

Capillary supply in hypertrophied human skeletal muscle

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An increase in capillary supply is a well-documented feature of endurance-training (e.g. Andersen & Henriksson 1977). There is, however, a paucity of information regarding capillary supply in connection with heavy-resistance training. In order to obtain more information on this matter, the capillary supply in heavy-resistance trained subjects with greatly hypertrophied muscles has been characterized and compared with untrained and endurance trained subjects.

Subjects. 5 heavy-resistance trained male subjects (bodybuilders, Swedish elite) volunteered to participate in this study. The means for their age, weight and height were 28 years, 91 kg and 1.76 m, respectively. They had been training systematically for an average of 7 years. Their training regimen has been described in more detail elsewhere (Schantz et al. 1981). For comparison, results from a study on endurance training of untrained subjects (Andersen & Henriksson 1977) and from study on rowers (Swedish elite) (Larsson & Forsberg 1980) have been used. The training performed by the untrained subjects in the study by Andersen & Henriksson (1977) consisted of bicycle exercise at 80% of the maximal oxygen uptake, 4 times 40 minutes/ week, 8 weeks.

Muscle biopsy sampling and analysis. Biopsies were obtained with the needle-biopsy technique (Bergström 1962) from the lateral head of m. quadriceps femoris (vastus lateralis) at the midpoint between trochanter major and the articular cleft between the femur- and tibiachondyles. Serial sections of the biopsies were stained for myofibrillar ATPase (Brooke & Kaiser 1970) for identification of type I, IIA, IIB, and intermediate (IB, IIC) fibres, as well as with the amylase-PAS method (Andersen, 1975) for visualization of capillaries. Cross-sectional areas of the muscle fibres were measured from the amylase-PAS sections (magnification 200 \times) with a grid method (Edström & Torlegård

1968-1969). The area of an average of 72 (range (R) 19-146) type I and 46 (R 16-88) type IIA fibres were measured. (Type IIB fibres were only seen to a very limited extent in a few individuals.) Capillary counts were performed as described by Andersen & Henriksson (1977). Capillary density was calculated as the number of capillaries per mm² of muscle cross-sectional area (cap \times mm⁻²). The capillary per fibre ratio (cap \times fibre⁻¹) was calculated as the total number of capillaries divided by the total number of fibres within a given area. The mean number of capillaries in contact with fibres of each type (CC) and CC per 1000 μ m² of fibre type area were calculated by counting all the capillaries around each type I and type IIA fibre. Cap \times mm⁻² was counted for an average cross-sectional area of 1.00 mm² (R 0.42-1.97). This contained an average of 126 (R 38-240) muscle fibres, 54% (R 46-74) of which were type I fibres.

Statistics. Results will be stated as means and standard errors of the means or ranges. The statistical significance of the differences between the rowers and the untrained subjects as well as between the bodybuilders and the untrained subjects was tested with Student's t-test for independent observations. An approximative t-test (Snedecor & Cochran 1980) was applied in one case when the variances differed. When the untrained subjects' values were used in two comparisons, a significance probability level of less than 0.01 was considered significant. Otherwise, a significance probability level of less than 0.05 was chosen. Only significant differences have been commented upon in the text.

Results and discussion. The mean number of capillaries per fibre in the heavy-resistance trained subjects (HT) was about 95% greater than in the untrained subjects before training (BT) (Fig. 1, Table 1). However, due to the 75% greater type I fibre area and the 105% greater type IIA fibre area in the HT, the number of capillaries per mm² was at the

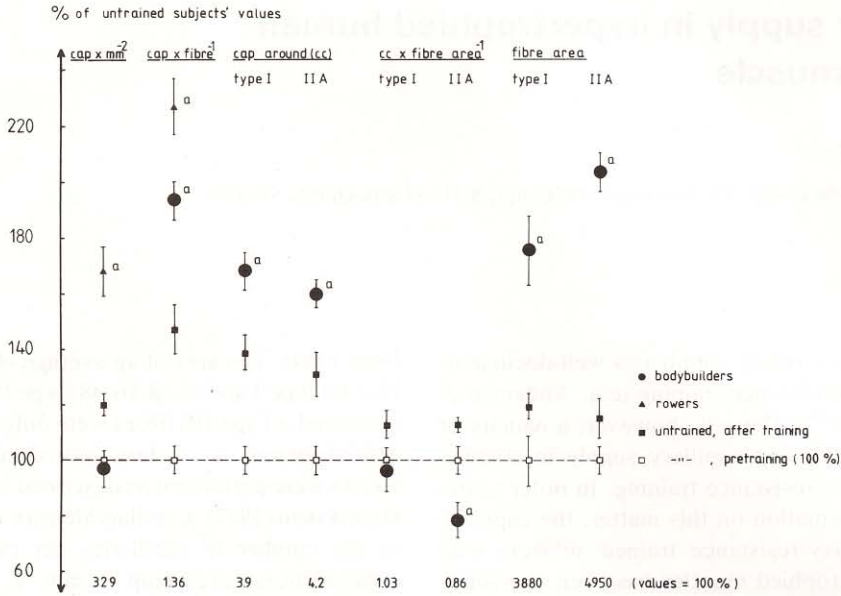


Fig. 1. The capillary supply in m. quadriceps femoris, vastus lateralis, of bodybuilders and rowers (values from Larsson & Forsberg 1980) in comparison with that in untrained subjects (values from Andersen & Henriksson 1977). Significant differences to the untrained subjects is designated with an *a* by the symbols. Also included in the figure are values for the "untrained" subjects after 8 weeks of endurance training. No statistical evaluation has been performed using those values. Values at the bottom of the figure are the absolute means for the untrained subjects, equivalent to the 100% level. The abbreviations for the different measures used to describe the capillary supply are explained in the text under "Muscle biopsy sampling and analysis". Values are given as means \pm standard error of the mean (SE). The SEs are expressed in per cent of the absolute mean.

same level as that for the BT. As a consequence of the above, the number of capillaries around each fibre type in the HT was about 65% higher than that for the BT. The mean number of capillaries around each fibre type per 1000 μm^2 fibre area was about the same magnitude for the type I fibres in the HT and the BT, while that for type IIA in the HT was about 20% lower than in the BT. Thus, it seems as if heavy-resistance training of a postural muscle, resulting in increased muscle fibre area, is associated with an increased number of capillaries, leading to an unaltered number of capillaries per

mm^2 , when compared to untrained. It should, however, be noted that the increased diffusion distance to the central part of the cell is probably not compensated for by the increased number of capillaries. It is not possible to state what the greater number of capillaries in the HT is due to. The lower value for the number of capillaries around each fibre divided by the fibre area, for the type IIA fibres in the HT compared to the BT, indicates, however, that an increase in number of capillaries is not directly coupled to cell growth. It is, however, conceivable that the cell enlargement causes metabolic distur-

Table I. Capillary supply in heavy-resistance trained subjects (means and ranges)

	Cap \times mm^{-2}	Cap \times fibre $^{-1}$	Cap around (CC)		CC \times fibre area $^{-1}$		Fibre area (μm^2)	
			type I	type IIA	type I	type IIA	type I	type IIA
Mean	320	2.64	6.6	6.7	0.99	0.68	6 800	10 100
Range	(265–397)	(2.18–3.24)	(5.9–8.0)	(6.0–7.6)	(0.84–1.21)	(0.58–0.79)	(5 200–9 500)	(7 600–12 200)

bances during normal usage of vastus lateralis, possibly due to oxygen deficit in the more central parts of the cell, which might in turn induce capillary neoformation. In such case, that could explain why the number of capillaries around each fibre divided by the fibre area in the HT was at an untrained level for the in daily life more frequently used type I fibres in vastus lateralis, but not so for the type IIA fibres.

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