31P-MR investigations of training effects on resting state concentration of phosphor metabolites in the M. gastrocnemius

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Purpose

Increased muscle activity by training induces several kinds of adaptation processes, like altered regulation of muscle contraction, muscle growth and perfusion. The possibility of training induced conversions between different types of muscle fibers has been already postulated in the past [1]. Due to different metabolic properties, concentrations of ATP, phosphocreatine (PCr), and inorganic phosphate (Pi) are also slightly different in muscles of a special fiber type [2]. As demonstrated by Takahashi *et al*. [3] the (PCr+Pi)/ATP ratio in the M. vastus lateralis increases with the fraction of type II fibers. In this study a group of professional volleyball players was investigated before and after performing a special strength and power training by ^{31}P-MRS of the M. gastrocnemius to estimate the (PCr+Pi)/ATP ratio as a marker of fiber conversion due to adaptation processes.

Fig. 1: *Applied surface coil at a marked position underneath the lateral head M. gastrocnemius prior to the ^{31}P-MRS.*

Methods and Materials

Six male professional volleyball players (age: 21 - 28 years) were examined during rest before and after a four-week complex training. The plyometric training consisted of a special succession of drop jumps and knee bend exercises. A modified trainings method was used four of the six subjects (Fig. 3, No. 3-4) including alternating changes between plyometric exercises and short EMS pulses (electromyo-stimulation). ^{31}P-MRS measurements were performed in supine position in a 3 T whole body scanner (Magnetom TIM Trio, Siemens Medical Solutions, Erlangen) using a double tuned ^{1}H/^{31}P-surface coil (Biomedical Rapid GmbH, Würzburg, Germany; diameter: 80 mm). The coil was fixed on the leg by elastic Velcro stripes at two positions underneath the muscle (underneath the medial and the lateral part of the M. gastrocnemius, as illustrated in Fig. 1 and 2). The coil position at the muscle was marked to ensure identical positions for both measurements. An FID-sequence (TR=5 s, NEX =128) without gradient mediated volume selection was used for spectroscopic measurement in both positions. Prior to spectroscopy, T_1-weighted MR images were acquired to select the sensitivity range of the coil for the shimming volume. Postprocessing and quantification of peak areas were performed using the software package MRUI (http://www.mrui.uab.es). ATP was quantified as the total peak area of β-ATP. Saturation effects were corrected by comparison of spectra with TR=5 s (with) and TR=25 s (without saturation).

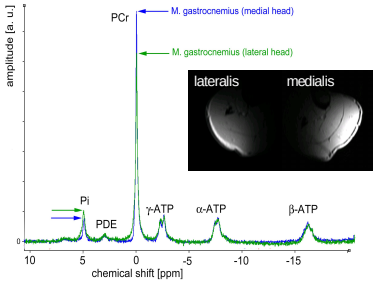

Fig. 2: *^{31}P-MR spectra of the medial (blue) and lateral (green) M. gastrocnemius and transverse T_1-weighted images to illustrate the position of the coil sensitivity range for both positions. Spectra are normalized by the ATP signal intensity. The spectrum of the medial muscle shows higher PCr and lower Pi intensities.*

Results

PCr/ATP ratios are presented as bar graphs in Fig. 3 for all subjects and both muscles before and after the special training. Generally higher ratios were observed in the medial head (*blue*) compared to the lateral head of the muscle (*green*). Comparing spectra before (*blue*) and after training (*blue striped*) in the medial head decreased (or unchanged) ratios were observed in all subjects. The decrease, however, was more pronounced for subjects without EMS (No.1-2), with the exception of No. 3. The spectra of the medial head of No. 3 before and after training are plotted in Fig. 4 to illustrate the intensity changes. In the lateral head no changes were observed. The reproducibility was investigated by 5 repeated measurements of the same subject (not included in the trainings experiment) and differences between the PCr/ATP ratios were below 10%.

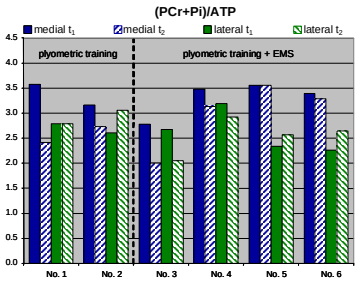

Fig. 3: *(PCr+Pi)/ATP ratio of the M. gastrocnemius (medial and lateral head) prior (t_1) and after (t_2) a four-week training of six test subjects (No. 1-6).*

Conclusions

Higher (PCr+Pi)/ATP ratios indicate a higher content of type II fibers [3]. The range of the fiber distribution of different human skeletal muscles is known from autopsy [4]. Commonly, both parts of the M. gastrocnemius have nearly equal contents of type I and II fibers, whereas the M. soleus is predominantly composed by type I fibers. Therefore, the higher values estimated for the medial head compared to the lateral head of the M. gastrocnemius are caused either by changes of the fiber distribution due to sportive specialization or by different partial volume effects due to the M. soleus. However, partial volume effects should be equal due to the identical coil positions on the muscle before and after the training. In all subjects training resulted in a more or less distinct decrease of the (PCr+Pi)/ATP ratio in the medial head. Based on experimental evidence it is commonly assumed, that resistance as well as endurance stimuli may ultimately cause conversions within the fast fiber population from type IIB to type IIA if these stimuli are sufficiently long and/or intense [5, 6]. As the medial head of the M. gastrocnemius is mainly stressed during the training, changes of the fiber distribution from type IIB to type IIA should be expected for the medial head rather than for the lateral head. Despite the variance of the estimated (PCr+Pi)/ATP ratios in the medial head before the training, the decrease after the training seems to be more pronounced for subjects without EMS. This may be explained by a less specific activation pattern with EMS compared to voluntary actions including more type II fibers during activation. Although the results of No. 3 contradict this interpretation, a comparison of the performance of the other participants before and after the training reveals the exceptional nature of this volunteer, indicating that additional factors affect his results. Although this study is preliminary due to the small number of volunteers, the results are encouraging that ^{31}P-MRS can be useful to monitor and evaluate trainings effects in professional sports.

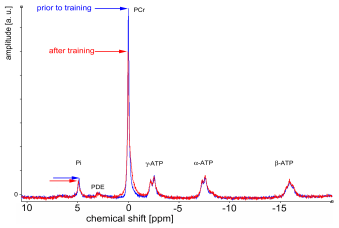

Fig. 4: *^{31}P-MR spectra of the M. gastrocnemius (medial head) prior (blue) and after (green) a four-week training. Spectra are normalized by the ATP signal intensity. The intensity of the PCr signal is clearly decreased after training.*

References

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