Load-dependence in the Electromechanical Model of the Human Cardiomyocyte

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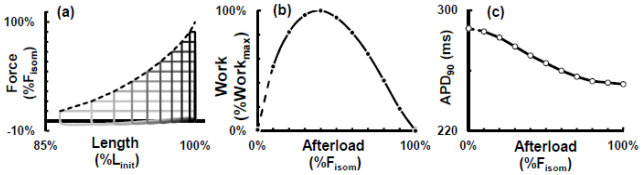
Cardiac contractility can be evaluated by the 'Pressure-Volume' relation (PV-loop) in the case of the whole heart or by 'Length – Force' (LF) loop for the isolated cardiac muscle preparations. The LF-loop is plotted using data obtained in the work-loop mode of the muscle contraction, which mimics the loading conditions of cardiomyocytes in the ventricular wall. Particular features of the work-loop twitch are as follows. After stimulation a muscle preparation starts to contract isometrically until its active force is lower than an imposed afterload. When the force achieves this afterload value the muscle shortens up to the end of the contraction phase. Then it relaxes isometrically at the end-systolic length. Finally the applied preload returns the muscle to its initial length.The area of the LF-loop presents the work performed by the muscle during the twitch. The study is aimed to simulate phenomena of the electromechanical coupling revealing themselves in the work-loop mode of the human myocardium contractions.

We utilised mathematical model of the electromechanical coupling in the human cardiomyocyte, TP+M model (Balakina-Vikulova ea, 2020), combining electrophysiological 'ten Tusscher–Panfilov'-2006 model with our model of the myocardium mechanical activity.



(a) LF-loop;
(b) 'Load-Work' relationship;
(c) 'Load–APD_{90}' relationship

We simulated electromechanical activity of the virtual sample contractions under a sequence of loads in the TP+M model. LF-loops for each afterload were plotted (Fig. a). An area of each LF-loop is equal to the useful work performed by the virtual sample during the shortening under the given load (Fig. b). The maximum value of the work has been obtained at the afterload of approximately 40% of the peak isometric force (F_{isom}). This is consistent with the data reported for the human ventricular muscle preparations (Holubarsch ea, 1998). The action potential duration (APD_{90}) turned out load-depended in the human myocardium model (Fig. c) due to the mechano-electric feedback mechanisms.