Skeletal Muscle Enzyme Activity, Fiber Composition and $\dot{V}O_2$ max in Relation to Distance Running Performance

C. Foster, D. L. Costill, J. T. Daniels, and W. J. Fink

Department of Health, Physical Education and Recreation, University of Texas at Austin, Austin, Texas 78712, U.S.A.
Human Performance Laboratory, Ball State University, Muncie, Indiana 47306, U.S.A.

Summary. Muscle biopsy samples were obtained from the gastrocnemius of 26 well-trained runners of widely varying ability. Portions of the sample were analyzed for succinate dehydrogenase (SDH) activity and for muscle fiber composition. $\dot{V}O_2$ max was determined during uphill treadmill running. Mean values for muscle SDH activity (14.6 U/g), fiber composition (55% slow twitch) and $\dot{V}O_2$ max (60.9 ml/kg x min$^{-1}$) were lower than reported previously for groups of elite and sub-elite runners. The physiological data were consistent with the performance ability of the sample [5 : 12, 11 : 20 and 36 : 40 (min : s) for 1, 2 and 6 miles, respectively]. Within the sample, performance was most strongly related to $\dot{V}O_2$ max ($r = -0.84, -0.87$ and $-0.88$ for 1, 2, and 6 miles). There was little relationship between muscle SDH activity and either performance ($r = -0.11, -0.14, -0.20$ for 1, 2, and 6 miles) or $\dot{V}O_2$ max ($r = 0.23$). The relationship between muscle fiber composition and performance was only modestly strong ($r = -0.52, -0.54, -0.55$ for 1, 2, and 6 miles). The results indicate that the primary determinant of cross-sectional differences in running performance is $\dot{V}O_2$ max. Skeletal muscle metabolism apparently contributes little to these cross-sectional differences and may be of much greater importance to variations in performance within an individual.

Key words: Maximal oxygen uptake — Succinate dehydrogenase — Fiber composition — Distance running.

The physiological characteristics of elite runners are well documented. These athletes are characterized by great aerobic power (Costill et al., 1976b; Daniels and Oldridge, 1970; Saltin and Åstrand, 1967), a preponderance of slow twitch muscle fibers (Costill et al., 1976b) and great oxidative enzyme activity in the skeletal muscles (Costill et al., 1976b). Various authors (Costill et al., 1973; Karlsson and Saltin,
1971; Matsui et al., 1972) have presented evidence indicating that the maximal oxygen uptake ($\dot{V}O_2$ max) is highly related to running performance over a wide range of values. Recent reports (Costill et al., 1976a, b) indicate that muscle enzyme activity and muscle fiber composition may, like $\dot{V}O_2$ max, be quantitatively related to distance running performance. The purpose of the present investigation was to further examine the relationship of muscle enzyme activity, muscle fiber composition and $\dot{V}O_2$ max to performance in middle and long distance running.

**Methods**

26 well trained male runners of widely varying performance capabilities were employed as subjects. The requirements of the study including potential discomfort and hazards were explained to the subjects before each gave his written consent to participate. A sample of muscle was obtained from the lateral head of the gastrocnemius using the needle biopsy procedure (Bergstrom, 1962). The muscle sample was divided into two portions. One was immediately frozen in liquid nitrogen and stored at $-80^\circ$ C. The other was mounted in OCT and frozen in isopentane cooled to the temperature of liquid nitrogen and stored at $-80^\circ$ C.

The first portion of the sample was assayed for the activity of succinate dehydrogenase (SDH) using a NAD-NADH linked fluorimetric assay according to the principles outlined by Lowry and Passoneau (1972). The procedures used have been reported previously (Costill et al., 1976a, b) and may be summarized as follows. Whole muscle homogenates of 1 : 100 dilution were made at 0–4$^\circ$ C in a 0.1 M TEA buffer (pH 7.6, 0.5% BSA, 5 mM 2-mercaptoethanol). SDH activity was then determined using a two step indirect method. Step A: an aliquot of muscle homogenate was incubated at 37$^\circ$ C for 5 min in an equal volume of incubation medium (600 mM sodium succinate and 8 mM potassium ferricyanide). The reaction was stopped with the same volume of 3 M perchloric acid and neutralized with 3 M KOH. Tissue Blanks were also prepared. Step B: an aliquot of the supernatant from Step A was added to a reaction mixture of 0.1 M hydrazine (pH 9.2) and 0.36 mM NAD. The initial fluorescence was read and the reaction begun by adding 0.25 mg/ml fumarase and 5 mg/ml malate dehydrogenase. The difference in fluorescence was determined after 2 h incubation at room temperature. The second portion of the sample was sectioned (10 $\mu$m thick) in a cryostat at $-20^\circ$ C and incubated for myosin ATPase and alpha glycerophosphate dehydrogenase activity according to Padykula and Herman (1955) and Wattenberg and Leong (1960), respectively. The stained sections were projected and the percentage of fast twitch (FT) and slow twitch (ST) fibers determined (Dubowitz and Brooke, 1973). Fiber areas were determined by planimetry from 20 FT and 20 ST fibers. $\dot{V}O_2$ max was determined during uphill treadmill running using a modified Douglas bag procedure (Daniels, 1971). The speed and elevation of the treadmill were adjusted to exhaust the subjects within 5–7 min. In general, the subject started the run at a speed about equal to his best performance for ten miles (~ 85% $\dot{V}O_2$ max). The elevation of the treadmill was progressed by 2% every 2 min until the subject indicated he could no longer continue. Gas analyses were made using a Lloyd-Gallenkamp analyzer and gas volumes were determined in a balanced spirometer. In order to assess the runners performance capabilities, each subject competed in races of 1, 2, and 6 miles (1.61, 3.22, 9.66 km). The competition was performed on an all-weather track under favorable environmental conditions, within 30 days of the laboratory tests.

**Results and Discussion**

In comparison with other groups of trained runners, the present sample was characterized by a lower quality of performance and lower values for $\dot{V}O_2$ max, percent ST fibers and muscle SDH activity (Table 1). Comparison of data from other studies in this laboratory (Costill, 1976a, b) revealed some relationship between performance