GLUCOSE METABOLISM DURING EXERCISE IN MAN

J. Wahren, G. Ahlborg, P. Felig and L. Jorfeldt

From the Department of Clinical Physiology, Karolinska Institutet at Serafimerlasarettet, Stockholm, Sweden and the Department of Medicine, Yale University School of Medicine, New Haven, Conn., U.S.A.

It is generally recognized that in man, blood glucose is taken up to some extent by muscle during physical exercise, but the quantitative importance of its contribution to muscle substrate utilization has not been defined and is the subject of some controversy. Recent studies of glucose uptake by exercising muscle, based on determinations of a - v differences with and without simultaneous blood flow measurements, have indicated both considerable glucose uptake (15, 17, 18, 23) and a virtual non-utilization of this substrate (1, 2, 19). The a - v differences for glucose are often small and close to the error of the method for glucose analysis and few of the studies have been specifically directed towards defining muscle glucose metabolism. The present study was undertaken in an attempt to characterize the use of blood glucose as a substrate for small and large muscle groups during exercise of differing duration and intensity in postabsorptive man.

METHODS AND PROCEDURE

All subjects studied were healthy male volunteers (age range 21 - 39, mean age 25 years). None of the subjects was obese. The studies were performed in the morning, the subjects having fasted overnight. Two types of studies were made, involving forearm exercise and leg exercise respectively.

Forearm exercise series

Catheters were inserted percutaneously into the radial and brachial arteries and into a deep forearm vein. The subjects per-
formed forearm exercise on a handergometer (30) at a moderately heavy work load (10 kpm/min) for periods up to 60 min and at heavier loads (15 - 20 kpm/min) for short periods until exhaustion. Blood samples from an artery and the deep forearm vein were collected at rest and at timed intervals during the exercise period for analyses of oxygen and carbon dioxide content, glucose and lactate concentrations. Forearm blood flow was determined using an indicator dilution technique (30) and uptake and production of oxygen, glucose and lactate were calculated per unit estimated forearm muscle mass as described earlier (17, 31).

Leg exercise series

Catheters were inserted percutaneously into a femoral vein in the distal direction, into an antecubital vein and into a brachial artery. A no 7 or 8 Goodale-Lubin catheter was positioned in the main right hepatic vein under fluoroscopic control after a venous cut down in either antecubital fossa. The catheter tip was placed 3 - 4 cm from the wedge position. Catheter position was checked repeatedly by fluoroscopy before and after the exercise period.

After the catheterization, a single intravenous injection of 18 - 20 mg indocyanine green dye was given and arterial blood samples were obtained at 2 min intervals during the following 8 min. The plasma volume was estimated from the zero time intercept of the exponential dye decay curve. The subjects were then studied at rest in the supine position and during upright exercise on a bicycle ergometer. The subjects exercised for 40 min at one of the work loads; 400, 800 or 1200 kpm/min. Blood samples were collected simultaneously from the femoral and hepatic veins and the brachial artery, twice at rest and repeatedly at timed intervals during exercise, for analysis of glucose, lactate, pyruvate, α-amino nitrogen, glycerol, hematocrit and oxygen content. Expired air was collected at rest and after 10 and 40 min of exercise for determination of oxygen uptake.

Hepatic blood flow was estimated at rest and during exercise using the continuous infusion technique (5) and indocyanine green dye (0.4 - 0.5 mg/min) (26). The infusion was started at rest and paired arterial and hepatic venous samples were collected at 5 min intervals throughout the study, starting after 15 min of infusion. After 30 min of infusion the subjects sat up on the bicycle and started the exercise. At the heavier work loads, a rise occurred in the arterial concentration of dye in several subjects. The rate of this rise was then determined graphically and subtracted from the rate of dye infusion in the calculation of blood flow. This correction factor did not exceed 0.04 mg · l⁻¹ · min⁻¹ in any subject and significant hepatic storage is thus unlikely to have occurred (4).