

LETTER TO THE EDITOR

EXTRA SYSTOLES IN THE FROG HEART

Sir,

(Received on June 15, 2001)

This is to bring to light an important discrepancy in the Physiology practical manuals used in many medical institutions in India.

The experiment in question is the one on 'Refractory period of the beating heart'. The preparation used is the frog heart. In a typical experiment, as the heart is beating, an external stimulus is given to induce an extrasystole (ES). This is followed most of the times by a compensatory pause (CP) and the beat that follows the compensatory pause is termed a post-extrasystolic beat (PES).

In addition to describing refractoriness, this experiment also includes a comment on the amplitudes of the ES and PES. The standard teaching is that the ES should be smaller and the PES potentiated (Post-extrasystolic Potentiation or PESP) as compared to a normal beat (Fig. 1). The explanation offered for the expected observation is that the amplitude variations are due to Starling's law. It is taught that the ES is smaller because it comes at an earlier time when ventricular filling is still incomplete, whereas the PES is larger because of more filling during the compensatory pause.

In our experience, the amphibian heart almost always shows a larger extrasystole

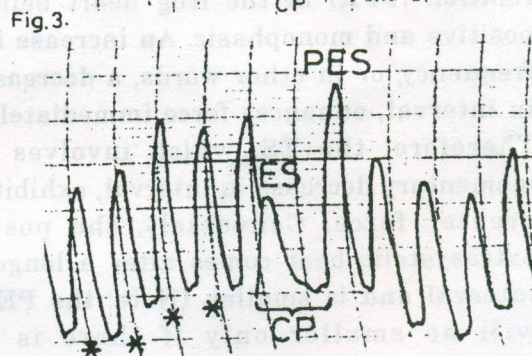
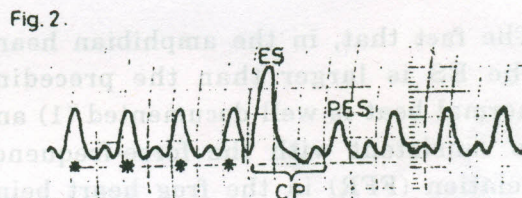
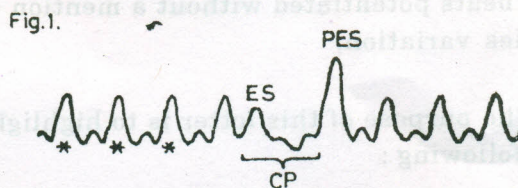


Fig. 1: A drawing of what is taught to the students pertaining to the frog ventricle.
Fig. 2: Physiograph recording from the ventricle (in situ) of a pithed frog.
Fig. 3: Physiograph recording from the ventricle (in situ) of a stunned rat.
* = Normal contractions
ES = extrasystole
PES = Post-extrasystolic beat
CP = Compensatory Pause
Isotonic fine movement transducer was used to record contractions in figures 2 and 3.

and a smaller than normal post-extrasystolic beat (Fig. 2) It must be a difficult time for the demonstrators to account for the diametrically opposite teaching and observation. Very often, the instrument used for recording contractions is a kymograph drum and the blame goes on the inertia of the recording system to explain the discrepancy between what is expected and what actually happens. The students are taught categorically that ES is smaller and PES beats potentiated without a mention of species variation.

The purpose of this letter is to highlight the following :

1. The fact that, in the amphibian heart, the ES is larger than the preceding normal beat is well documented (1) and is consistent with the force-frequency relation (FFR) in the frog heart being positive and monophasic. An increase in frequency, or in other words, a decrease in interval, enhances force immediately. Therefore, the ES, which involves a momentary decrease in interval, exhibits greater force. Conversely, the post-extrasystolic beat comes after a longer interval and is smaller. (Note: the PES will be smaller only if there is a compensatory pause preceding it. On the other hand, if the ES is a truly intercalated beat without a CP following it, the post-extrasystolic beat will be larger than the control but still smaller than the ES).

The findings are exactly opposed to what should be observed if Starling's law was operative. The phenomenon in question is the 'Force-Frequency relation' (FFR) or the 'Interval-Strength' relation (ISR) demonstrated by Bowditch in 1871 (2).

2. The statement that ES is smaller and PES larger (Post Extrasystolic Potentiation or PESP) is true however for the mammalian heart (Fig. 3). In the mammalian heart too, Starling's law cannot explain the phenomenon because this behaviour is exhibited even by isolated cardiac muscle preparations like the papillary muscle, where filling is not an issue (1).

The smaller extrasystoles and the Post-extrasystolic potentiation in the mammalian heart are because the Force-Frequency relation in the mammalian heart is positive but biphasic. What is meant is that, an increase in frequency (or a decrease in interval) produces an immediate decrease in force (and hence the smaller ES). If however, the increase in frequency is maintained, there is a gradual build-up of force and the steady-state amplitude is more than control level. Conversely, a longer interval leads to a larger beat immediately, (and therefore the post-extrasystolic potentiation, coming after the compensatory pause) but if the intervals are longer for many beats after that, the force declines to reach a value smaller than normal (1).

The force-frequency relation in the mammalian heart, when the force at the steady state after a frequency change is taken into account, is similar to the frog heart. But immediately after the frequency change, there is a diagonally opposite change in force in the mammalian heart, which is why, the extrasystolic and

PES beats, which involve only momentary changes in interval are different from the frog heart.

Our cause for concern is that, even commercially published manuals in experimental physiology in our country have not given this issue due consideration.

SATHYA SUBRAMANI* AND PRIYA MAMMEN**

Departments of *Physiology and **Psychiatry,
Christian Medical College and Hospital,
Vellore - 632 002

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*Corresponding Author

DEBARBATA CHOSH

Department of Physiology

All India Institute of Medical Sciences

New Delhi - 110 029