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A MATHEMATICAL MODEL OF OXYGEN TRANSPORT IN SKELETAL MUSCLE DURING SPACEFLIGHT

Abstract

In microgravity fluid shifts to the upper body region and is depleted in the lower body region due to the loss of the hydrostatic gradient in the venous vascular system. Skeletal muscles located in the lower body direct the diminished blood reserve to certain muscles such as the white portion of the gastrocnemius. They do this by increasing the vascular resistance to other muscles, such as the soleus or red portion of the gastrocnemius, thus redirecting the flow (Colleran, P.N. *et al.*, 2000. *J Appl Physiol.* vol 89: 1046-1054). The capillary-to-fiber ratio has also been shown to diminish within disused skeletal muscles (Tyml, K. *et al.*, 1999. *J Appl Physiol.* vol 87: 1496-1505). Using a Krogh-type Cylinder model, a mathematical formulation was developed to predict the distribution of oxygen in skeletal muscle tissue by varying the blood flow, capillarity, and muscle metabolism. For the first time, we mathematically predicted the oxygen distribution in the tissue of two types of muscles, the soleus and the gastrocnemius, after a long-term space flight. We found that the simulated long-term microgravity environment causes the soleus muscle to become hypoxic while the gastrocnemius maintains a normal tissue oxygen distribution. We hypothesize that the downregulation of protein synthesis observed in the space-simulated soleus muscle is a consequence of an inadequate oxygen supply to the mitochondria which limits ATP production and, in turn, causes an energy deficit. Since protein synthesis is a major ATP sink it is a target for downregulation. This leads us to believe that the depletion of oxygen that we predict is at least in part an instigator of the degeneration of skeletal muscles in space.