Serum Glycoprotein Levels in Athletes in Training[1]

It was previously reported that athletes, examined at rest after several days of physical training, have a significantly higher level of the serum total protein-bound hexoses than healthy non-athletes or athletes after 2–4 days of interruption of their training program[2–6]. The protein-bound hexose values are still significantly higher if only subjects of the 'training' group with up to 20% γ-globulins in the electrophoretic pattern are taken into consideration. Further investigations in long-distance cyclists in training showed a significantly higher level – as compared to normal subjects – of the following individual glycoproteins: transferrin and α_2-macroglobulin[5], α_1-acid glycoprotein[7] and ceruloplasmin[8].

It seemed of interest to check these latter observations in subjects engaged in other sports than cycling, as well as to extend the investigations to other serum glycoproteins in the conditions mentioned above.

2 groups of apparently healthy, young adult males were investigated: The 'control' group was formed of medical students, most of them physically active, examined after 3–4 days without noticeable physical strain. Only subjects with a normal electrophoretic pattern (i.e. α_2-globulins up to 9% and γ-globulins less than 20%) were taken into consideration.

The group of 'athletes in training' consisted of runners, rowers, boxers and skiers, members of the West German national teams, aged 18–30. They were examined after 3–5 days of intense physical activity (either 90 min daily, or 60 min twice a day). Only subjects having had no recent athletic injury or illness were selected. The mean level of the immunologically estimated serum γ-G globulin in this group was 1060 ± 120 mg/100 ml, which is to be considered as normal.

Serum copper was determined with the sulphonated bathocuproin procedure[9]; protein-bound hexoses with the sulfuric acid-boric acid-tryptophan method[3]. The glycoproteins ceruloplasmin, α_2-macroglobulin transferrin, α_1-antitrypsin and α_2-HS glycoprotein were determined with the single radial immunodiffusion procedure, on Partigen-Plates (Behringwerke, Marburg/Lahn). The Table summarizes the results obtained in both groups.

The level of the total protein-bound hexoses is comparable to the values previously reported for athletes in training[2–6] and significantly different from the normal value (110–120 mg/100 ml). Values of the individual glycoproteins in the control group agree well with earlier published data from this laboratory[5,8,10]. The significantly higher level of α_2-macroglobulin, ceruloplasmin and transferrin is comparable to similar observations in long-distance cyclists. Like ceruloplasmin, serum copper is also elevated in athletes, but the ratio copper to ceruloplasmin is not significantly altered. Higher values of α_2-HS glycoprotein and α_1-antitrypsin in athletes are for the first time reported in this paper.

It could be assumed that athletes in training have a level of serum protein-bound hexoses 20–25 mg/100 ml higher than that of control subjects[3,5,6]. If the hexose content of the analysed glycoproteins is calculated from the data available in the literature[11–14], then about 7 mg hexoses/100 ml of the above-mentioned difference are accounted for by the higher level of the glycoproteins in the sera of athletes.

It was previously reported that the increased α_1-acid glycoprotein level also accounts for about 5 mg of protein-bound hexose/100 ml more in athletes in training[7]. Thus, the 6 determined glycoproteins could be responsible for somewhat more than the half of the 'plus' 20–25 mg bound-hexoses in athletes.

The biological significance of these findings is not yet clear. Several facts could nevertheless be discussed. The physiological functions of the α_2-HS glycoprotein are not known; besides, its elevated value in athletes needs more confirmation.

α_1-antitrypsin is known to behave as an inhibitor of several proteolytic enzymes[11], and it could be speculated whether its higher level controls a possible enhanced proteolytic activity in the serum after exercise. In fact, such an enhanced activity in athletes was found for the amino acid-arylpeptidases[15]. Experimental evidence is lacking concerning changes of other protein- and peptide-degradating enzymes in serum, in conditions of exercise.

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Serum glycoprotein and copper levels in control subjects and in athletes in training. The number of subjects is given in parentheses

mg/100 ml	Control group		Athletes		Significance of the difference (Students t-test)
Protein-bound hexoses	—		135 ± 7.1	(14)	—
α_1-antitrypsin	222 ± 31.4	(15)	275 ± 36.8	(12)	$p < 0.001$
α_2-HS-glycoprotein	50.5 ± 7	(19)	57.8 ± 5.35	(10)	$p < 0.01$
α_2-macroglobulin	214 ± 35.5	(11)	295 ± 39.3	(14)	$p < 0.001$
Transferrin	225 ± 27.8	(11)	263 ± 31.7	(14)	$p < 0.01$
Ceruloplasmin	31 ± 1.7	(10)	41 ± 4.6	(18)	$p < 0.001$
Copper µg/100 ml	92 ± 9.2	(16)	117 ± 6.4	(18)	$p < 0.001$

The rise of the α_2-macroglobulin level is also difficult to explain. This protein seems not to belong to the acute phase reactants[16,17] and the possibility of its extrahepatic synthesis has been suggested[18,19]. It is generally assumed that it has more than one biological function, but whether it participates in some manner to the recovery processes after exercise or not, remains unclear.

The possibility was previously discussed that the increase of serum transferrin after exercise and training, with the concomittant rise of plasma iron, is connected with the increased iron requirement for the biosynthesis of Fe-containing proteins in the exercised muscle[5]. OSAKI et al.[20], showed that ceruloplasmin, which has a ferroxidase activity, strongly enhances the incorporation of Fe^{II} into apotransferrin[21]. Animal experiments also showed that an elevation of only 10% of the initial ceruloplasmin level in the blood stream markedly increased the plasma iron values[22]. It can therefore be concluded that the higher level of both ceruloplasmin and transferrin in athletes serum is related to the increased turnover of iron after exercise. In this respect one could think of an increased loss of iron from the fatigued muscle, as well as of an enhanced iron uptake for the biosynthesis of iron-containing compounds. Data obtained in animals by YOSHIMURA et al.[23] seem to favour the latter possibility.

The present results particularly point to 2 facts: repeated, heavy physical exercise has a definite effect – maybe of a cumulative nature – on the level of several serum glycoproteins, very probably connected with the recovery processes after the exercise stress; in studies concerning the normal values of these glycoproteins in man, care should be taken as to the physical activity of the subjects on the days before examination.

Résumé. Les sportifs examinés au repos, après plusieurs jours consécutifs d'entraînement ou de compétitions ont un niveau nettement plus élevé que le groupe de contrôle pour l'α_1-antitrypsine, l'α_2-HS-glycoprotéine, l'α_2-macroglobuline, la transferrine, la céruloplasmine et le cuivre sériques. La signification biologique possible de ces faits est discutée.

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Catecholamine Biosynthesis in Vascular Tissue

Rates of noradrenaline (NA) biosynthesis in heart, spleen, vas deferens and brain are generally reported to lie within the range, 0.1–0.3 $\mu g/g/h$[1–3]. However, with the exception of a recent study[4] from this laboratory, in which pulmonary artery was used, there are no reports of NA biosynthesis in vascular tissue. Yet it is vascular NA biosynthesis that is presumably the target of tyrosine hydroxylase inhibitors now receiving increasing attention as potentially useful drugs in the treatment of human hypertension[5]. Lack of knowledge concerning vascular synthesis of NA and its regulation may underlie the unexpected ineffectiveness of one such inhibitor, α-methyl tyrosine, in essential hypertension[5]. As a preliminary to detailed study of the relationship of sympathetic transmission and NA biosynthesis in vascular tissue, we examined the conversion of the amino-acid precursor, tyrosine, to catecholamine in a variety of blood vessels of the rabbit. It was our goal to identify a vascular bed with a catecholamine biosynthesis rate sufficiently high to permit its use as a model in our future work.

Rabbits (1.5–2.5 kg) were killed by cervical fracture. Descending thoracic aorta, right femoral artery, main pulmonary artery, superior mesenteric artery and portal vein were rapidly removed, cleared of adherent non-vascular tissue as far as possible and incubated for 15, 30 or 60 min in a total of 2.5 ml of oxygenated Krebs medium (37 °C) containing $4 \times 10^{-5} M$ uniformly labelled tyrosine C^{14} (New England Nuclear Corporation; Final specific activity = 50 mc/mmole). After incubation, vascular segments were removed, blotted dry and immediately frozen on dry ice. They were then weighed and homogenized in 10% trichloro-acetic acid. After centrifugation of homogenates in the cold (4 °C) at 15,000 $\times$ *g* for 10 min, supernatant portions were decanted and either analyzed immediately or frozen for subsequent analysis of catecholamine-C^{14} and endogenous NA by methods described earlier[4]. In previous experiments[4] it was found that over 80% of the radioactive catecholamine was in fact NA. Initial experiments in the present study showed that the rate of tyrosine to NA conversion was not consistently linear if incubation was prolonged beyond 15 min. Accordingly all subsequent experiments involved only 15 min incubation periods. The Table documents the calculated catecholamine-C^{14} synthesis rate and endogenous NA content of the blood vessels used. It can be seen that the superior mesenteric artery had a surprisingly high synthesis rate which was more than 3 times that reported[1,3] in heart or brain, while rates in pulmonary artery and portal vein fell within limits previously reported. The rapid NA biosynthesis

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