Energy metabolism in the extensor muscles of the hand and wrist of musicians with overuse syndrome studied by 31P-MRS

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Background: Overuse syndrome of the upper-extremity is one of the most prevalent medical problems among musicians. It is believed to result from overuse or misuse of the affected parts in the repetitive movements of playing. The muscles are primarily affected and the predominant symptoms are pain, tenderness and swelling during and after playing (1). As a result, there is an impairment of musical performance that may severely disable musicians from practising or performing. As biopsy might risk breaking the neuromuscular balance and thus worsen the symptoms, there have been few studies on structural and biochemical changes in musicians and the nature of the pathology remains obscure. Accordingly, the aim of the present work was to study the muscle energy metabolism in patients with overuse by means of non-invasive ^{31}P-MRS in order to gain further insight into possible alterations underlying the syndrome.

Methods: Nineteen musician volunteers were included in the study: 8 controls and 11 subjets with overuse. Groups were comparable on forearm anthropometry, age and sex composition. The musical instruments played were mainly piano and guitar. Studies were carried out using a 1.5 T Signa system (Signa Advantage, General Electric Medical Systems, Milwaukee, WI, USA). Subjects were placed in the magnet in a prone position, head first with their forearm centered. For all subjects, both dominant and nondominant arms were studied. ^{31}P spectra were obtained by using a pretuned elliptical transmitter and receiver surface coil (14.5 x 6.5 cm). The coil was fixed on the dorsal surface of the forearm over the hand and wrist extrinsic extensor musculature. Spectra were recorded using a one-pulse sequence with a 180° pulse at the center of the coil. A total of 1024 data points were collected over a spectral width of 2500 Hz. After 4 dummy scans, data acquisition was performed at rest (32 scans) and during exercise continuously in blocks of 8 scans with a scan repetition time of 2 s. The total acquisition times ranged from 1.5 to 19.5 minutes. Quantification of the signals was performed in the time-domain in blocks of 32 scans for adequate signal-to-noise ratio. AMARES (2), as included in the MRUI software package (3), was used to fit the PCr, Pi and the ATP resonances. Intracellular pH was calculated from the chemical shift of Pi relative to PCr (4). The exercise consisted of low-intensity rhythmic finger extension-contraction (30 cicles/min) performed with a home-built ergometer. The device forced the fingers closed over the palm by means of elastic bands and muscular work had to be performed to overcome the elastic resistance. Contraction was also active resulting in an eccentric exercise. The exercise was continued until the subject could no longer sustain due to pain or exhaustion, or after 1000 seconds without signs of fatigue. Student's t-test was used to assess the statistical significance of the results.

Results: Exercise duration was significantly reduced in subjects with overuse compared to controls. As expected, PCr decreased and Pi increased in the spectra of extensor muscles during the exercise. However, two different patterns of phosphate metabolites were observed (Figures 1,2). Pattern A (19 forearms) showed a single peak of Pi and the intracellular pH did not change significantly throughout the exercise and remained within the neutral range. By contrast, in pattern B shortly after the onset of exercise (97 ± 31 s, n = 19 forearms) another Pi peak appeared from the original Pi peak at a more acidic pH (pH 6.54 ± 0.17). Thereafter, the Pi peak splitting became obvious. The pH value of the high-pH Pi peak followed a similar time course to Pattern A, while pH of the low-pH Pi peak further decreased down to 6.35 ± 0.11 (17/19 forearms). Pattern A was mainly present in control subjects and Pattern B in patients (Table 1). Pi/PCr ratio values reached a steady-state during exercise in all 16 forearms of control subjects and in 3 forearms of subjects with overuse and without Pi peak splitting (in 3 other forearms exercise was too short to reach steady-state). Instead, extensor muscles of subjects with overuse and Pi peak splitting showed mostly an incapacity to reach such steady-state with Pi/PCr ratio values that increased until the end of the exercise (11/16 forearms). Moreover, the Pi/PCR ratio was on average approximately twofold higher in subjects showing Pi peak splitting compared with subjects who did not. (0.67 ± 0.23, n=19 vs 0.35 ± 0.09, n=19, p<0.001).

Conclusion: Pattern A, present mostly in control subjects, with single Pi peak, little acidification, low and steady-state Pi/PCr values, suggests that most of the work output in such subjects was generated by oxidative metabolism (5). The splitting of the Pi peak observed in Pattern B, mostly associated to the overuse condition, has been demonstrated in other situations to reflect the metabolic differences between oxidative (high-pH Pi peak) and glycolitic (low-pH Pi peak) fibres on human skeletal muscle (6). Upon this assumption, the present results would indicate that in patients there is a primary recruitment of glycolitic fibers, possibly consistent with a failure of oxidative metabolism to meet energy needs through the exercise. Such failure might well be the result of a number of factors including decrease in the relative ratio of oxidative/glycolitic fibres, reduction in muscle blood flow or diminished muscle oxidative capacity. In conclusion, the extensor muscles in overuse patients showed a different metabolic response to exercise compared to control subjects, which would suggest a greater reliance on glycolitic sources of energy and diminished oxidative performance. Further work and analysis is needed to assess the causes and extent of the affectation and its relationship with the clinical manifestations.

References: 1.Fry HJH. Med J Aust. 144:182-183, 1986. 2. Vanhamme, L et al. J Magn Reson. 129: 35-43, 1997. 3. Naressi A et al. MAGMA 12: 141-152, 2001. 4. Moon RB and Richards JH. J Biol Chem 248: 7276–7278, 1973. 5. Chance B et al. Proc Natl Acad Sci USA. 82: 8384-8388, 1985. 6. Mizuno M et al. Am J Physiol. 267: R408-414, 1994. **Acknowledgements:** The MRUI software package was kindly provided by the participants of the EU Network programmes: Human Capital and Mobility, CHRX-CT94-0432 and Training and Mobility of Researchers, ERB-FMRX-CT970160.

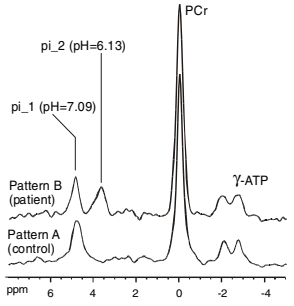

Figure 1. Spectra from time 384-448 s after the onset of the exercise

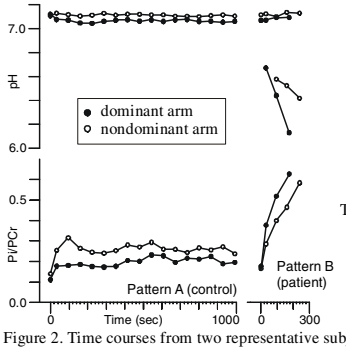

Figure 2. Time courses from two representative subjects

	subjects			forearms
Pi splitting:	yes		no	yes/total
	unilateral	bilateral		
controls	3	-	5	3/16
patients	2	7	2	16/22

Table 1. Ocurrence of Pi splitting in the studied population