Initiation of Spleen Contraction Resulting in Natural Blood Boosting in Humans

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AKADEMISK AVHANDLING
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Opponent är Professor Lars Folkow, Institututt for Arktisk og Marin Biologi, Universitetet i Tromsø – Norges Arktiske Universitet, Tromsø, Norge.
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Abstract
The spleen has been shown to contract in apneic situations in humans as well as in other diving mammals, expelling its stored red blood cell content into circulation. This natural blood boosting may increase the circulating hemoglobin concentration (Hb) by up to 10%, which would enhance the oxygen carrying capacity and likely increase performance. However, the triggers of this response in humans have not been fully clarified. Study I was therefore focused on the effect of hypoxia as a trigger of spleen contraction. It was found that 20 min of normobaric hypoxic breathing evoked a substantial reduction in spleen volume showing that hypoxia is an important trigger for spleen contraction. Knowing the role of hypoxia, Study II compared two different hypoxic situations – a 2 min apnea and 20 min normobaric hypoxic breathing – which resulted in the same level of arterial hemoglobin desaturation. Apnea evoked a twice as great spleen volume reduction, implying that variables other than hypoxia were likely involved in triggering spleen contraction. This may be hypercapnia which is present during apnea but not during normobaric hypoxic breathing. Study III therefore investigated the effects of breathing gas mixtures containing different proportions of CO₂ prior to maximal apneas. Pre-breathing mixtures with higher percentages of CO₂ resulted in greater spleen contraction, thus demonstrating hypercapnia’s likely role as a trigger in addition to hypoxia. Study IV explored whether an all-or-nothing threshold stimulus for triggering spleen contraction existed, or if contraction was graded in relation to the magnitude of triggering stimuli. Exercise was therefore performed in an already hypoxic state during normobaria. Rest in hypoxia produced a moderate spleen volume reduction, with an enhanced spleen contraction resulting after hypoxic exercise, with a concomitant increase in Hb. This implies that spleen contraction is a graded response related to the magnitude of the stimuli. This could be beneficial in environments with varying oxygen content or work loads. Study V examined the possibility that spleen contraction is part of the acclimatization to altitude, during an expedition to summit Mt Everest. The long-term high altitude exposure, combined with physical work on the mountain, had no effects on resting spleen volume but resulted in a stronger spleen contraction, when provoked by
apnea or exercise. This indicates that acclimatization to altitude may enhance the contractile capacity of the spleen, which may be beneficial for the climber. From these studies I concluded that hypoxia is an important trigger for spleen contraction but that hypercapnia also contributes in apneic situations. The spleen contraction likely provides a graded expulsion of erythrocytes in response to these stimuli, causing a temporary increase in gas storage capacity that may facilitate activities such as freediving and climbing. The storage of erythrocytes during rest serves to reduce blood viscosity, which would also be beneficial for the climber or diver. The human spleen contraction appears to become stronger with acclimatization, with beneficial effects at altitude. Such an upgraded response could be beneficial both in sports and diseases involving hypoxia.

**Keywords:** Acclimatization, altitude, apnea, breath-hold diving, hemoglobin, hypercapnia, hypoxia, triggers.