M. Quadriceps femoris of Man,
a Muscle with an Unusual Enzyme Activity Pattern
of Energy Supplying Metabolism in Mammals

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Summary. 1. The following enzyme activities were estimated in needle-biopsy
samples of the lateral part of the human quadriceps femoris muscle: triosephosphate
dehydrogenase (TPDH), lactate dehydrogenase (LDH), NAD: glycerol-3-phosphate
dehydrogenase (GPDH), hexokinase (HK), NAD: malate dehydrogenase (MDH),
citrate synthase (CS) and hydroxyacyl-CoA dehydrogenase.

2. Although the enzyme activities in muscles of women were lesser than in
those of men, no difference was found in the calculated enzyme activity ratios.
There is thus no sex-dependent metabolic type-differentiation in this muscle.

3. The human quadriceps femoris is a low-activity muscle, in comparison with
muscles of homiotherm laboratory animals. The enzyme activity ratio of TPDH
to CS, characterizing the glycolytic pyruvate formation to aerobic oxidative capa-
cities, shows this muscle to be of an intermediate type in this respect, similarly as
the extensor digitorum longus of the rat. The relatively very high capacity of glucose
phosphorylation (HK), the high aerobic regeneration of cytoplasmic dehydroge-
nated NAD (GPDH) and the very low anaerobic regeneration (LDH), show the
unusually high proportion of carbohydrates (glucose) which can be broken down aerobically.

Key words: Muscle — Human Enzyme Pattern — Energy Supply — Sex Dif-
ferences.

Although the energy supplying metabolism is in general outline
rather uniform in tissues of higher animals, a quantitative differentiation
of enzyme activities, representing different metabolic pathways (with
accentuation, for example of anaerobic glycolysis or aerobic oxidation) is
well known especially in various types of muscles. (see Dubowitz an
Pearse, 1960; Ogata, 1960; Zebe, 1960; Pette and Bücher, 1963; Amber-
and 1969; Bass et al., 1969; etc). There is, however, also a relationship
between the activities of individual enzymes, as that of the ubiquitous
“constant proportion groups” (Pette and Bücker, 1963; Pette, 1971), or
in groups confined to a limited group of tissues. For example the relation
of hexokinase to citrate synthase activities in muscles of higher animals kept under normal (non-experimental) conditions, or that of triosephosphate to lactate activities in skeletal muscles of higher animals (Bass et al., 1969; Staudte and Pette, 1971). A deviation of this pattern is therefore of interest, especially since this pattern has been studied in some detail in animals, but very little in man. Studies on human muscles were performed mostly for clinical purposes, often with very small reference groups of healthy controls (Kleine and Chlond, 1967; Mertens et al., 1969; Hofer et al., 1971; Nolte et al., 1972).

**Methods**

The investigations were performed on muscles biopsy samples of 16 healthy lean subjects, 10 women and 6 men.

Tissue samples of the lateral part of the quadriceps femoris weighing 15 to 30 mg, were obtained with the aid of a biopsy needle according to Vondra et al. (1974), under local anaesthesia of the skin and subcutaneous tissues. The samples were freed, whenever necessary, from adhering fat under visual control. Parallel controls under a light microscope showed no apparent contamination with adipose tissue. The samples were weighed immediately and transferred into small glass-teflon homogenizers containing 0.2 ml of phosphate buffer solution (50 mM K-Na phosphate, 5 mM EDTA, 0.1% Triton X 100, pH 7.25). The volume was then made up to 20 times (v/w) that of the sample, homogenized in a glass-teflon homogenizer under cooling and centrifuged at 15000 g for 10 min at 0--4°C in a cooled centrifuge. Homogenization of the sediment and centrifugation was then repeated in the same amount of buffer, the supernatants were pooled and used for enzyme activity determinations. The final volume was 40 times that of sample weight.

The aditivity of the following enzymes were estimated: hexokinase (HK) — ATP: D-hexose-6-phosphotransferase (EC 2.7.1.1.), of cytoplasmic glycerol-3-phosphate dehydrogenase (c-GPDH) — L-glycerol-3-phosphate: NAD oxidoreductase, of triosephosphate dehydrogenase (TPDH) — D-glyceraldehyde-3-phosphate: NAD oxidoreductase (phosphorylating) (EC 1.2.1.12), of lactate dehydrogenase (LDH) — L-lactate: NAD oxidoreductase (EC 1.1.1.27), of citrate synthase (CS) — citrate oxaloacetate lyase (CoA acetylating) (EC 4.1.3.7), of malate: NAD dehydrogenase (MDH) — L-malate: NAD oxidoreductase (EC 1.1.1.37) and of hydroxyacyl-CoA dehydrogenase (HOADH) — L-3-hydroxyacyl-CoA: NAD oxidoreductase (EC 1.1.1.35).

The enzyme activities were estimated according to the methods of Büchler et al. (1964), Stern et al. (1951) (CS) and Wakil (1955) (HOADH), using an Eppendorf registrating photometer at 25°C. The enzyme activities were expressed as international units per gram wet weight of tissue sample. The dimensionless enzyme activity ratios are used for comparative purposes only.

Statistical evaluation of differences was performed by non-parametric tests of Wilcoxon, or Mann and Whitney, and also by Student’s t-test.

**Results and Discussion**

In Tables 1 and 2 a list of activities are given of the enzymes investigated in the human quadriceps femoris muscle, the human tibialis anterior muscle (from Nolte et al., 1972) and some other homiotherm muscles of interest for comparative reasons (Pette and Büchler, 1963; Bass et al., 1969; Bass, unpublished results).