A gated ^{31}P-NMR protocol for estimation of contractile ATP cost and PCr recovery time without strenuous exercise.

J. M. Slade[1], T. F. Towse[1], R. W. Wiseman[1], M. C. DeLano[2], R. A. Meyer[1]

[1]Physiology, Michigan State University, East Lansing, Michigan, United States, [2]Radiology, Michigan State University, East Lansing, Michigan, United States

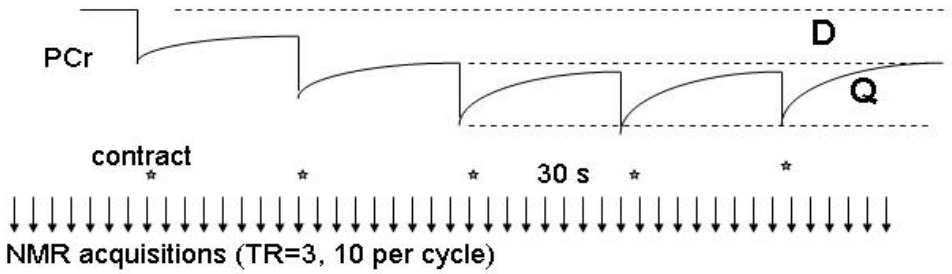
Introduction

^{31}P-NMR is increasingly used to estimate skeletal muscle contractile cost (ATP used per s) and an index of muscle aerobic capacity (time constant for phosphocreatine [PCr] recovery) from PCr and pH changes during and after repetitive exercise (e.g. ref 1). This requires fairly intense exercise (to deplete PCr) and good spectral S/N and time resolution (to measure PCr recovery). In this study we show that ATP cost and PCr recovery time constant can be estimated from a gated protocol, in which subjects contract only briefly at 30 s intervals, and spectra are continuously acquired for as long as needed to obtain the desired S/N.

Methods

Nine adult subjects (21-53 yrs old) performed two ankle dorsiflexion exercise protocols. In the first, gated protocal (Fig. 1), subjects performed 2 s duration, maximum contractions at 30 s intervals for 8 min (total 15 contractions), while ^{31}P spectra (51.7 MHz, 2500 Hz sweep, 1024 points, 1 NEX, TR 3 s) were continuously acquired via an 8x5 cm surface coil placed on the anterior tibial muscle. Retrospective adding of FID's acquired every 30 s after the fifth contraction yields 10 spectra (each 10 scans) gated to the contractions (Fig. 2). The drop in PCr after contraction (Q in Fig. 1) directly yields the ATP cost, while the steady-state PCr change from rest (D) yields the monoexponential PCr recovery time constant (τ) from $\tau = -\Delta t / \ln(D/[D+Q])$, where Δt is the interval between contractions. In the second, repetitive protocol, the subjects performed 1 s contractions at 0.5 Hz for 30 s. FID's were added in 15 s blocks, and PCr recovery time constant was estimated by monoexponential fit to PCr from 15 s to 240 s after the exercise.

FIG 1: Gated 31P-NMR exercise protocol



Results and Discussion

In the gated study, the PCr/ATP ratio at rest was 4.02±0.12 (SE), and the drop in PCr due to contraction (Q) was 14.7±2.5 %. Assuming 8.2 mM ATP, this corresponds to contractile ATP cost of 2.37±0.37 mM/s, which agrees well with previous studies (e.g., ref 2). PCr τ computed from Q and D (11.4±1.6 %) was 38.8±4.1 s, and PCr τ measured after the repetitive exercise was 41.5±4.5 s (correlation in Fig. 3). There was no significant change in pH during the gated protocol, whereas pH dropped from 7.00±0.01 to 6.81±0.05 during the repetitive protocol. Thus, the gated protocol allows estimation of muscle ATP cost and PCr recovery without strenuous exercise or muscle acidification, and is well-suited for studies of patients with cardiovascular or muscle diseases.

References:

1) Conley, KE, et al, Med Sci Sports Exerc. 34:1719, 2002.

2) Russ, DW, et al, AJP: Endo 282:E448, 2002.

FIGURE 2

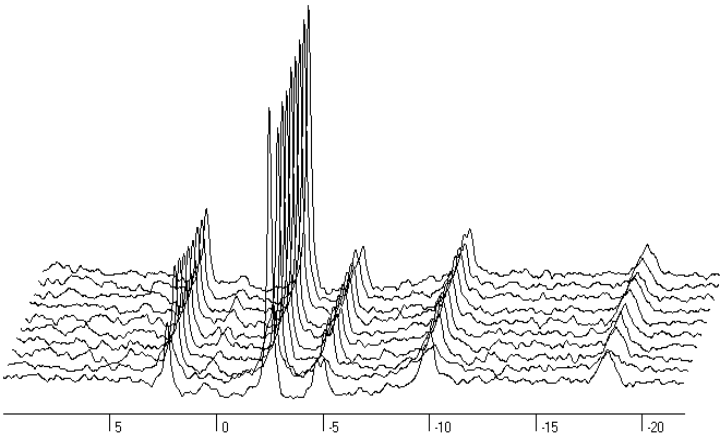


FIGURE 3