Reproducibility of dynamic phosphorus MRS of plantar flexion: Influence of ergometer design, magnetic field strength, and RF-coil design

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Target audience: Physicians and physicists interested in large multi-centric studies on oxidative muscle metabolism

Introduction: Dynamic phosphorus MR spectroscopy (^{31}P MRS) during exercise allows non-invasive determination of mitochondrial capacity of the skeletal muscle *in vivo*. Although this method is used in many institutions for a wide range of applications, the published data in healthy volunteers often differ between research sites[1,2]. This discrepancy is most usually attributed to different subject pool. However, different study equipment used (e.g., the ergometer, the radiofrequency [RF]-coil, and the magnetic field strength) can also play an important role and has to be considered.

The aim of this bi-centric study was therefore to assess the impact of the used ergometer, RF-coil and different field strength on the metabolic parameters measured by dynamic ^{31}P MRS.

Materials&Methods: Eleven healthy subjects (3f/8m, age 36±13y) were recruited for this study. ^{31}P-MRS acquisition was performed on three MR systems from the same manufacturer (Siemens Healthcare, Erlangen, Germany) equipped with dual channel ^{1}H/^{31}P surface coils (Rapid Biomedical, Rimpar, Germany) in two research laboratories (RLs). Details on the experimental equipment used are given in Table 1. The subjects were examined in a supine position with the RF-coil fixed to the gastrocnemius muscle. The dynamic examination (2 min rest – 6 min exercise – 6 min recovery) with the plantar flexion performed once every TR (2s) was carried out two times with different, fixed workloads (~15%, and ~25% of maximal voluntary contraction force [MVC]; with at least 15 minutes break in-between to ensure metabolic recovery[4]). The surface coil sensitivity volume was used for signal localization. The measurement parameters were almost identical for all three MR systems (rectangular 400μs excitation pulse, TE*=0.4ms, FA=42° for 3T and 48° for 7T). The phosphocreatine (PCr) concentration, PCr depletion, PCr recovery rate time constant τ_{PCr}, and maximal oxidative flux Q_{max} were calculated and compared between RLs (different ergometers and RF-coils at 3T) as well as between 3T & 7T in RL2 by a Bland&Altman analysis of agreement[5]. To evaluate the repeatability of the experiments, five volunteers underwent test-retest measurements in every setup at both workloads. The repeatability of the τ_{PCr} and Q_{max} determination, in particular, was assessed by a mean coefficient of variation (CV).

Table 1. Details about the used experimental equipment

	RL1	RL2	
MR system	3T (Trio)	3T (Trio)	7T (Magnetom)
RF-coil	flexi, Ø11cm	rigid, Ø10cm	rigid, Ø10cm
Ergometer	Home-built[3]	Trispect (Ergospect, Innsbruck, Austria)	

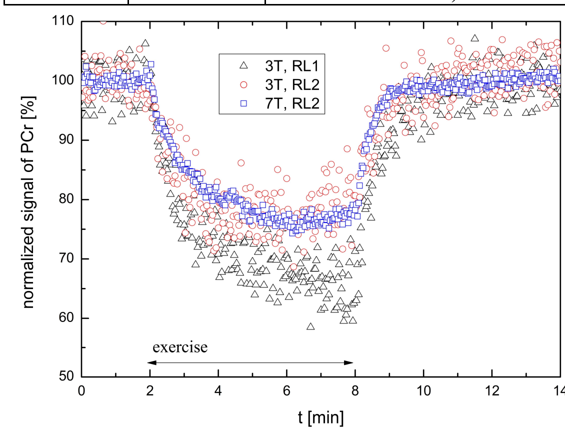

Figure 1. Time courses of the normalized PCr signal, from dynamic ^{31}P-MRS measurements, with a workload of 25% MVC.

Results&Discussion: The test-retest CV of the τ_{PCr} measurement was in all setups under 10% and of the Q_{max} under 13.5%. At the 25% MVC workload was the repeatability even higher, what is in agreement with previously published reports[6]. Representative time courses of the PCr signal intensity for all of the used set-ups are depicted in Figure 1. The data quality was significantly increased at 7T, but the agreement between metabolic parameters measured at 3T and 7T using the same ergometer and similar RF-coil in RL2 was high (i.e., results not affected). However, when comparing the measurements at 3T systems in two RLs equipped with different ergometers and RF-coils, several discrepancies occurred. The values of PCr concentration and depletion were both found higher in the RL1. The first was probably caused by the difference in sensitivity volume of the used RF-coils (11 cm vs. 10 cm in diameter) and the latter by the more concentric contraction necessary to perform plantar flexion using the ergometer in RL1. The agreement between the measurements in RL1 and RL2 improved when the higher workload of 25% MVC was applied (Figure 2).

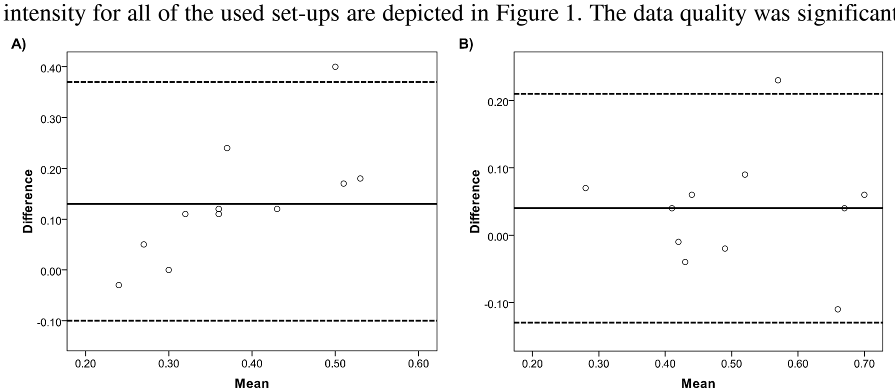

Figure 2. Plots of agreement between measurements of Qmax at 3T in RL1 and RL2. A) at 15% MVC and B) at 25% MVC workload. Note that at higher workload in comparison to lower workload is the bias closer to zero (0.04 vs. 0.13) and the range of agreement is narrower (-0.13–0.23 vs. -0.1–0.37)

Conclusion: We have shown that the measurements of oxidative metabolism, although repeatable in different setups, depend on the used experimental equipment (i.e. ergometer, RF-coil). Furthermore, we have found that this influence tends to decrease with increased workload.

References:

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