
A.L. Hof is with the University of Groningen, Laboratory of Medical Physiology, Bloemsingel 10, NL-9712 KZ Groningen, The Netherlands.

---

**Stretch Reflexes Can Have an Important Role in Force Enhancement During SSC Exercise**

*Paavo V. Komi and Albert Gollhofer*

The stretch–shortening cycle (SSC) of muscle function has a well-recognized purpose: enhancement of performance of the final phase (concentric action) when compared to the isolated concentric action (e.g., Komi, 1984). This can be demonstrated in isolated muscle preparations with constant electrical stimulation (e.g., Cavagna, Dusman, & Margaria, 1968), in animal locomotion with natural and variable muscle activation (e.g., Gregor et al., 1988), and in maximal effort conditions of human SSC actions (Cavagna et al., 1968; Komi, 1983). Ingen Schenau et al. seem to agree with this basic concept. However, in discussing the mechanisms involved in the performance potentiation, the authors use countermovement jump (CMJ) as their basic model of SSC. In our understanding, an effective SSC requires three fundamental conditions: a well-timed preactivation of the muscle(s) before the eccentric phase, a short and fast eccentric phase, and immediate transition (short delay) between stretch (eccentric) and shortening (concentric phase). While the CMJ can easily be demonstrated to produce higher jumping height as compared to the squatting jump (SJ) (Asmussen & Bonde-Petersen, 1974; Cavagna, Komarek, Citterio, & Margaria, 1971; Komi & Bosco, 1978), it does not meet well all the criteria for an efficient SSC.

The purpose of this commentary is not to try to comment on all the aspects of performance enhancement as discussed in the target article. Instead, we have chosen to focus on the argument that stretch reflexes can have considerable importance in stiffness regulation of the muscle, which would consequently enhance force and power during SSCs. Thus, we do not agree with the target article that stretch reflexes have limited possibilities to operate in SSCs. We will not discuss H-reflex—as mentioned in the target article—because H-reflex is not a naturally occurring phenomenon and has little in common with true stretch reflexes. For many neurophysiological and mechanical aspects, it is evident that the CMJ is not a suitable model to elaborate on the specificity of SSCs. Instead, one has to look for more “normal” activities such as running and hopping, where the conditions of preactivation, faster stretch, and short transition time are well met. In addition, the forces measured in the muscle tendon complex during these activities can present a typical “bouncing ball” type form (Figure 1).

**Possibilities for Stretch Reflexes to Operate During the SSC**

There is no doubt that stretch reflexes play an important role in stiffness regulation. Hoffer and Andreassen (1981) demonstrated well that when reflexes are intact, muscle stiffness is greater per same operating force than in an areflexive muscle. Thus, stretch reflexes may make a net contribution to muscle stiffness already during the eccentric part of SSC.
This could be a logical consequence of how muscle spindles and Golgi tendon organs (GTO) operate in the control of muscle length and tension (Houk & Rymer, 1981). It is difficult to imagine that proprioceptive reflexes, the existence of which has been known for centuries, would not play any significant role in human locomotion including SSCs. It is, however, true that in normal movements with high EMG activity, the magnitude and net contribution of reflex regulation of muscle force are methodologically difficult to assess. The task becomes much easier when one studies relatively slow (1.2–1.9 rad s⁻¹) passive dorsiflexions, where the stretch-induced reflex EMG has been reported to enhance Achilles tendon force (ATF) by 200–500% over the pure passive stretch without reflex EMG potential (Gollhofer, Komi, Voigt, & Nicol, 1995; Nicol & Komi, 1997; Nicol, Komi, Belli, Huttunen, & Partio, 1995; see also Figure 2a). In these conditions, the time delay between EMG and force enhancement varies between 13 and 15 ms.

In normal hopping and running, even when performed submaximally, the reflex contribution to total EMG can be substantial due to a great number of motor units receiving Ia afferent stimuli from the condition of relatively high stretch velocities (10–12 rad s⁻¹ in the ankle joint). In this regard, hopping and running differ greatly from the CMJ or SJ. While the angular displacement of the ankle joint is clear and fast during hopping, CMJ and SJ may even demonstrate no stretching phase at all (see Figure 3 in Fukashiro, Komi, Järvinen, & Miyashita, 1993). The situation would not change considerably if one considers the possible consequences of the two-joint muscle behavior.