Comparative analysis of calf muscle metabolism in children and adults: a 31P MRS study

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Introduction

When applying muscular Phosphorous Magnetic Resonance Spectroscopy (31P MRS) in children, developmental variations of muscle metabolism need to be taken into account. Previous studies have reported a greater resistance to fatigue in children [1], but 31P MRS studies have shown controversial results [2-5] probably owing to the dependence of 31PMRS data on a large number of variables. The aim of this study was to compare 31P MRS data obtained in the calf muscle of a sample of children with those obtained in adults at rest, at the end of a short-term isometric intermittent incremental exercise normalized to the Maximum Voluntary Contraction (MVC) and during the recovery from the effort. The evaluation of difference in pH and PCr values at the end of exercise and in the measurement of the PCr resynthesis rate during recovery could be the indices of developmental differences in the muscle metabolism.

Materials and methods

31P MR spectra of 4 children (2 boys and 2 girls with mean age 11.6 years and range 10.0-12.9) were compared with those obtained in 8 adults (4 men and 4 women with mean age 29 years, range 21-37). Data were acquired using a 1.5 T MR system (LX Signa Horizon 1.5 GE Healthcare, Milwaukee, WI, USA) operating at 25.86 MHz, with a transmit/receive spectroscopy coil centred in the middle of the gastrocnemius. A short TE slice selective spin echo sequence (8 cm slab) was used both for the spectrum at rest and for the data set sampled during the exercise-recovery protocol (Repetition Time TR of 4 sec, flip angle FA of 60°, phase cycling 180°, 2 NEX, 128 signals, acquisition time of about 8 min, spectral width of 2500 Hz, 2048 complex data points). All subjects performed a foot plantar flexor exercise using a MR compatible ergometer [6] that permits to register the flexion amplitude and to calculate the work spent from the calf in each exercise beat. The exercise beat was performed at a frequency of 0,75Hz with an isometric intermittent incremental workload starting from 20% of the MVC and gradually increased by 10% every 30 seconds until the 60% or the 70%. The MVC was measured before the examination through a conventional myometer.

Signals were processed using jMRUI and quantified in the time-domain by AMARES. For the data at rest, the relative concentration of Phosphocreatine (PCr), inorganic Phosphate (Pi), Phosphodiesters (PDE) and Phosphomonoesters (PME), were computed using the ATP signal as internal reference (supposed at a concentration of 8.2 mM). The 64 couples of signals acquired during the exercise-recovery protocol were analyzed individually and the relative changes in the amplitude of the Pi and PCr were evaluated.

The pH was calculated by the tritation curve: $pH=6.75+\log_{10}[(3.27-\delta_{Pi\text{-}PCr})/(\delta_{Pi\text{-}PCr}-5.69)]$ were $\delta_{Pi\text{-}PCr}$ is the relative chemical shift of Pi and PCr.

The PCr recovery was fitted through the mono-exponential function $PCr(t) = PCr_{end\text{-}ex} + (PCr_{\infty}-PCr_{end\text{-}ex})(1-e^{-t/\tau})$ where $PCr_{end\text{-}ex}$ and PCr_{∞} respectively are the PCr level at the end of the exercise and of the recovery and τ is the time constant of the function.

The initial rate of recovery V(mM/min) was calculated from the expression $V=PCr_{rest}[mM]\ (1 - PCr_{end\text{-}ex}/PCr_{\infty})/\tau(min)$, assuming a PCr concentration at the end of the recovery equal to that measured at rest.

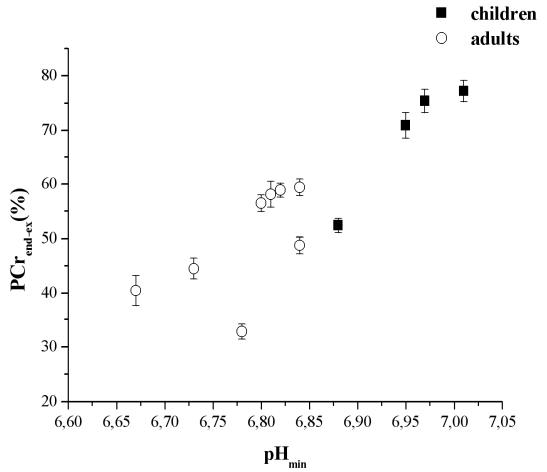
Results

Resting muscle: No differences were found between children and adults in the basal concentrations of PCr, Pi, PDE, PME and in cytosolic pH.

End of Exercise: As reported in Table significant differences between children and adults were found in the mean values of the variables characterising the end of exercise: the pH level at the end of exercise, $pH_{end\text{-}ex}$; the minimum pH reached during recovery, pH_{min} ; the PCr concentration at the end of the exercise, $PCr_{end\text{-}ex}[mM]$ and the percentage end-exercise PCr level relative to rest value, $PCr_{end\text{-}ex}$ (%). Moreover as reported in Figure the same linear behaviour between the end of exercise PCr and the minimum pH has been observed in children and adults, but with children data clustered at the higher values of the plot variables. The child (a girl,12.9 years old) with values closer to the adult group has already reached puberty.

	Subjects	$pH_{end\text{-}ex}$*	pH_{min}*	$PCr_{end\text{-}ex}$[mM]*	$PCr_{end\text{-}ex}$ (%)*	τ (sec)	V(mM/min)
Children	4	7.02±0.08	6.95±0.05	21±2	69±11	26±14	25±11
Adults	8	6.89±0.06	6.79±0.06	15±4	50±10	32±8	29±6
P (two samples t-test)		0.013	0.001	0.033	0.014	0.35	0.41

Recovery from exercise: The PCr recovery analysis showed in the children a slightly even if not significant reduction both of the time constant τ and of the initial rate of recovery V (Table).



Discussion

Even though the exercise normalization is a critical point in muscular 31P MRS, the significant reduction of PCr consumption at the end of the exercise combined with a significant higher pH could be the expression of a greater resistance to fatigue in children than in adults for an exercise of comparable intensity. This preliminary result is in agreement with biochemical data and previous 31P MRS studies [1-4]. Different findings with respect to previous studies [5] could be explained with different kind of exercises and different investigated muscular districts.

Even if not significant, the reduction both of the time constant τ and of the initial rate of recovery V could be relevant if proved in a larger sample of children. The observed reduction of τ could be due to the influence of a difference in $pH_{end\text{-}ex}$ at the end of exercise, whilst, given the V end-of-exercise-pH independence [7], the reduction of V could be related to a greater oxidative activity in children as previously reported [1,3,5].

References

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