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Short communication

Immersing the foot in painfully-cold water evokes ipsilateral extracranial vasodilatation

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ABSTRACT

Temporal pulse amplitude was recorded bilaterally in 56 participants before, during and after three ice-water immersions of the foot. Half of the participants were told that prolonged exposure to freezing temperatures could cause frostbite. Increases in pulse amplitude were greater in the ipsilateral than contralateral temple during and after the three foot-immersions. Although pulse amplitude decreased after threatening instructions and repeated immersion of the foot, the vasodilator response persisted during all three immersions. These findings suggest that nociceptive stimulation of the foot evokes an ipsilateral supra-spinal extracranial vasodilator response, possibly as part of a broader defense response.

1. Introduction

Immersing the hand in painfully-cold water provokes extracranial vasodilatation that is more pronounced in the ipsilateral than contralateral temple (Drummond and Granston, 2003, 2004). The response appears to involve loss of sympathetic vasoconstrictor tone, because local pretreatment with guanethidine (which inhibits sympathetic noradrenergic neurotransmission) prevents the response (Drummond, 2006a). The functional significance of this nociceptive vasodilator response is uncertain but could be worth exploring, as loss of sympathetic vasoconstrictor tone may aggravate the extracranial vascular component of pain in disorders such as cluster headache and migraine (Drummond, 1991, 2006b).

The present study had two aims. The first was to establish whether immersion of the foot in ice water would also provoke ipsilateral extracranial vasodilatation. If so, this would imply that hemilateral nociceptive processing involves a supra-spinal mechanism. The second aim was to determine whether fear-evoked constriction of facial blood vessels would counteract the vasodilator response.

2. Methods

2.1. Participants and ethics approval

The sample consisted of 16 male and 40 female undergraduate psychology students aged between 19 and 55 years (mean age of 25 ± 8 years) who earned course credits for participating. The gender imbalance reflects differences in the proportions of women and men enrolled in undergraduate psychology classes at Murdoch University. None of the participants had cardiovascular or psychiatric disorders or took prescribed medication for any other medical complaint. Each participant provided informed consent for the procedures, which were approved by the Murdoch University Human Research Ethics Committee.

2.2. Procedures

The experiments were carried out in a temperature-controlled room maintained at 23 ± 1 °C. To monitor changes in facial blood flow, pulse transducers (photoplethysmographs, Grass Instruments, Quincy, MA) were attached with adhesive washers to the left and right fronto-temporal region in the distribution of branches of the superficial temporal artery. The pulse transducers were covered with a black elastic headband to reduce interference from random illumination of the recording site. The headband was stretched slightly to hold the pulse transducers in place but was not tight enough to interfere with skin blood flow. Signals were sampled at 200 Hz by a Biopac MP100 data acquisition system and displayed and analyzed using Biopac AcqKnowledge software on a personal computer.

After a physiological baseline was established, participants were assigned randomly to receive threatening or neutral information about the up-coming cold pressor tests. In the threatening condition, they were informed by the female experimenter (CC) that "Prolonged exposure to freezing temperatures may lead you to experience persistent shivering, display signs of inflammation such as blistering or skin peeling and, in more severe cases, may lead to frostbite.

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Frostbite is defined as freezing of the tissue in the exposed part of the body. In particular, ice crystals which form inside the skin can damage the tissues, and you could lose skin or part of a finger or toe. Before the tissue freezes, you may experience sensations of tingling, pain and numbness in exposed skin. Additionally, your skin may become hard or waxy and may blister or peel; and it may turn purple. Because the tissues feel numb, most victims only realize that they have frostbite when someone else brings it to their attention." Both groups were then told "In a short while, I will ask you to immerse your foot in cold water at approximately 2 °C for 1 min. I would obviously like you to keep your foot in the water for the full minute. However, please note that you are free to withdraw your foot at any point if the discomfort is too much for you to tolerate. I will ask you to repeat the procedure two more times at 4-minute intervals".

Participants placed their left or right foot to approximately 2.5 cm above the lateral malleolus into a container of water maintained at 32 °C for 4 min, then into another container of water maintained at 2 °C for 60 s, then back into the 32 °C water. This cycle was repeated two more times. Half of the participants placed their right foot into the water and the remainder placed their left foot into the water. None of the 56 participants who completed the experiment withdrew their foot early. However, one additional participant withdrew from the experiment after the first cold pressor test. Participants who received threatening instructions were told afterwards that frostbite takes approximately 100 min to develop after prolonged exposure to freezing temperatures.

2.3. Data reduction and statistical approach

To minimize movement artifacts, the pulse waveform was filtered with a low pass filter at 15 Hz and a high pass filter at 0.5 Hz. Pulse amplitude was measured as the peak-to-trough height of the filtered pulse waveform, with a greater difference indicating greater blood flow. Pulse amplitude was measured for 60 s before the threatening or neutral instructions, for 60-second blocks immediately before the participant moved their foot from warm to cold water, and during and immediately after each immersion of the foot in cold water. As pulse amplitude is influenced by individual differences in the density and location of cutaneous vessels and the pressure of application of the transducer against the skin, pulse amplitude was expressed as a percentage of the level before the instructions were given.

In preliminary analyses, effects did not depend on whether the left or the right foot was immersed. Therefore, extracranial vascular responses to the foot immersions were compared in an Instructions (threatening, neutral) × Side (ipsilateral, contraleral) × Block (before, during or after foot immersion) × Trials (1–3) repeated measures analysis of variance. The multivariate approach was used for factors with more than two levels.

3. Results

As shown in Fig. 1, the amplitude of vascular pulsations increased during and after the cold water immersions [main effect for Block, $F(2,53) = 30.7$, $p < 0.001$]. In general, increases were greater ipsilateral than contralateral to the cold water immersion [main effect for Side, $F(1,54) = 4.93$, $p < 0.05$] (Fig. 1). However, pulse amplitude decreased during the four-minute recovery period between immersions, and generally declined across the course of the experiment [main effect for Trials, $F(2,53) = 5.81$, $p < 0.01$]. Vasodilatation during the first trial was greater in participants who received neutral than threatening instructions [Trial × Instructions interaction, $F(2,53) = 3.59$, $p < 0.05$] (Fig. 1). No other effects achieved statistical significance.

4. Discussion

Immersing the foot in ice water provoked a bilateral increase in pulse amplitude that was greater in the ipsilateral than contralateral temple. Although threatening instructions and repeated immersion of the foot in ice-water evoked signs of extracranial vasoconstriction, the

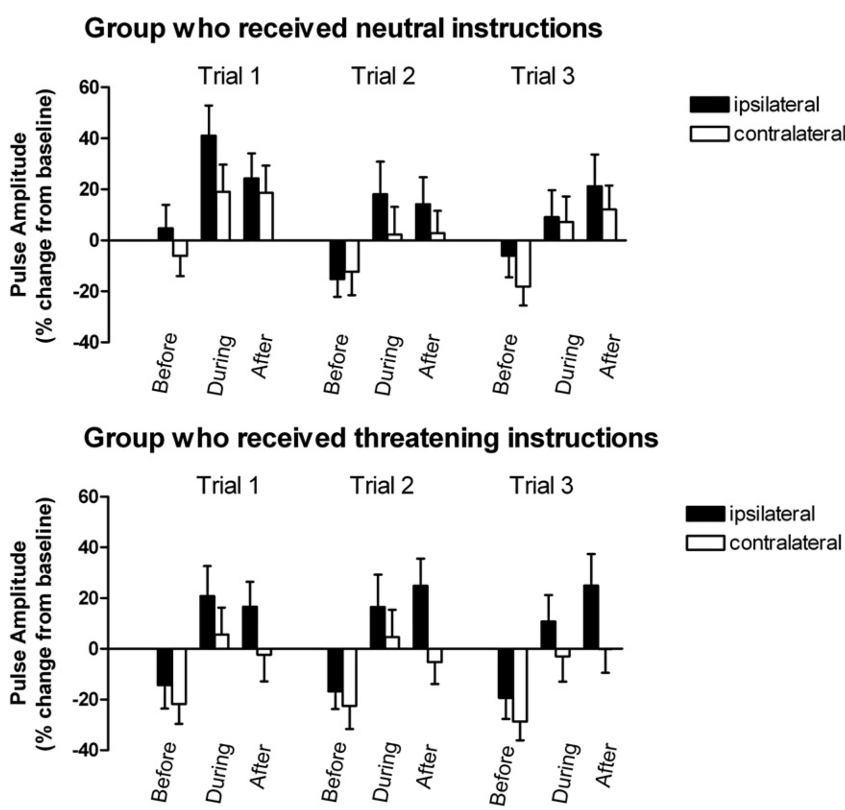

Fig. 1. Change in the amplitude of vascular pulsations (± S.E.) in the fronto-temporal region before, during and after immersion of the left or right foot into ice water for 60 s for participants who received threatening or neutral instructions.