REDUCTIONS IN FINGER BLOOD FLOW INDUCED BY LOW MAGNITUDE HAND-TRANSMITTED VIBRATION

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1. INTRODUCTION

Experimental studies have shown that vibration applied to one hand can provoke digital vasoconstriction in fingers on both the exposed hand and the non-vibrated hand (Bovenzi *et al*., 1999, 2000, 2004, Griffin *et al*., 2006). It has been hypothesized that the vasoconstriction in fingers on the non-exposed hand indicates a central sympathetic vasomotor reflex.

The dependence of vibration-induced vasoconstriction on the magnitude of vibration has been investigated in several studies, but the magnitudes investigated have mostly been high (unweighted accelerations from 5.5 to 88 ms^{-2} r.m.s.).

This study was designed to investigate the effect on finger blood flow of lower magnitude vibration in healthy female subjects. The hypothesis is that vibration applied to a controlled area of the thenar eminence of one hand would reduce finger blood flow in fingers on both the exposed and the unexposed hand, and that there would be greater reductions in finger blood flow with a higher magnitude of vibration.

2. APPARATUS AND METHOD

2.1. Subjects

Twenty healthy females aged 18 to 30 years participated in the study. All subjects were university students with no history of regular use of hand-held vibrating tools in occupational or leisure activities. They were asked to avoid caffeine for 2 hours and alcohol for 12 hours prior to testing. The subjects read written instructions and gave informed consent before beginning the experiment that was approved by the Human Experimentation Safety and Ethics Committee of the ISVR at the University of Southampton.

2.2. Apparatus

Finger blood flow (FBF) was measured in the middle fingers of both hands using plethysmography. A mercury-in-silicone strain gauge was placed around the distal phalanx at the base of the nail, with a plastic cuff for air inflation around the proximal phalanx, of the right and left middle fingers, with soft plastic tubes from the cuffs connected to an *HVLab* Multi-channel Plethysmograph (*HVLab*, University of Southampton). Blood flow was measured using a strain gauge venous occlusion technique: the pressure cuffs were inflated to a pressure of 60 mm Hg, and the increase in finger volume was detected by means of the strain gauges according to the criteria given by Greenfield *et al*. (1963). Finger blood flow was expressed in ml/100 ml/s.

An *HVL*ab Vibrotactile Perception Meter (VPM) generated sinusoidal vertical vibration at a frequency of 125 Hz at an unweighted acceleration of either 0.5 ms^{-2} r.m.s. or 1.5 ms^{-2} r.m.s., corresponding to frequency-weighted accelerations of 0.063 and 0.188 ms^{-2} r.m.s. according to International Standard 5349-1 (2001). The 6-mm diameter vibrating probe of the VPM was surrounded by a fixed circular surround. The gap between the probe and the surround was 2 mm. The vibration was measured using an accelerometer in the VPM, and was monitored using a digital meter and oscilloscope. Visual feedback of the downward force applied on the fixed surround (i.e. 2 N) was monitored on an electronic display of the VPM control unit.

2.3. Method

Subjects lay supine throughout the study, with both hands supported at heart level. After acclimatisation for 15 to 20 minutes, finger blood flow was measured simultaneously in the left and right hand at 30-second intervals for 28 minutes throughout seven successive 4-minute periods (with no break between the seven periods).

For the right hand, the seven periods were:

- (i) pre-exposure: no force,
- (ii) pre-exposure application of 2-N force,
- (iii) vibration 1: 2-N force with 125-Hz vibration at 0.5 ms^{-2} r.m.s. (unweighted),
- (iv) rest period with 2-N force,
- (v) vibration 2: 2-N force with 125-Hz vibration at 1.5 ms^{-2} r.m.s. (unweighted),
- (vi) post-exposure application of 2-N force, and
- (vii) recovery: no force.

The left hand remained motionless with no vibration and no force thoughout the 28-minute session. In each subject and on both hands, finger blood flow was expressed as the median of the eight measurements obtained during each 4-minute period. Statistical analysis with the non-parametric Wilcoxon test (for two-related samples) was conducted using SPSS (version 17.0) with a significance criterion of p=0.05.

3. RESULTS

The medians and inter-quartile ranges of the FBF in the middle fingers of the exposed and unexposed hands during each of the seven 4-minute periods are shown in Figure 1. During the pre-exposure period (i), the FBF did not differ between the exposed right hand and the unexposed left hand (p=0.16).

There was no significant change in FBF between period (i) and period (ii) on either hand, indicating the 2-N force applied by the right hand did not change finger blood flow on either hand.

During period (iii), on the exposed right hand there were significant reductions in the FBF compared to period (i) (p<0.001) and compared to period (ii) (p<0.001). On the unexposed left hand, there were no significant differences between period (iii) and either period (i) (p=0.28) or period (ii) (p=0.19). During period (iii), the FBF was less on the right hand than on the left hand (p=0.001). So, 0.5 ms^{-2} r.m.s. vibration applied to the thenar eminence of the right hand caused significant reductions in finger blood flow on the right hand but not on the left hand.

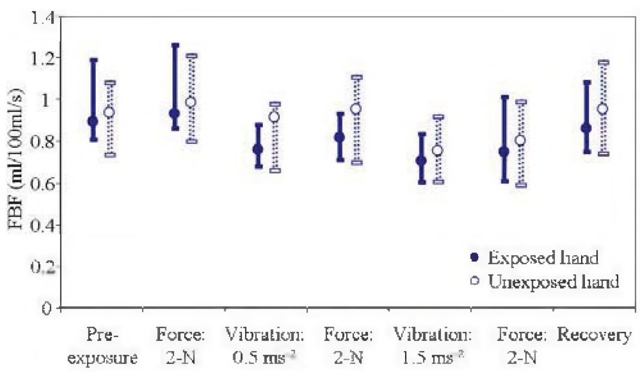

Figure 1. Medians and inter-quartile ranges of FBF in fingers on the exposed and unexposed hand during seven periods

During period (iv), on the exposed right hand there was a significant reduction in FBF compared to period (ii) (p=0.024), but a signficant increase in FBF compared to period (iii) (vibration exposure at 0.5 ms^{-2} r.m.s.; p<0.001). On the left hand, there was no significant difference in the FBF between period (ii) and period (iv) (p=0.37).

During period (v), on both the exposed right hand and the unexposed left hand there were reductions in the FBF compared to the previous four periods: period (i) (right: p<0.001, left: p<0.01), period (ii) (right: p<0.001, left: p<0.01), period (iii) (right: p=0.036, left: p=0.028), and period (iv) (right: p<0.001, left: p=0.041). During period (v), the FBF on the exposed right hand was significantly less than that on the unexposed left hand (p=0.001).

During period (vi), the FBF on both hands was less than during period (ii) (right: p=0.001, left: p=0.031). During period (vii), the FBF on the right hand was less than during period (i) (p=0.018) and less than during period (ii) (p=0.024), but greater than during period (vi) (p=0.045). On the left hand, the FBF during period (vii) did not differ from the FBF during period (i) (p>0.1) or period (ii) (p>0.1), but was greater than during period (vi) (p=0.025).

4. DISCUSSION AND CONCLUSIONS

Vibration of a small area of the thenar eminence of the right hand at 125-Hz at a magnitude of only 0.5 ms^{-2} r.m.s. caused signficant reductions in blood flow in the middle finger of the vibrated right hand, but not the middle finger of the unexposed left hand. Increasing the vibration magnitude to 1.5 ms^{-2} r.m.s. reduced finger blood flow in both hands, but most noticeably in the vibrated hand.

Stronger reductions in finger blood flow in both exposed and unexposed fingers have been reported, as the magnitude of 125-Hz vibration increased from 5.5 to 62 ms^{-2} r.m.s. (unweighted) (Bovenzi *et al.*, 1999) and from 16 to 64 ms^{-2} r.m.s. (unweighted) (Bovenzi *et al.*, 2004). Progressively greater reductions in FBF have been found with 16, 31.5, 63, 125, 250 and 315-Hz vibration and magnitude increasing continuously from 0 to 15 ms^{-2} r.m.s. (weighted) (Thompson and Griffin, 2009). With greater magnitudes of vibration, a larger area is vibrated, so it is unclear to what extent the effects of vibration magnitude found previously were due to increased magnitude of vibration or increased area of excitation. In the present study, the probe's static surround restricted vibration transmission to other locations, so the greater reductions in finger blood flow found here with the greater magnitude of vibration are probably not linked to vibration transmission to distant locations. Reflex control of skin blood flow is mediated through sympathetic vasoconstriction and vasodilation (Bovenzi *et al.*, 2001). The present results are consistent with some, but not all, of the vasoconstriction during and after exposure to vibration being mediated by central sympathetic vasomotor activity.

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