Stress-induced increase in muscle force: truth or myth?

In their elegant study, Andersson and colleagues (2012) further our understanding of the molecular mechanisms of Ca$^{2+}$ handling by the sarcoplasmic reticulum, namely the potentiation of the Na$^+$/K$^+$ pump of the sarcolemma (Overgaard et al. 1999; Clausen & Nielsen, 2007). Besides the positive inotropic effect, adrenaline also exerts a less known weakening effect, specifically on slow-twitch muscle fibres, consisting of a shortening of the twitch force duration, i.e. a positive lusitropic effect (Bowman, 1980; Roatta & Farina, 2010), similar to the one exerted on cardiac muscle. As early as 1958, Bowman & Zaimis (1958) reported that the force enhancement in the fast-twitch tibialis anterior muscle of the cat was attained with a much higher i.v. dose of adrenaline (3–10 μg kg$^{-1}$) than the force reduction in the slow-twitch soleus muscle (0.06–0.5 μg kg$^{-1}$). They considered the former dose to result in blood concentration beyond the physiological range and they expressed doubts about the physiological relevance of the positive inotropic effect. Therefore, the positive lusitropic effect may be the main effect of stress in physiological conditions. Nevertheless, we should mention that 20 years later, in his comprehensive review, Bowman also referred to unpublished observations concerning the occurrence of some positive inotropic effects at lower adrenaline concentrations (i.v. dose of 0.5 μg kg$^{-1}$), which he considered to be compatible with a physiological condition of extreme stress (Bowman, 1980). In addition, we note that the paper by Andersson et al. (2012) did include an in vivo measure, in which transgenic stressed rats showed greater grip forces than control rats. However, since an adrenergic positive inotropic effect is not the only possible explanation for the results, this test cannot provide a strong support for the existence of a stress-induced enhancement of muscle force in vivo. Very recently, the adrenergic effects on skeletal muscles have been investigated during a physiological stress response in humans (Roatta et al. 2008; Roatta & Farina, 2011). Interestingly, these studies showed weakening of selectively activated low-threshold (thus presumably slow-twitch) motor units during activation of the sympathetic nervous system by the cold pressor test (painful stimulus induced by immersion of one hand in icy water; Roatta et al. 2008), in accordance with the positive lusitropic effect. Further, it was not possible, using the same physiological stressor, to identify a positive inotropic effect when assessing all muscle fibres in the soleus and in the tibialis anterior muscles (Roatta & Farina, 2011). Of course, we cannot exclude that a stronger or different type of stress is necessary to produce a detectable enhancement of force. Even so, a lusitropic effect seems to occur in a greater range of physiological conditions than the inotropic effect, in agreement with the observations of Bowman (1980). Administration of adrenaline and β2-agonists in humans indeed results in a weakening effect (Marsden & Meadows, 1970; Crivelli et al. 2013), so that the functional consequences of a potential inotropic effect due to stress actually seem to be marginal for force production, at least in humans.

In conclusion, while we appreciate the useful data provided by Andersson et al. (2012), we challenge the view that physiological stress enhances muscle force, which is assumed in their paper as an established fact. Conversely, we find the scientific evidence for this effect very limited, to the extent that the force enhancement with stress may be a myth generated more by a very appealing functional explanation of the phenomenon than by strong experimental evidence. We contend that the main physiological effect of stress on muscle contractility is the positive lusitropic effect, for which there is more experimental evidence. This results in an increased relaxation rate of the muscle fibres which may serve to increase the speed of rapidly alternating movements (Roatta & Farina, 2010). While less intuitive than an increase in force, this effect would also be beneficial in the context of fight or flight.

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