

Subject Preparation and Thermal Acclimatization Prior to Mild Cold Challenge Testing Using Dynamic Thermal Imaging

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Abstract — Measurement protocol and standardization are important in the physiological assessment of re-warming such as mild cold challenge (MCC) testing of patients with suspected Raynaud's. The aims of this study were to a) form a consensus pre-test protocol for dynamic studies of the hands and b) to assess the length of time it takes a healthy adult's fingers to warm in a thermo-neutral room when coming from a cold room (20 minutes whole body cooling). The settling time before measurement is expected to be an important parameter for MCC testing. For aim a) informal advice was sought from 5 specialists in various European microvascular and thermography centres. For aim b) finger temperatures were measured in a normothermic measurement facility using thermal imaging. Sixteen subjects were studied. One subject had persistently cold fingers throughout. In the remaining 15 subjects finger warming was achieved in a median (inter-quartile range) period of 15 (10 - 20) minutes in the thermo-neutral room. We have shown using a sample of healthy controls from northern England that 30 minutes is a reasonable acclimatization time before commencing thermographic studies of the hands. It is recommended though that measurement centres in different climates evaluate the appropriate acclimatization period for their subjects and for specific body test sites.

Keywords: acclimatization, thermoregulation, mild cold challenge, Raynaud's.

Resumo — Protocolos de medição e padronização são importantes na avaliação fisiológica de re-aquecimento, como o teste de provocação de frio (PF) em pacientes com suspeita de fenômeno Raynaud. Os objetivos deste estudo foram a) formar um consenso de protocolo pré-teste para estudos dinâmicos das mãos e b) avaliar o período de tempo que leva para os dedos de um adulto saudável aquecerem em uma sala normotérmica após permanecerem 20 min em uma sala fria. O período de fixação antes da medição é esperado para ser um importante parâmetro para o teste PF. Para o objetivo a) foram questionados cinco especialistas de vários centros Europeus de termografia microvascular. Para o objetivo b) as temperaturas dos dedos foram medidas em uma instalação de medição normotérmica usando imagens térmicas. Foram inclusos na pesquisa dezesseis participantes. Os resultados mostram um aquecimento dos dedos dentro de um período de 15 min (de 10 a 20 min). Mostrou-se usando uma amostra controle do norte da Inglaterra que 30 minutos é um tempo razoável de aclimação antes de iniciar estudos termográficas das mãos. Recomenda-se que embora os centros de medição termográfica possuam diferentes climas, que seja avaliado o período e local de aclimação adequada para seus estudos.

Palavras-chave: aclimação, termoregulação, teste de provocação de frio, fenômeno de Raynaud.

1. INTRODUCTION

The mild cold challenge (MCC) test is frequently used to assess the hands of patients with Raynaud's phenomenon (1, 2). Measurement protocol and standardization (3) are important to help reduce uncertainty in measurement. Great emphasis is placed on the degree of *mild* cold, temperature measurement technique, follow-up period, and subsequent analysis. However, protocols involving subject preparation, the key starting point in the measurement process, are also important. Subjects need to achieve cardiovascular and thermal acclimatization prior to the cold challenge. Typically, 10 to 15 minutes is used for thermal imaging (4), irrespective of external ambient temperatures, climate, dress, subject preparation, or specific measurement site and context. The aims of this study were (a) to form consensus on appropriate pre-test subject preparation to develop our Centre's MCC testing protocol, and (b) to estimate an appropriate time for thermal acclimatization from normal healthy subjects for subsequent hand studies (5).

2. METHODS

For aim (a) the pre-test preparation protocol was compiled from information obtained from 5 European microvascular measurement experts (please see acknowledgements). Informal advice was sought and consensus formed by researcher JA for use in the Newcastle Centre protocol in respect of diet and medication, dress, relaxation, and hand preparation within specified times prior to their study.

For aim (b) subjects completed a health questionnaire and were excluded from the study if they had cardiovascular disease, persistently cold hands, or Raynaud's phenomenon. All subjects were asked to wear similar layers levels of clothing, e.g. shirt and trousers / skirt with no extra clothing layers when taking part in the study. Each gave written informed consent.

Subjects followed the formed pre-test protocol before sitting in a cool temperature-controlled room for 20 minutes (local study temperature 17 °C, sufficient to result in peripheral vasoconstriction but without inducing shivering or significant discomfort). During cooling the subject sat quietly with their hands gently resting on a table in front of them before moving to an adjacent warm but in the normothermic range

medical infrared imaging facility (ambient temperature 24 °C). Subjects then sat for a further 30 minutes whilst their hand skin temperatures were measured using thermography (FLIR Systems, SC300 camera). Here, the average temperature of the 4 fingers of each hand (thumbs not included) was monitored at 5 minute intervals. The thumbs were not included in the region of interest because when monitoring Raynaud's patients the thumbs can often be thermally spared to some degree. Both the operator and subject were blinded from the thermal image display during the warming phase. Images were analysed by researcher AY using ThermoCam Researcher image processing software with skin emissivity assumed to be 0.97 (Figures 1 and 2).

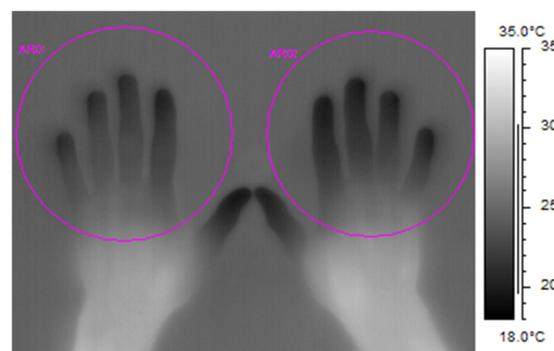


Figure 1. Example thermogram of the hands for a subject after sitting in a cool room for 20 minutes (i.e. at 17 °C ambient).

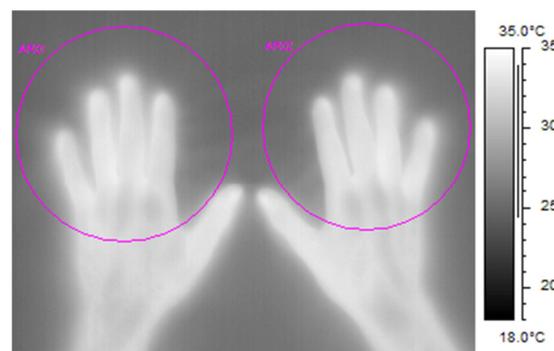


Figure 2. Example thermogram of the hands for a subject after sitting in a normothermic room for 30 minutes (i.e. at 24 °C ambient).

Subject core temperature was measured using an ear canal infrared thermometer at the end of cooling and after 30 minutes in the normothermic room. Subject age, sex, height and weight (for body mass index, BMI) were also recorded.

3. RESULTS

Aim 1: Pre-thermography protocol

Feedback and advice on important pre-test protocol factors was informally sourced from advice from 5 European colleagues significantly involved in microvascular assessment, and pre-test guidance formed for use in Aim 2. The key factors and subject guidance are summarized below:

- **Diet:** in the 2 hours before your study is due to start please refrain from chocolate, tea, caffeinated soft drinks (e.g. cola), alcohol, smoking, cigarettes, and taking non-prescribed stimulating drugs or substances. You may eat a light meal and drink water or juice.
- **Medicine:** continue taking any prescribed medicine as usual.
- **Exercise:** avoid physical exercise or exertion up to 2 hours before your study.
- **Skin preparation:** do not use skin moisturizer (or other hand cream), talcum powder or nail varnish.
- **Dress:** do dress appropriately for the weather conditions by wrapping up well to keep warm and if necessary by wearing gloves on your way to the hospital. When in the measurement room you will need to wear suitable clothing that allows us to study the temperature of the skin surface from just above elbow down to the hands. The clothing around the upper arms should also be loose fitting (not restrictive).
- **Be relaxed:** do arrive for your appointment in good time so you are not unduly stressed when you arrive.

Aim 2: Thermal acclimatization time

Sixteen normal healthy subjects (8 male) were entered into the study. Their median (inter-quartile range, IQR) age was 33 (23 - 38) years, weight 68.3 (64.8 - 76.0) kg, height 1.73 (1.63 - 1.78) m, and BMI 23.8 (22.6 - 25.0) kg/m².

Median (IQR) finger temperatures after 20 minutes of sitting in the cool room were 24.0 (22.6 - 27.8) °C and after 30 warming were 32.4 (31.4 - 33.2) °C, with overall increases in finger temperatures of +7.1 (4.8 - 9.1) °C. In one male subject the hands stayed cold (i.e. <25 °C) throughout the whole session. For the remaining 15 subjects whose fingers did clearly warm then this was achieved in a median (IQR) period of 15 (10 - 20) minutes. There were no differences overall in finger warming between the sexes, with males at 15.0 (12.5 - 22.5) minutes and females at 15.0 (10.0 - 16.5) minutes. Furthermore, there was no clear relationship with subject BMI.

In the normothermic room there was bilateral similarity in finger temperatures between the right and left hands with right-left median (IQR) finger area temperature differences of +0.2 (0.1 - 0.7) °C at 15 minutes follow-up and +0.1 (-0.1 to +0.5) °C after 30 minutes follow-up.

From a thermoregulation point of view it was interesting to contrast the marginal warming of core temperature +0.2 (-0.2 - 0.8) °C with the much larger finger temperature changes under the same ambient conditions.

4. DISCUSSION

A working protocol covering the key pre-test preparation factors has been formed and is largely based on informal advice offered by European colleagues in the microvascular field and from the literature. The pre-test protocol for MCC testing of the hands is used routinely in our thermal imaging centre. The pre-test preparation is considered easy to follow and not too onerous for the patient to comply with as part of their thermal imaging assessment.

Studying the time for hands to warm and settle was also an informative exercise. In most (15/16, ~94%) subjects studied their hands had shown clear warming within the 30 minute follow-up period. The upper quartile time was 20 minutes and so we recommend at least 30 minutes for acclimatization before commencing any microvascular assessment of the hands. The Newcastle microvascular centre routinely uses 30 minutes on entry to the thermally neutral department reception area followed by a further 10 minutes within the temperature controlled room and just prior to their MCC test.

Limitations of study – each volunteer entered the chilled room for 20 minutes, but it was not

taken into consideration where each subject had come from prior to this point, e.g. from inside or outside the hospital. It would be possible to let each volunteer's hands reach a plateau of even temperature, then let them enter the chilled room and then re-enter the thermally neutral room. Practically this wasn't feasible for this pilot but we recommend it be considered in future studies.

at rest. *Infrared Physics and Technology*. 2014;65:30-5.

5. Allen J, Oates CP, Chishti AD, Ahmed IA, Talbot D, Murray A. Thermography and colour duplex ultrasound assessments of arterio-venous fistula function in renal patients. *Physiological Measurement*. 2006;27:51-60.

5. CONCLUSION / FURTHER WORK

The pre-test protocol was acceptable for the subjects. We have shown using a sample of healthy controls from northern England that a period of 30 minutes is a reasonable acclimatization time for microvascular studies of the hands. It is recommended though that measurement centres in different climates evaluate the appropriate acclimatization period for their subjects and for specific body test sites. Future work should also look at greater numbers of both male and female subjects, and assess the repeatability of hand warm in acclimatization phase over different days.

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REFERENCES

1. Allen J, Howell K. Microvascular imaging: techniques and opportunities for clinical physiological measurements. *Physiological Measurement*. 2014;35:R91-141.
2. Ring EFJ and Ammer K. Infrared thermal imaging in medicine. *Physiological Measurement*. 2012;33:R33-46.
3. Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body *Thermology International*. 2008;18:125-44.
4. Marins JCB, Moreira DG, Cano SP, et al. Time required to stabilize thermographic images