Modelling diffusive O_2 supply to isolated muscle preparations

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The sole source of oxygen (O_2) to an isolated muscle preparation is by diffusion from the muscle surface. A.V. Hill (1928) derived equations that described the spatial and temporal dependencies of intramuscular O_2 partial pressure (PO_2) for muscles of various shapes and showed solutions for frog muscles. The purpose of the current study was to use Hill's diffusion equation for cylindrical muscles to assess the adequacy of diffusive O_2 supply into commonly-used mammalian cardiac and skeletal muscles during typical experimental contraction protocols. The diffusion equation was solved numerically to give (1) the maximum O_2 diffusion distances during steady-state activity at various contraction duty cycles and temperatures and (2) the time, in more severe contraction protocols, before central anoxia would develop during the rest-to-work transition. The effects of incorporating myoglobin-facilitated O_2 diffusion were also assessed.

The analysis was performed for soleus, extensor digitorum longus (EDL) and cardiac papillary muscles from the rat and mouse and for frog sartorius muscle using published metabolic data. The results indicated that for all the preparations considered, it would be difficult to ensure adequate O_2 supply using whole muscles; adequate O_2 supply can only be ensured over a reasonable range of duty cycles by using preparations with radii substantially smaller than those of whole muscles. Reducing experimental temperature is an effective strategy for enhancing O_2 supply to skeletal muscle. However, diffusive O_2 supply to isolated papillary muscles is not greatly affected by temperature because increasing temperature has opposite effects on active and resting metabolic rates of cardiac muscle. Taking account of O_2 supply from myoglobin had only minimal effects on oxygenation under typical isolated muscle conditions.

Hill, A.V. (1928) *Proceedings of the Royal Society of London Series B: Biological Sciences* 104, 39-96.