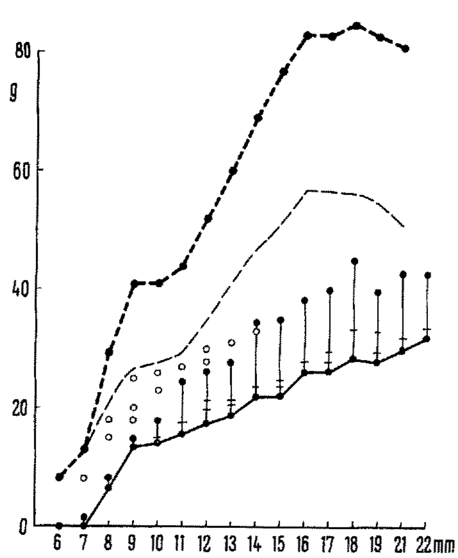
Isometric Length-Tension Diagram for Maximal Tetanic Contractions of Cardiac Muscle from a Gastropod, *Busycon canaliculatum*

In length-tension diagrams published for cardiac muscle, length is plotted against resting tension, systolic peak tension, twitch tension, or contracture tension but not against maximal tetanic tension[1-4]. This is to be expected for vertebrate cardiac muscle, which is non-tetanizable[5,6] except in special conditions which shorten the refractory period[7,8], but it leads to a difficulty when studying mechanical properties of cardiac muscle in that maximal contractile tension appears dependent on time[6,9] unless determined by an ionic contracture method[10]. Molluscan cardiac muscle is readily tetanizable[11] and yet it shares with vertebrate cardiac muscle the slow onset and slow decay of active state which may be considered a characteristic feature of the activation of cardiac muscle[12].

The Figure is a length-tension diagram for a 0.4 g ring of ventricular muscle from the heart of a prosobranch gastropod, *Busycon canaliculatum*. The ring was stretched between 2 glass rods, each wrapped with platinum foil to serve as a stimulating electrode. The upper rod was mounted on the plate shaft of a RCA 5734 mechano-electronic transducer, which served to measure tension, while the lower rod was moved by a Palmer large adjustable screw stand in order to stretch or release the muscle ring. The experimental procedure was to start with the muscle length just corresponding to zero tension in the unstimulated fresh preparation and stretch by increments of 1 mm, with a return to base length before each stretching to a new length. At each new length stress relaxation was recorded at 1 min intervals until the 1 min change approached the limit of resolution of the recording system. At that time the cardiac muscle ring was tetanized with 50 msec, 14 volt shocks at a frequency of 15 shocks/sec, until maximum tension was attained (ca. 1 sec). Experiments were completed on 10 preparations with very similar results. All were at room temperature of 20–24 °C., during the season November–January of 1966–67, and were kept moist with natural sea water.

The experiment illustrated was carried from zero resting tension to the point at which the muscle ring pulled apart during tetanic contraction. The shape of the length-tension curve is typical of cardiac muscle as contrasted to skeletal muscle in that tetanic tension is minimal at zero resting tension and both resting and total tension increase with increasing stretch[1]. The plasticity of molluscan cardiac muscle is such[4] that even at maximum extension passive resting tension never approaches total tetanic tension (heavy dashed line) or active tetanic tension (thin dashed line). Total tension of spontaneous beats, which sometimes followed stretching or tetanizing (unfilled circles), also continued to increase with increased stretch. If the diagram is compared to those that have been obtained for molluscan non-cardiac muscle[13,14] we see that active tension in fresh non-cardiac muscle rises with increasing length on a curve beginning at less than reference length and rising to a maximum at a length where resting tension is zero. Thus the tetanic tension vs. length curve for molluscan cardiac muscle differs from that for molluscan non-cardiac muscle in the same manner as length-tension diagrams for vertebrate heart muscle differ from length-tension diagrams for skeletal muscle. This places the peculiar nature of cardiac muscle on a potentially sounder footing since the maximal tetanic responses of a myocardium with the typical active state properties of cardiac muscle can now be compared with maximal tetanic responses of non-cardiac muscle[15].



Length-tension diagram for isolated ventricular muscle of *Busycon canaliculatum*. Upper line: total tetanic tension; middle line: active tetanic tension; lower line: passive resting tension, with vertical extensions indicating stress relaxation at 1 min intervals. Unfilled circles: total tension of spontaneous beats.

Zusammenfassung. Der Herzmuskel von Mollusken unterscheidet sich von der übrigen Molluskenmuskulatur entsprechend wie sich der Herzmuskel der Wirbeltiere von ihrer Skelettmuskulatur unterscheidet, insofern man die Beziehungen zwischen passiver und aktiver Kraft betrachtet. Im Herzmuskel der Mollusken lässt sich der maximale Tetanus für die Messung der aktiven Kraft verwenden.

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