Institute of Medical Physics

Chair of Medical Physics

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Research focus

- Effects of whole-body electromyostimulation (WB-EMS) on unspecified chronic back pain in patients with unspecified chronic dorsal pain
- 3D imaging and image processing for musculoskeletal applications
- High-resolution computed tomography of the breast
- Functional and metabolic MR imaging

Structure of the Institute

Professorships: 2
Personnel: 25

- Scientists: 12 (there of funded externally: 9)
- Graduate students: 6

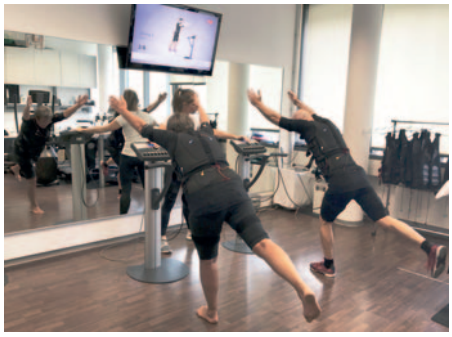
Research

The focus of the research projects and cooperations is the development and the application of imaging procedures in medical diagnosis and image-guided therapy. In the field of computed tomography (CT) where the Institute of Medical Physics (IMP) has gained a worldwide leading position, the foci are on dose reduction and the development of a special CT scanner for early detection of breast cancer. In the field of magnetic resonance imaging (MRI), new functional and metabolic imaging techniques are being developed in close collaboration with the Institute of Radiology. With new measurement methods and ultra-high field MRI (7 Tesla), the concentrations of the two most common ions (sodium and potassium) in tissue can now be determined for the first time. The main topic of the medical imaging processing group are musculoskeletal problems in the area of osteoporosis, inflammatory diseases, osteoarthrosis, and sarcopenia. The focus of the osteoporosis research group lies on the prevention and therapy of osteoporosis by non-pharmacological intervention. The achievements and experiences of IMP in the area of imaging procedures and their development for the determination of bone density, bone erosion, muscle tissue, and imaging processing emphasizing on quantitative CT ensure the scientific evaluation of the extensive and high frequented studies and substantiate the impressive results.

Effects of whole-body electromyostimulation (WB-EMS) on unspecified chronic back pain in patients with unspecified chronic dorsal pain

PI: Prof. Dr. W. Kemmler

In this clinical study, conducted in parallel group design, a total of 155 men and women suffering of unspecified chronic back pain were assigned by computer generated block randomization (1-1-1) to three different groups: (a) whole-body electromyostimulation (WB-EMS), (b) whole body vibration (WBV) and (c) conventional training to improve back strength. The WB-EMS was carried out 1x20 min/week (85 Hz, 350 µs, intermittently 4s-4s), the WBV took place 2x15min/week and the strength training 1x45min/week. After 12 weeks, at the end of the study, all groups showed a similar high and significant improvement of the mean pain intensity, the back strength and the ADLs (Activities of Daily Living). This study was realized in cooperation with the company miha-bodytec (Gersthofen, Germany) and the German Sport University Cologne. The study results showed that all three training options have a significant and clinically high impact on chronic unspecified back pain. Therefore, patients may choose the kind of therapy according to their preferences (time efficiency, high degree of mentoring etc.).



Whole-body electromyostimulation (WB-EMS)

Whole body vibration (WBV)

3D imaging and image processing for musculoskeletal applications

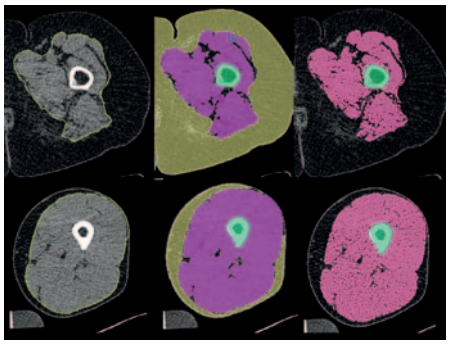
PI: Prof. Dr. K. Engelke

Main topic is the development of innovative 3D imaging and analysis techniques to improve the diagnosis and monitoring of osteoporosis, osteoarthritis, rheumatoid arthritis, and sarcopenia. The combination of imaging of the bone and imaging of the muscle showed interestingly that the fat distribution in the thigh, especially in the thigh musculature, is besides bone density an important risk factor for hip fractures. In the meantime, this research has been extended to the spine column.

At the IMP, validated MRI as well as CT based evaluation methods are available to determine the muscle-fat distribution for the femur, the paraspinal musculature, and the hand. These tools are used to some extent in exercise studies of the OFZ (Center of Osteoporosis Research).

Another research topic is the imaging of the subchondral bone for the diagnosis and progression of the osteoarthritis of the knee within the European research collaboration Approach (Applied Public-Private Research enabling Osteoarthritis Clinical Headway) and in a close collaboration with the Radiology Ostéo-Articulaire, Paris. Basis is a multimodal image processing of high-resolution CT and MR patient scans and micro-CT scans of single bones. The spatially resolved analysis of the subchondral bone density *in vivo* indicated the protective character of the meniscus. Further results show that the subchondral bone structure can be determined by an analysis of the texture. This is of high relevance because *in vivo* the single trabeculae cannot be segmented exactly due to the limited spatial resolution. An according analysis module was implemented in the analysis toolkit MIAF (Medical Image Analysis Framework) which has been developed at the IMP. This tool is now used, for the first time, for the evaluation of an international multi-center clinical study to determine the subchondral bone structure and

density of the tibial plateau and the femoral condyle in patients with osteoarthrosis.



CT image of the thigh
Top: Elderly subject age 62; bottom: Younger healthy female age 44 for comparison; Left: Segmented fascia shown as yellow contour; Center: Subcutaneous adipose tissue (yellow), muscle (purple), femoral bone (green), perimuscular adipose tissue (uncolored); Right: Muscle tissue

High-resolution computed tomography of the breast

PI: Prof. Dr. W.A. Kalender, PhD

Since 2008, the early detection of breast cancer using CT has been a main topic. Very good results have been achieved in different respects. Especially the feasibility of the proposed concepts and the target performance parameters were verified.

In autumn 2018, the scanner received the CE label and clinical trials are currently performed at the University Hospital Zurich (USZ).

Funding: EU, BMBF, DFG

Functional and metabolic MR imaging

PI: Prof. Dr. A.M. Nagel

New image acquisition and processing techniques for MRI are being developed. The focus is on ultrahigh field (UHF) MRI (7 Tesla) and in particular X-nuclei MRI. „X" stands for any atomic nucleus with nuclear spin, except for 1H. In this area, the distribution of tissue sodium and potassium concentrations could be determined for the first time in patients. X-nuclei MRI particularly benefits from UHF MRI. UK Erlangen is one of the few sites where a clinically approved UHF 7 Tesla MRI system is installed. The increased magnetic field strength compared to conventional systems allows for a significantly improved signal-to-noise ratio (SNR), so that image resolutions of a few hundred micrometers can be achieved. In close cooperation with Siemens Healthineers, a time-of-flight angiography sequence was developed that enables high-resolution (0.3 mm isotropic) resolutions of blood vessels in clinically acceptable measuring times (about 5 minutes) without administration of contrast agents. Similarly, new functional techniques, such as Chemical Exchange Saturation Transfer (CEST) MRI, particularly benefit from the increased SNR and higher spectral resolution. On the other hand, there are also some challenges with UHF MRI, which require the development of new data acquisition techniques. For example, a parallel transmission technology (pTx) could be implemented for CEST-MRT, which enables a significant improvement for quantitative CEST-MRI measurements. With the CEST-MRI, conclusions can be drawn about metabolite concentrations and pH levels.

Teaching

Besides the teaching, Bachelor's and Master's theses as well as doctoral (PhD) theses are supervised.

Selected publications

Engelke K. Quantitative Computed Tomography-Current Status and New Developments. J Clin Densitom. 2017 Jul – Sep;20(3):309-321

Kalender WA, Kolditz D, Steiding C, Ruth V, Luck F, Rossler AC, Wenkel E. Technical feasibility proof for high-resolution low-dose photon-counting CT of the breast. Eur Radiol 2017; 27(3): 1081-1086

Kemmler W, von Stengel S. Bone: High-intensity exercise to prevent fractures - risk or gain? Nat Rev Endocrinol 2018, 14:6-8

Kemmler W, Weissenfels A, Willert S, Shojaa M, von Stengel S, Filipovic A, Kleinöder H, Berger J, Fröhlich M. Efficacy and safety of low frequency Whole-Body Electromyostimulation (WB-EMS) to improve health-related outcomes in non-athletic adults. A systematic review. Frontiers of Physiology. 2018, May 23;9:573

Engelke K, Museyko O, Wang L, Laredo JD. Quantitative analysis of skeletal muscle by computed tomography imaging-State of the art. J Orthop Translat. 2018 Oct 28;15:91-103

Gast LV, Gerhalter T, Hensel B, Uder M, Nagel AM. Double quantum filtered 23Na MRI with magic angle excitation of human skeletal muscle in the presence of B0 and B1 inhomogeneities. NMR Biomed 2018; 31(12): e4010

International cooperations

Prof. V. Bousson, Radiology Ostéo-Articulaire, Université Paris VII Denis Diderot, Paris: France

Prof. P. Zysset, Institute for Surgical Technology and Biomechanics, University of Bern, Bern: Switzerland

Prof. X. Cheng, Department of Radiology, Bejing Jishuitan Hospital, Peking: China

Dr. A. Ghasem Zadeh, Department of Medicine, University of Melbourne, Melbourne: Australia

Prof. Dr. L. Bragazoni, Department for Life Quality Studies, University of Bologna, Bologna: Italy

Prof. J. Mayhew, Trueman State University Kirksville Missouri, Kirksville: USA