Estimation of Cardiac Contractility Using Work-Loop End-Systolic Relations is Problematic

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Motivation: Cardiac contractility is often quantified in whole hearts and its tissues by taking the slope of the work-loop end-systolic pressure-volume or stress-length relations (ESSLR), respectively. Construction of these relations is achieved by joining together the end-systolic points of work-loops generated at different preloads and afterloads. Given that contractility is an intrinsic property of the muscle, one might expect its estimation to be independent of preload and afterload conditions.

Methods: The ESSLR of rat ventricular trabeculae (n = 15) was measured at physiological temperature and stimulus frequency (4 Hz). Each muscle was subjected to isometric contractions at 7 muscle lengths and work-loop contractions at 3 preloads (each contracting against 5 afterloads). A mathematical framework was devised from these experimental data to allow simulation of work-loop ESSLRs at any combination of preload and afterload. The work-loop ESSLRs for three scenarios were simulated. In these scenarios, loading conditions were chosen such that the: (a) shortening extent remained constant with increasing preload, (b) afterload remained high with increasing preload and, (c) relative afterload decreased with increasing preload.

Results: The three scenarios did not produce the same work-loop ESSLR and are all distinct from the isometric ESSLR (Fig 1). Moreover, the curvilinearity of the work-loop ESSLR also depends on the loading scenarios.

Conclusions: Estimation of cardiac contractility using work-loops is problematic because it depends on the loading conditions prescribed to the muscle. Contractility is an intrinsic property of muscle which, in our opinion, is best estimated from the isometric ESSLR and not its work-loop equivalent.

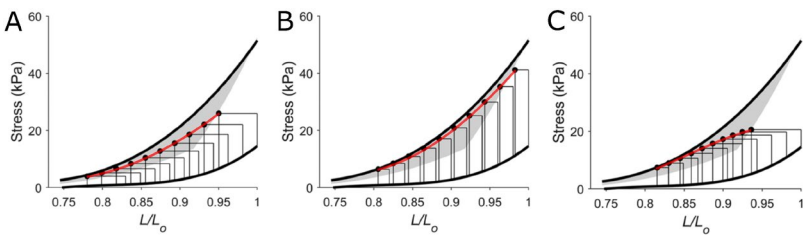

Fig 1. The end-systolic zone (shaded area) is a region that contains all possible end-systolic points. End-systolic stress-length relations (ESSLR) were generated from work-loops using three different sets of preload and afterload scenarios (red line). The different work-loop ESSLRs suggest three different estimations of contractility. The isometric ESSLR (top black line) and passive stress-length relation (bottom black line) for all three scenarios are identical.