"Real-Time" Detection of Intramyocellular Lipids (IMCL) During Exercise by Means of 1H-MRS

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Introduction: Intramyocellular lipids (IMCL) play an important role as one of the major energy sources of skeletal muscle and are related to insulin sensitivity in diabetes patients. Despite extensive studies, there is still limited knowledge about the dynamics of IMCL consumption during exercise, since IMCL levels typically are measured before and after the workload. The goal of this work was to investigate the possibility of assessing IMCL directly even during exercise by means of in situ 1H-MRS.

Methods: Eight endurance trained (VO_{2max} = 60±6 ml/min·kg_{bw}), lean (BMI = 22±1 kg/m^2), young (35±6 years) male volunteers participated in a cross over study that compares the effects of a 3 hours continuous exercise session (CES) with an intermittent exercise session (IES) of 6×½ hour. Breaks during IES lasted 11 min 46 s ± 42 s while one MRS-measurement was done. Both exercise sessions (ES) consisted of treadmill-running. Running velocity was continuously adjusted such that the volunteers performed at a constant heart rate corresponding to an oxygen uptake of 65% of VO_{2max}. Each ES was preceded by a three day run-in period where the volunteers were asked to stop their usual training, to omit any strenuous all-day activities and to change their eating habits such that they increased their usual fat intake by 2g/kg_{bw} per day. Food uptake and physical exercise were recorded in a diary and exactly repeated before the second ES. For logistical reasons, all volunteers started with the CES while the IES was performed 16±9 days after the CES (minimal gap was 6 days).

^{1}H-MRS: IMCL were determined with a single voxel (11×12×18mm^3) PRESS sequence (TR=3s, TE=20ms, 128 acquisitions). The voxel was placed in the tibialis anterior muscle. For all MRS-examinations the volunteers were placed on a specially designed mount that guaranteed a reproducible placement of the right calf within the coil as well as relative to the external magnetic field. Preliminary testing has shown an accuracy of about 1mm in all spatial directions. Shimming, adjustments of pulse power and water suppression were performed at the initial MRS-sessions and at the recovery-measurement 40±5 minutes after the ES. Spectra during IES and at the end of IES and CES were recorded without any adjustments, however additional reference scans were added to correct for improper pulse power settings during post-processing. Spectra were fitted with TDFDFIT [1] and quantified using the fully relaxed water signal as internal concentration standard.

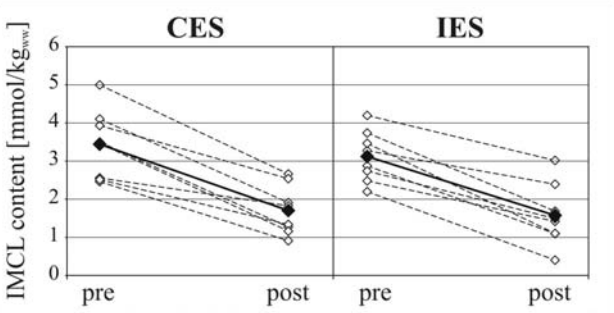

Figure 1: *IMCL levels of all eight volunteers determined prior and after either 3 hours continuous (CES) or intermittent (IES) exercise. The filled symbols together with the solid line represent average values.*

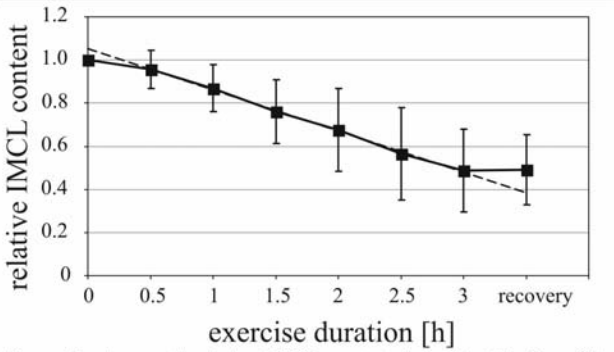

Figure 2: *Averaged relative IMCL content determined before (0h), during (0.5 - 3h) and 40±5 minutes after exercise (recovery). IMCL contents were normalized to the individual starting value. The dashed line represents a linear trend line fitted to the values between 0.5h and 3h.*

Results: Neither the daily average energy uptake (17618±2609 kJ vs. 17629±2645 kJ; CES vs. IES) during the three days nor one of the components (carbohydrates 46±8% vs. 45±10%, fat 45±11% vs. 46±11%, proteins 10±2% vs. 11±1%), or the daily intake of fat (2.9±0.5g/kg_{bw} vs. 2.9±0.5g/kg_{bw}) showed a statistical difference between the two run-in periods. The volunteers performed identically in both ES (7.7±1.3km vs. 7.9±1.3km) at the targeted heart rate of 137±12 beats/min (138±11 vs. 136±12).

As shown in Fig. 1, the preparation period led to statistically similar IMCL levels (3.44±0.90 mmol/kg_{ww} vs. 3.13±0.68 mmol/kg_{ww}) and IMCL levels decreased similarly by 50±14% during CES and 51±19% during IES, respectively. The decrease of IMCL during both ES was highly significant ($p<0.01$).

Fig. 2 shows the temporal development of the mean IMCL concentration during 3 hours IES. The dashed line indicates that, except for the initial 30 min, IMCL levels decreased constantly until the end of exercise (3h). An average of 5.1±14.5% of the initial IMCL content was consumed during the initial 30 min whereas 19±3% was used in subsequent bouts. The decrease reached statistical significance ($p<0.05$) for all periods except the first bout.

During 40 min of recovery (intake of water only), IMCL levels remained constant for IES (Fig.2) as well as for CES (1.70±0.65 mmol/kg_{ww} immediately after exercise vs. 1.67±0.68 mmol/kg_{ww} after 40 min of recovery).

Discussion: The results show that the preparation of the volunteers was identical for IES and for CES, and it can be assumed that the IMCL storages were optimally filled. The data support an identical usage of IMCL during both types of exercise. This could be questioned with the argument that a higher IMCL consumption during CES was compensated by an additional decrease during the 12 minutes breaks for MRS-measurements. However, the recovery measurement after cessation of exercise (see Fig.2) shows that IMCL levels remain constant during the first 40 minutes after exercise. It can be concluded that short breaks of 12 min do not influence IMCL consumption during exercise despite the fact that the metabolism needs a certain amount of time at the beginning of IES to fully develop. In addition, it seems that the lower decrease during the initial 30 minutes is not repeated after every break of 12 minutes since this would lead to reduced IMCL usage and therefore to a significant difference between IES and CES.

Conclusions: 1) These results show that short interruptions of 12 minutes do not significantly influence IMCL consumption during a 3 hour exercise of moderate intensity. 2) The proposed method can be used to asses the IMCL levels non-invasively by means of ^{1}H-MRS to provide information about the dynamics of IMCL consumption during exercise. 3) It is demonstrated that IMCL consumption stays at a constant rate for at least 2½ hours after an initial run-in phase and that it ceases immediately after exercise.

References: [1] Slotboom J et al. Magn Reson Med 1998;**39**:899-911

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