Comparison of Cold-induced Vasodilation Responses in Fingers and Toes of Able-bodied and Paraplegic Individuals: An Investigation into the Central versus Peripheral Mechanisms of Cold-induced Vasodilation

Lydia Tsoutsoubi[1,2]*, Leonidas G. Ioannou[1,2], Billie K. Alba[3], Stephen S. Cheung[4], Hein A. Daanen[5], Igor B. Mekjavic[1], Andreas D. Flouris[2]

[1] Department of Automatics, Biocybernetics and Robotics, Józef Stefan Institute, 1000 Ljubljana, Slovenia
[2] FAME Laboratory, Department of Physical Education and Sport Science, University of Thessaly, Karies, 42100 Trikala, Greece
[3] Thermal and Mountain Medicine Division, U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA
[4] Department of Kinesiology, Brock University, St. Catharines, ON, Canada
[5] Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
*Correspondence: lydiatsoutsoubi@gmail.com

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Introduction

Exposure to a cold stimulus causes vasoconstriction of the cutaneous vasculature to reduce heat loss [1,2]. Paradoxically, during extreme cold exposures, Lewis (1930) reported that this vasoconstrictor response may be interrupted by periods of vasodilation, a phenomenon termed “cold-induced vasodilation” (CIVD). Since its discovery, studies have focussed on the teleological nature of this response, and on the physiological mechanisms involved in its initiation and maintenance. Despite the multitude of studies conducted to address these issues, they remain largely unresolved. It has been proposed that the purpose of the CIVD response may be cryoprotective, that is to minimize the risk of cold injury [3-5]. Interestingly, similar physiological adaptations have been observed in the Jeju haenyeo, traditional Korean female divers who exhibit significant cold tolerance during extended periods in cold waters, providing a unique perspective on human adaptability to cold environments. This adaptability is seen in older Jeju haenyeo, who keep stable core temperatures and lower skin temperatures, showcasing a refined cold acclimatization influenced by their unique diving practices [6]. This study [7] compared physiological and perceptual parameters related to cold-induced vasodilation (CIVD) during cold water immersions between able-bodied (AB) individuals and paraplegics (P), with the aim of resolving the origin of the CIVD response, namely whether it is central or peripheral. Under the assumption that paraplegic participants have no central control over blood vessels under the level of the lesion, the CIVD reactions in paraplegic and able-bodied participants were investigated during exposure to different environmental conditions, resulting in different levels of heat content, since body heat content is known to significantly influence CIVD reactions.

Methods

Paraplegic (N=7) and able-bodied (N=7) individuals participated in a randomized matched-controlled study involving left hand and foot immersion in cold water (8 ± 1°C) for 40 min during exposure to cool (16 ± 1°C), thermoneutral (23 ± 1°C), and hot (34 ± 1°C) ambient conditions, as shown in Fig. 1. In the analysis of the finger (T_f) and toe (T_t) temperature responses, it was assumed that the observed changes in T_f and T_t reflected a skin microvascular response. Responses were identified as a CIVD occurrence, if they met the criteria regarding the transient elevation of T_f and T_t, with an increase of at least 1°C.

Figure 1. An able-bodied participant during the data collection. The right sleeve of the shirt was cut at elbow height to avoid constricting blood flow.

Results

Based on the criteria regarding the T_f and T_t, response representing a CIVD occurrence, similar CIVD occurrences were observed in the fingers of both groups. In contrast to the able-bodied individuals who did not exhibit any CIVD response in the toes in the cool and thermoneutral environments, CIVD responses were observed in three paraplegics: one in cool, two in thermoneutral, and three in hot conditions. No able-bodied participants exhibited CIVDs in cool and thermoneutral conditions, however CIVD was observed in four able-bodied participants in the hot condition. The toe CIVDs of paraplegic participants were counterintuitive in several respects: i) they were more frequent in cool and thermoneutral conditions (compared to the able-bodied participants), ii) they occurred in these conditions despite lower core and skin temperatures of these participants, and iii) they were evident only in cases of thoracic level lesions (instead of lesions at lower spinal levels).

Conclusions

Our findings demonstrate considerable inter-individual variability in CIVD responses in both the paraplegic and able-bodied groups. While we observed vasodilatory responses in the toes of participants with paraplegia that technically fulfilled the criteria for CIVD, it is unlikely that they reflect the CIVD phenomenon observed in able-bodied individuals. Taken together, our findings favour the contribution of central over peripheral factors in relation to the origin and/or control of CIVD.

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