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What Is the Series Elastic Component in Skeletal Muscle?

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Because of space restrictions, I will focus my comments on issues related to the enhancement of work and will ignore all aspects discussed regarding efficiency. I will start with a few general comments aimed at illustrating conceptual problems I encountered when reading the manuscript; I will then address statements made by the authors, which I hope will provide additional information or insight into an unresolved topic.

General Comments

1. In Part I, Ingen Schenau et al. provided four possible explanations for the enhanced work output of a concentrically contracting muscle following a stretch (time available for force development, storage and reutilization of elastic energy, potentiation of the contractile machinery, and the contribution of reflexes). They derived support for their arguments from a Hill-type muscle model for the first two explanations and from a Huxley-type model for the third explanation. Switching from one conceptual model to another mid-argument made for easier argumentation than attempting to resolve all arguments within a consistent framework. (I will try to illustrate later with specific examples how difficult it is to reconcile all the proposed ideas within a consistent framework; i.e., a Huxley-type model.)

2. In the entire manuscript, the notion of elastic elements in muscles is very important, specifically the series elastic element. However, throughout the manuscript, the series elastic element is never defined except as the elastic element in series with the contractile element (but the contractile element is not defined either). It is generally accepted that the cross-bridge has elasticity in series with its force-producing site (Ford, Huxley, & Simmons, 1981; Huxley & Simmons, 1971). Furthermore, recent experiments have shown that there is considerable elasticity in the thin and possibly the thick myofilaments (Higuchi, Yanagida, & Goldman, 1995; Huxley, Stewart, Sosa, & Irving, 1994; Kojima, Ishijima, & Yanagida, 1994; Wakabayashi et al., 1994). These series elasticities appear to be neglected in the discussion of Ingen Schenau et al.; rather, their considerations seem to be generally correct only if the series elastic component is exclusively associated with aponeuroses and tendons.

3. I regretted that in the discussions on *in vivo* length changes of muscle fibers and tendons, Ingen Schenau et al. largely neglected experimental evidence (e.g., Griffiths, 1989; Hoffer, Caputi, Pose, & Griffiths, 1989; Roberts, Marsh, Weyand, & Taylor, 1997) but relied on indirect information.

Specific Comments

1. The idea that force production in skeletal muscle occurs via cross-bridges connecting thick with thin myofilaments has been accepted in the scientific community, as has the idea that the cross-bridge contains an elastic component in series with the force-producing cross-bridge head (Figure 1 in Huxley & Simmons, 1971). The force in a single cross-bridge and thus its work potential depend directly on the x-distance (Figure 1), a measure of the elongation of the elastic element in the cross-bridge.

When an active muscle is stretched, the average x-distance becomes larger compared to an isometric or concentric contraction, therefore increasing the force and the work potential of the individual cross-bridges (e.g., Cole, van den Bogert, Herzog, & Gerritsen, 1996). Therefore, I do not quite agree with Ingen Schenau et al. that the amount of elastic energy stored at the beginning of a concentric contraction is determined not by the amount of negative work but solely by the force. What the authors neglect to say is that the force depends (in some instances) on the negative work; the two cannot be separated into completely independent entities (if one accepts the cross-bridge theory and the idea that there is series elasticity directly within the cross-bridge mechanism).