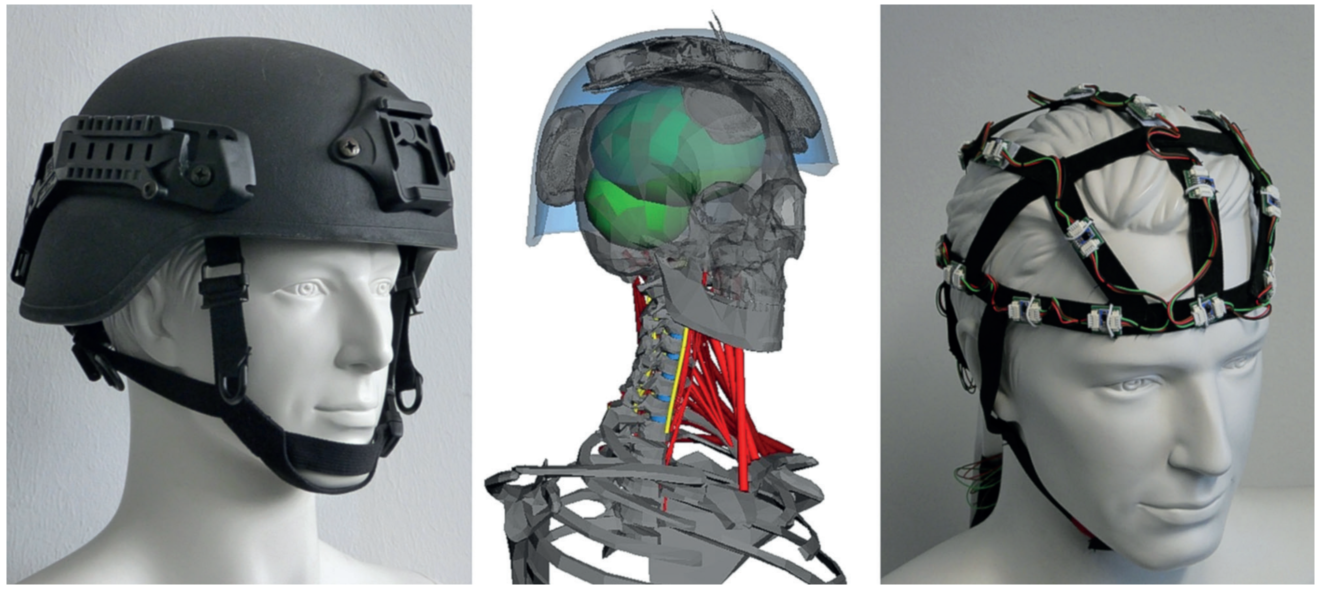
Sustainable support for sport and health through technology

In this year we intensified and expanded joint research and teaching cooperation with other universities. Students from France and the USA spent their internship or research summer in our department. In contrast to the years before, when we focused on publishing, in 2018 more effort was put into applications for research funding (DFG) and joint R&D with companies. New cooperation contracts with sporting goods companies and also with a Swiss outdoor journal resulted from these efforts. We were able to maintain a constant number of staff and to successfully finish the habilitation review of one of our former staff members, Dr. Böhm.

From our 2018 activities five highlights are worth mentioning:

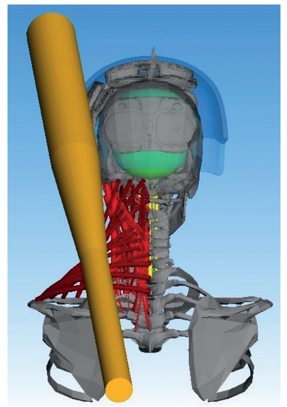
- Comparison study on touring ski bindings investigating safety and performance behavior.
- Organization and hosting the first joint conference on sport informatics and sport technology *spinfortec2018* in cooperation with TUM Sport and Health Sciences. Student workshop over two days prior to the conference.
- Invitation to participate in the exhibition *Highlights of Physics* in September 2018 in Dortmund.
- Beginning of an R&D cooperation with global player PUMA Europe on the future of wearables.
- Book chapter in the Routledge handbook 'Modelling and simulation in sport and exercise'

More Safety with Improved Protection Gear



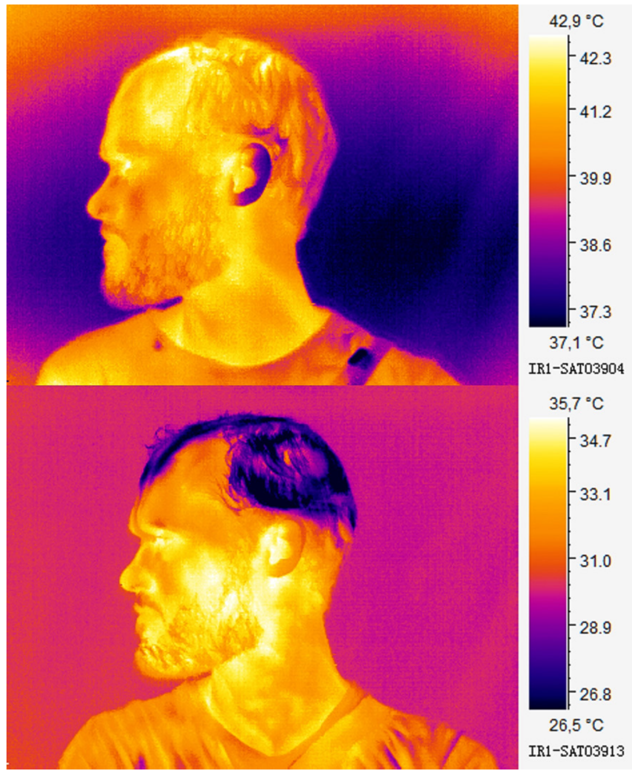
From left to right: Ballistic helmet (Busch PROtective Germany GmbH & Co. KG), multibody model (Schaal-Mulacek, 2018), temperature and humidity measurement system (TUM)

For protection against head injuries, helmets are worn both in the leisure and industrial sector. Especially for police and military personnel, safety helmets are part of the basic safety equipment. Their protective function comes at a price of additional mechanical and thermal burdens for the wearer. Our research deals with their intended purpose as well as the quantification of those burdens and possible solutions.
Images of escalating riots, as in Hamburg during the G20 Summit in summer 2017 or in autumn 2018 in France, show in an alarming way, what violence police and security staff can be exposed to. Therefore, protective helmets are part of the standard equipment for every police officer, who goes into action in this kind of scenario.



Biomechanical simulation of head impact with a baseball bat (Schaal-Mulacek, 2018)

For optimized protection of the sensitive human head-neck system, ballistic helmets dampen local impacts and thus reduce the risk of skull fractures. Additionally, their inertial properties shall decrease head acceleration and prevent the wearer from concussion and possibly lethal brain injuries. As a consequence, the loading on the cervical spine due to the weight of the helmet should not be underestimated.
Biomechanical multibody systems allow a non-invasive method to investigate a variety of load cases up to severities, that exceed the possibilities of volunteer studies by far. We harness our expertise in biomechanical modelling to quantify occurring loads on the head-neck system in critical situations to identify possible risk factors for severe injuries.
Due to their properties and the closed surface, safety helmets act as an additional insulation layer and hinder the body's thermoregulation. This initially leads to unpleasant temperatures and a high humidity in the area between head and helmet. In the case of excessive heat, the thermoregulation can get off balance and lead to health problems. One of the research topics of the Associate Professorship is to improve thermal comfort of personal protection equipment.
In order to determine the microclimate between head and helmet objectively, a measuring system was developed in cooperation with Reutlingen University – Faculty of Textile & Design. By applying the measuring system shown above, both temperatures and relative humidity can be measured. This allows conclusions to be drawn about the thermal properties of the helmets and to generate solutions for reducing thermal discomfort. On that note, a



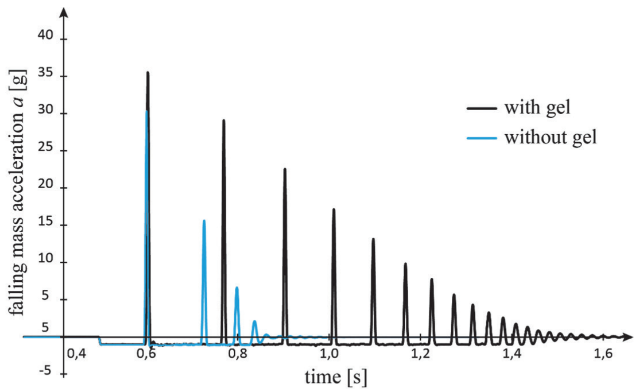
Skin temperature pre and post active cooling process (Stöckl, 2018)

concept of an active cooling system has been developed, implemented in a functional model and proved initially. The infrared images on the right show the skin temperature before and after use of the active cooling system. The thermal discomfort, caused by the ballistic helmet, was significantly reduced.

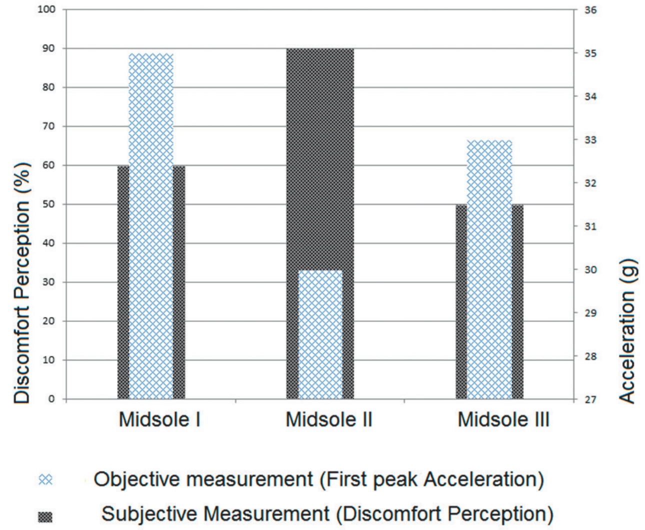
Towards Better Performance with Optimized Sport Equipment

3D-printed Midsoles for Running Shoes
Ideally improving performance and the prevention of overuse injuries go in line with each other. Whereas there is no doubt that the performance of running footwear has reached very high levels, the rates of running injuries have remained relatively unchanged over the last 40 years.
Our research tries to systematically include the athletes' perception of shoe discomfort or sense of effort as an additional factor into shoe design. Today's possibility to produce 3D-printed sole structures with varying elasticity and damping properties even being locally different offers a great research opportunity to combine subjective feedback with material changes.
In one of our 2018 studies, different lattice structures of the midsole were produced with a selective laser sintering (SLS) printer.
Cushioning properties of the printed midsoles are tested with an impactor device (objective measurement). In the next step, discomfort perception of the cushioning impact is rated by runners through a questionnaire. Lastly, the potential gap between subjective and objective measurements are identified and compensated with a new lattice structure produced by rapid prototyping.


Renderings of the shoe prototype



Acceleration-time curve from the impact test of a body-centered lattice structure printed with SLS in PA12 with gel (blue) and without gel (black)



Comparison between rated perception and measured cushioning impact

Future Aspects
We believe that measuring perception parameters in parallel with other shoe characteristics such as cushioning will help in designing a new generation of running shoes. Ongoing studies evaluate other shoe characteristics (weight and traction) in parallel with discomfort perception. The future goal is to produce running shoes with the lowest risk of injuries without a trade-off in performance.

Understanding the Interaction between Athlete Equipment and Environment


Sensors from Head to Toe
At the 'Highlights der Physik' exhibition in Dortmund in September 2018, we presented a skiing mannequin equipped with multiple wearable sensor systems. Related to our work on a mechatronic ski binding, the dummy was wearing knee angle measuring underpants as well as a sock to determine pressure distribution inside the ski boot. With this sock we try to estimate the external loads acting on the foot and thus on the body. A shirt for measuring upper body movements completes posture detection. With a highly precise GPS-IMU system the position and the speed of the skier can be recorded. A sports watch