TEMPERATURE- DEPENDENCE OF CARDIAC CONTRACTILITY IN A STENOTHERMIC FISH SPECIES, THE BURBOT (*Lota lota* (L.))

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EXTENDED ABSTRACT ONLY -- DO NOT CITE

Introduction

Previous studies have indicated that temperature acclimation modifies cardiac function in eurythermal fish species and that the changes are in several respects opposite in cold-active and cold-torpid fish species. In the cold-active rainbow trout (*Oncorhynchus mykiss*), adaptation to cold increases heart size, basal heart rate, Ca^{2+} -uptake rate of the sarcoplasmic reticulum (SR) and Ca^{2+}-Mg^{2+}-ATPase activity of the myofibrils and makes the heart more sensitive to the inhibitory effect of ryanodine. In the cold-torpid crucian carp (*Carassius carassius*), cold adaptation is associated with reductions in heart rate, SR Ca^{2+} -uptake and myofibrillar Ca^{2+}-Mg^{2+}-ATPase activity. Indeed, thermal acclimation induces opposite changes in the subcellular systems of the cardiac myocyte in these two relatively eurythermic fish species. The objective of the present study was to extend these studies to a stenothermic and cold-active fish species to see whether the evolutionary adaptation to cold involves the same subcellular mechanisms which are typical for temperature acclimation. Burbot is a stenothermic fish species which is well adapted to a cold-water environment. The maximum ambient temperature which the burbot experience is slightly above 10 °C, but most of the year they inhabit water around 1-5°C. We have examined the basic contractile properties and the activity of myofibrillar Ca^{2+}-Mg^{2+}-ATPase of the heart in this stenothermic cold-water fish.

Methods

Contractile experiments were conducted at the 1-2°C. Pacing frequencies were selected to correspond the physiological heart rates. Contractile parameters were recorded on computer and were analysed off-line using Pclamp6-software. Ca^{2+}-Mg^{2+}-ATPase activity of purified atrial and ventricular myofibrils was measured at four different temperatures (1,5,10 and 15°C).

Results

he beating rate of the excised burbot heart *in vitro* was high (27 min^{-1}) at 1°C, but on the other hand thermal tolerance of the heart rate was low, since the heart beating became irregular at temperatures above 12°C (Figs. 1 and 2). Heart rate increased with the increasing temperature, whereas the force of contraction decreased strongly. The pumping capacity of the heart (calculated as the product of force and heart rate) was maximal at 1-2°C, and decreased strongly with increasing temperature. The temperature optimum of the myofibrillar ATPase activity was also relative low (at 10°C) for the burbot heart. Ryanodine (10mM), an inhibitor of the SR Ca^{2+}-release channel, decreased the steady state force of contraction by 15% in ventricular tissue and by 30% in atrial tissue. Additionally, ryanodine application caused small right-ward shift (to longer intervals) in the restitution curve of the atrial preparations but not in that of the ventricle. Rest-potentiation was greater in atrial muscle than ventricular muscle and was completely abolish by 10mM ryanodine in both tissues.

Conclusions

These findings indicate that the burbot heart is able to maintain high heart rate at low body temperatures and this is associated with rapid contraction kinetics which is supported by cold-adapted myofibrillar ATPase and relatively well-developed Ca^{2+}-release from the SR. Additionally, cardiac pumping capacity is greatest at 1°C, further supporting the contention that the burbot is exceptionally well-adapted to live at cold temperatures. The contractile properties of the burbot heart are similar to those of the cold-adapted rainbow trout. Thus, evolutionary adaptation to cold and acclimation to cold seem to involve the same subcellular mechanisms, the myofibrillar ATPase and SR, in order to support cardiac contractility at low temperatures.

Acknowledgments

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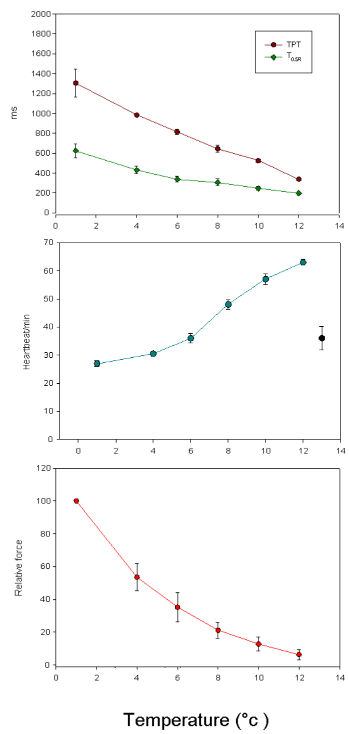

Fig. 1. Temperature dependence of contractile properties in Burbot heart. Time to Peak Tension (TPT) and Time to 50% Relaxation ($T_{0.5R}$) (top panel), spontaneous heart beat (middle panel) and relative force (bottam panel).

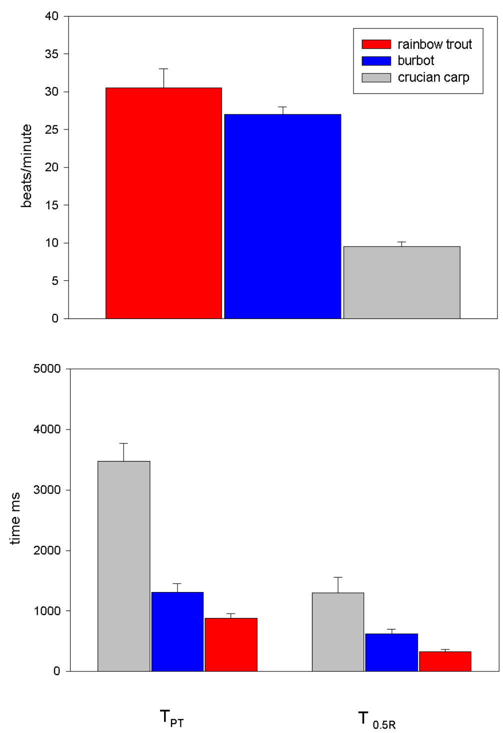

Fig. 2. Species comparison of spontaneous heart beat (top panel) and Time to Peak Tension (T_{PT}) and Time to 50% relaxation ($T_{0.5R}$) (lower panel) in Rainbow Trout, Burbot and Crucian Carp. Species differences are statisically significant $p<0.05$.