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Cold challenge to provoke vasospastic reaction in fingers:a systematic review

Cryotherapy modalities and skin temperature

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Contents (INHALTSVERZEICHNIS)

Does neuromuscular thermography record nothing else but an infrared sympathetic skin response?

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A recent submission to this journal proposed to re-name Neuromuscular Thermography to Infrared Sympathetic Skin Response Studies. The reasoning for this proposal was the following:

When abnormalities due to vasomotor/sudomotor dysfunction occur there are associated changes in skin galvanic impedance and skin temperature. Skin galvanic impedance changes map closely with skin temperature. In physics this is explained by the fractal nature of infrared waves and their relationship to resistance and conductivity.

This statement raises the old question what physiological change is imaged by infrared thermography. There have been an number of answers to this question in the past including pain [1], radiculopathy [2], disc herniation [3], and of course, the level of activity of the sympathetic nerve system [4].

All these statements suffer from the fact that they confuse cause and effect. It is out of debate, that infrared thermal imaging is technique for mapping the infrared emission from an object, encoded as temperature values. It is also well accepted that the superficial blood vessels play a major role in the heat exchange of a living body,.

Temperature regulation system

Infrared radiation is one of the mechanisms of heat exchange of the human body In principle, a constant temperature gradient exists between the core temperature, the shell temperature and the environment. Most of the time, the environmental temperature is below the core temperature. In a system dependent on heat gain from the environment, the mean challenge of temperature regulation would be to defend the body against heat loss. But homoiothermic beings, achieve their heat balance by the net sum of heat generation and heat exchange with the environment. Due to endogenous heat generation, particularly through muscle work., the mechanisms of heat loss predominate the mechanisms of heat preservation.

The heat from the temperature core travels by conduction through tissues and by convection along blood vessels to the surface and is dissipated in 70% percent by infrared radiation. Additional heat loss occurs by conduction with respect to contact areas or convection dependent on moving air at the body surface.

The vascular network in the subepidermal skin layer was identified as the anatomical structure that is both the source of infrared radiation and the active vascular bed where thermoregulation takes place within the thermoneutral zone. The thermoneutral zone is defined as the temperature range, where disturbances in the thermal balance are equalised by variation in the width of the vascular bed [5] Increase of the vessel diameter is called vasodilation and is followed by increase of blood flow leading to bigger surface area of warm blood, from which infrared radiation will occur. Narrowing the vascular bed or vasoconstriction reduces the surface for heat dissipation and is therefore a mechanism for heat preservation. Both vasoconstriction and vasodilation in the vascular bed dedicated to temperature regulation are under the control of sympathetic nerve fibres [6, 7].

Temperature regulation is not the only influence on the width of vessels. External chemical compounds such as nicotinic acid, mustard oil or CO_2 , endogenous NO_2 or mediators of inflammation such as bradykinin, histamine, substance P or calcitonin gene related peptide may force vasodilation without involving the temperature regulation system. Ergotamine, norepinephrine or endothelin will cause vasoconstriction similar as cold environment. Inflammation, reactions to mechanical or chemical stimuli or permanent occlusion of vessels can lead to changes of the skin temperature without or only minor involvement of the sympathetic nerve system.

Nerve system and skin temperature

20 years ago, Ash et al. questioned the ability of thermography to image sensory dermatomes [8]. They came to the following conclusion:

1. Thermographic imaging of the sensory dermatome is not plausible.

2. There are no predictable sympathetic dermatomes.

Although the involvement of sensory and sympathetic nerve fibres in thermal regulation is nowadays much better understood as previously [9-11], the conclusion of Ash et al. is a still valid statement.

The clinical value of the electrical sympathetic skin response (SSR) was critically reviewed [12]. The authors stated that current procedures for the elicitation of SSR are not sufficiently reliable for diagnostic purposes, and show imperfect correlations both with clinical features and other measurements of autonomic, in particular, sudomotor dysfunction. The SSR can be provoked by a number of non specific stimuli including inspiratory gasp, a cough, a loud noise, an electrical shock, or a stroke of the skin. Typically, a single electric square pulse, 0.1–0.2ms in duration, delivered randomly and at a minimal interstimulus interval >30 seconds is applied. Nevertheless, the SSR must be provoked and is not a continuous reaction to an ongoing pathological process. Simultaneous recording of SSR and skin temperature is not published yet, although transient skin temperature changes have been reported in the vicinity of the site of applied mild, non specific stimuli [13] and during needling of acupuncture points [14].Successful sympathetic nerve blocks have been evaluated by the absence of SSR [15] and by infrared thermography [16].

Whilst the relationship between a sweat film on the skin and electrical skin conductivity and resistance is well established, the proposed relationship between infrared emission and electrical skin resistance needs further explanation. Profuse sweating may lead to binding of water molecules in the keratine layers of the skin similar as the immersion in water for 15 minutes or more [17]. Such a water film may act as filter against infrared radiation and may also result in prolonged evaporative cooling. Transient deprivation of sympathetic nerve supply of sweat glands by anaesthetic nerve block will lead to an increase of skin temperature as long as the temperature regulation occurs within the thermoneutral zone [5] and the mean skin temperature is above a level of 33°C.

References

1. Sherman RA, Barja RH, Bruno GM. Thermographic correlates of chronic pain: analysis of 125 patients incorporating evaluations by a blind panel. Arch Phys Med Rehabil. 1987; 68(5):273-9

2.Ching C, Wexler CE. Peripheral thermographic manifestations of lumbar disk disease. Appl Radiol 1978; 100: 53-58

3. Raskin MR Thermography of the spine. Appl Radiol 1976, 103

4. Schwartz RG. Infrared Thermographic Vasomotor Mapping and D ifferential Diagnosis. In. Cohen J. Rehabilitation Medicine and Thermography, 2008. 35-46

5.Savage MV, Brengelmann GL. Control of skin blood flow in the neutral zone of human body temperature regulation. J Appl Physiol. 1996;80:1249-1257.

6.Charkoudian N. Skin Blood Flow in Adult Human Thermoregulation: How It Works, When It Does Not, and Why. Mayo Clin Proc. 2003;78:603-612

7.Kellogg DL Jr. In vivo mechanisms of cutaneous vasodilation and vasoconstriction in humans during thermoregulatory challenges. J Appl Physiol 2006; 100: 1709–1718

8. Ash CJ.,Shealy CN, Young PA,. Van Beaumont W. Thermography and the sensory dermatome. Skeletal Radiol 1986; 15:40-46

9. Johnson JM, Yen TC, Zhao K, Kosiba WA. Sympathetic, sensory, and nonneuronal contributions to the cutaneous vasoconstrictor response to local cooling. Am J Physiol Heart Circ Physiol. 2005; 288(4): H1573-9.

10. Hodges GJ,. Kosiba WA, Zhao, K. Johnson JM. The involvement of norepinephrine, neuropeptide Y, and nitric oxide in the cutaneous vasodilator response to local heating in humans. J Appl Physiol, 2008; 105(1): 233 - 240.

11. Hodges GJ Traeger JA III, Tang , Kosiba WA, Zhao K, Johnson JM. Role of sensory nerves in the cutaneous vasoconstrictor response to local cooling in humans. Am J Physiol Heart Circ Physiol, 2007; 293(1): H784 - H789

12. Vetrugno R, Liguori R, Montagna P. Sympathetic skin response Basic mechanisms and clinical applications. Clin Auton Res 2003, 13 : 256-270

13.Kitzinger E. .Ammer K Thermologie in der Akupunktur Dtsch Zschr Akup 1992; 35: 132-139

14.Ammer K, Schartelmüller T, Cao G, Kitzinger E, Melnizky P. Thermometrische Evaluierung unterschiedlicher Nadelungstechniken der Akupunktur Dtsch Zschr Akup 1995; 38: 33-36

15. Schmid MR, Kissling RO, Curt A, Jaschko G, Hodler J. Sympathetic Skin Response: Monitoring of CT-guided Lumbar sympathetic Blocks. Radiology: 2006; 241(2): 595-602

16. Kim Y-C, Bahk J-H, Lee S-C, Lee Y-W. Infrared Thermographic Imaging in the Assessment of Sucesfull Block of Lumbar Sympathetic Ganglion. Yonsei Med J. 2003, 44: 199- 124

17. Ammer K. Einfluß von Badezusätzen auf die Wärmeabstrahlung der Haut. ThermoMed 1994; 10; 71-79

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Cold challenge to provoke a vasospastic reaction in fingers determined by temperature measurements: a systematic review

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SUMMARY

BACKGROUND: Raynaud´s Phenomenon is characterised by 3-phasic colour changes of fingers and/or toes caused by vasospam of the digital arteries due to low temperature and/or psychological stress. These colour changes may be accompanied by decreased skin temperature which can be identified by infrared thermal imaging.

OBJECTIVE: To identify procedures which address patient´s preparation, temperature of the examination room, temperature and duration of the immersion bath, position of hands, time of follow-up after the cold challenge and method of evaluation

METHOD: A computer assisted literature search was performed for publications related to thermographic investigations of patients with suspected Raynaud´s phenomenon in Embase, Medline, Google Scholar and the literature archive of the author.

RESULTS: Out of 170 hits in Google and 98 in Embase/Medline, in total 50 articles and 6 reviews were included. The information on procedures performed was incomplete in the identified studies. There was a wide variation in water temperature of the immersion bath and also of duration of immersion. More than 20 different methods for evaluation of hand temperatures were reported

CONCLUSION The description of the methodology must improve. A evidence based guideline for standard procedures of performing and evaluation of thermal images from patients with Raynaud´s phenomenon is needed.

KEY WORDS: cold challenge, Raynaud´s phenomenon, thermography, systematic review

VERWENDUNG DES KALTWASSERTESTS, UM EINE DURCH TEMPERATURMESSUNG NACHGEWIESENE VASOSPASTISCHE REAKTION DER FINGER ZU PROVOZIEREN: EIN SYSTEMATISCHE ÜBERSICHT

HINTERGRUND: Das Raynaud´s Phänomen ist durch eine 3-phasische Farbänderung der Finger und/oder Zehen charakterisiet, die durch Kälteexposition oder psychischen Stress bedingten Gefäßspasmus der Fingerarterien ausgelöst wird. Die Farbänderung kann von einer verminderten Hauttemperatur begleitet sein, die durch Infrarot- thermographie nachgewiesen werden kann.

ZIEL DER STUDIE: Verfahren zu entdecken, die über die Vorbereitung der Patienten, die Raumtemperatur des Untersuchungsraums, die Temperatur und Dauer des Tauchbades, die Handposition, die Nachbeobachtungszeit nach dem Kaltwasserbad und die Methode der Ergebnisauswertung Auskunft geben.

METHODE: Es wurde eine Computer gestützte Literatursuche über thermographische Untersuchungen bei Verdacht auf Raynaud Phänomen in den Datenbanken Embase/Medline, Google Scholar und im Literaturarchiv des Autors durchgeführt.

ERGEBNISSE: Aus 170 Treffern in Google und 98 in Embase/Medline wurden insgesamt 50 Arbeiten und 6 Übersichtsartikel ausgewertet. Die Informationen über die durchgeführte Prozeduren war in den ausgewählten Studien unvollständig. Es zeigte sich eine große Variation hinsichtlich der Temperatur des Wasserbades und der Dauer des Tauchbades. Mehr als 20 verschiedene Methoden zur Auswertung der Handtemperatur wurden berichtet.

SCHLUSSFOLGERUNG: Es besteht Verbesserungsbedarf in der Beschreibung der Methodik in den Studien. Wünschenwert ist eine evidenzbasierte Leitlinie über Standardverfahren zur Durchführung und Auswertung von Wärmebildern, die von Patienten mit Raynaud Phänomen angefertigt wurden.

SCHLÜSSELWÖRTER: Kaltwassertest, Raynaud Phänomen, Thermographie, systematische Übersicht

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Introduction

Raynaud´s Phenomenon is characterised by 3-phasic colour changes of fingers and/or toes caused by vasospam of the digital arteries due to low temperature and/or psychological stress. These colour changes may be accompanied by decreased skin temperature which can be identified by temperature measuring devices including infrared thermal imaging. Secondary Raynaud´s phenomenon is seen in connective tissue disease, especially in systemic sclerosis and may lead to severe impairment of the involved fingers including skin ulcers and tissue necrosis whilst in the primary form severe tissue damage is rarely seen although the disease may be troublesome for the patient . The prevalence of the disease in England is 11.to 16 percent in men and 19 to 21% in women. [1].

Exposure to vibrating tools in combination with cold and wet environment may also lead to blanching of the fingers which may be the first sign of the onset of a hand-arm-vibration syndrome [2]. For both conditions a cold challenge may provoke a long standing vasospastic reaction in the hand which is followed by a decrease of the surface temperature of the fingers. This temperature drop can be measured by contact or infrared thermometers and such a test was suggested for confirmation of either Raynaud´s phenomenon or hand-arm-vibration syndrome.

A cold challenge test can be used as diagnostic test or as an outcome measure [3]. However, cold provocation is not yet standardised for either applications and a wide range of variation of this procedure have been published. A literature search on published procedures related to the cold challenge test applied for Raynaud´s phenomenon or hand- arm-vibration syndrome is the first step in defining standard procedures for this test.

Methods

A computer assisted literature search was performed for publications related to thermographic investigations of patients with suspected Raynaud´s phenomenon or hand-arm-vibration syndrome in Google Scholar, Embase and the literature archive of the author. The terms "Raynaud´s phenomenon" or "hand-arm-vibration syndrome" and "cold-stress-test"were used in the Google Scholar search. The search in Embase/Medline was performed with the key words "Raynaud´s phenomenon" or "hand-arm- vibration- syndrome" and "temperature measurements" and limited to "humans. T

After reading the abstracts articles and reviews were selected for further data extraction. The method section of these articles was screened for procedures which ad- dress details of patient´s preparation such as dressing and body position during acclimatisation, temperature of the examination room, temperature and duration of the immersion bath, position of hands, time of follow-up after the cold challenge, definition of measurement areas and method of evaluation. Whether temperature measurements were applied as diagnostic test or as outcome measure, was extracted from the objective statement of the studies.

Results

170 papers were found in Google Scholar and 98 publications in Embase/Medline. Of these 6 reviews [[4-9], 43 original articles [13-16, 18-32, 34-43, 45-59], 3 conference papers [10, 12,17], 1 abstract [33] and 1 thesis [44] were selected

Reviews

EFJ Ring [5] reported 12 papers of which all but one used a cooling time of 60 seconds and the preferred water temperature was 20°C (5/12 papers), followed by 0°or 10° (both 2 papers) and 14°, 15° or 16° were proposed in the remaining 3 publications

Laskar & Harada [6] extracted from 30 publications conditions for the cold water immersion test for diagnosing hand-arm vibration syndrome The most common temperature values for the cold challenge were 10°(12 papers) and 15° (11 papers). Immersion time was 10 min or 5 min in 10 papers each, only 3 studies used a cold challenge for 1 min (2 papers with 5°, 1 study with 15°).

Herrick [7] reported 3 different ways for evaluation of thermograms recorded from Raynaud´s patients including the time interval from the end of the cold challenge to the onset of rewarming, the rate of rewarming and the maximum temperature recovery, the degree of temperature variation between different areas of the hands, and an index combining the temperature gradient along the index finger during rewarming with the temperature change of the finger after cold challenge.

Indication (table 1)

8 papers reported the use of the cold challenge test as diagnostic tool for hand-arm vibration syndrome. The authors of the remaining 45 papers used cold provocation in patients suffering from Raynaud´s phenomenon.

Objectives (table 1)

64 % of papers related to Raynaud´s phenomenon reported diagnostic use of the cold challenge test. The test was applied as an outcome measure in the remaining publications.

Patient´s preparation (table 2)

Dressing

Information on dressing during acclimatisation was given 26% of all papers. 9 publication reported subjects with undressed forearms, 1 with bare arms, 1 with bare hands, 1 with bare forearms and bare lower legs and 1 with undressed legs. In 39 articles dressing of the subjects investigated was not mentioned. None of the papers related to hand- arm-vibration syndrome provided any information on dressing status.

Body position during acclimatisation

More than 50% of papers reported the body position of the subjects during acclimatisation. In 25 studies the subjects sat in an comfortable chair prior to the cold challenge and 3 publications reported a supine position of the subjects.

Time for acclimatisation

The mean duration of acclimatisation before a diagnostic cold challenge test was 20.7 ± 8.0 minutes and for an outcome measure 18.7 ± 18.7 minutes. The predominant acclimatisation times for a diagnostic test were 15 (11 papers) and 20 minutes (8 papers). For outcome measures 15 (6 papers) and 10 minutes (3 papers) were most frequently reported.

Room temperature

Information on room temperature was not available from 8 publications. Figure 1 shows the distribution of room temperatures when the cold challenge was applied for diagnosis or as an outcome measure. 26 papers did not report variations of room temperature, room temperature varied by 1 degree in 9 studies, and by 0.5 degrees in 6 other pub-

Table 1
Year of publication, indication and use of temperature measurement

publication	Reference	year of publication	objective	indication
Chucker et al.; Am Fam Physician 1974; 10(2):70-78.	9	1974	diagnostic	Raynaud´s phenomenon
in; Birly DM(eds), Horsham, 1980, 267-275	10	1980	outcome	Raynaud´s phenomenon
Ring; Acta thermographica, 5:35-38	11	1980	diagnostic	Raynaud´s phenomenon
Ströbel & Engel, Thermographische Fachberichte 1980, 1: 46	12	1980	diagnostic	Raynaud´s phenomenon
Ring et al; J Int Med Res; 9: 393-400.	13	1981	outcome	Raynaud´s phenomenon
Martin et al, Ann Rheum Dis;40: 350-354	14	1981	outcome	Raynaud´s phenomenon
Carrol et al.; Ann Rheum Dis 40:567-570	15	1981	diagnostic	Raynaud´s phenomenon
Freedman & Ianni; BMJ , 287: 1499-1502	16	1983	diagnostic	Raynaud´s phenomenon
In Ring & Philips; Plenum Press 1984: 355-360	17	1984	diagnostic	Raynaud´s phenomenon
Bosmansky et al, Z.Rheumatol, 44:242-245	18	1985	outcome	Raynaud´s phenomenon
Mohrland et al.;Ann Rheum Dis;44;754-760	19	1985	outcome	Raynaud´s phenomenon
McHugh et al.; Ann Rheum Dis; 47;43-47	20	1988	outcome	Raynaud´s phenomenon
Ring et al, Thermology 3: 69-73.	4	1988	diagnostic	Raynaud´s phenomenon
Dupuis, ThermoMed 5:70-74	21	1989	diagnostic	Hand-Arm-Vibration Syndrome
Darton & Black; Br J Rheumatol; 29:291-292	22	1990	diagnostic	Raynaud´s phenomenon
Darton & Black; Br J Rheumatol; 30:190-195	23	1991	diagnostic	Raynaud´s phenomenon
Shawket et al.; Br. J. clin. Pharmac. 32, 209-213	24	1991	outcome	Raynaud´s phenomenon
Kvle et al. J Rheumatol. 19(9): 1403-6	25	1992	outcome	Raynaud´s phenomenon
O'Reilly et al.; Ann Rheum Dis 1992;51;1193-1196	26	1992	outcome	Raynaud´s phenomenon
Tauchmannova; Thermologie Österreich 1992: 2(2) 61-64.	27	1992	outcome	Raynaud´s phenomenon
Zurak et al. Neurologica Croatica 42(2) 93-106	28	1993	diagnostic	Raynaud´s phenomenon
Vacariu et al, Thermologie Österreich 4(2): 66-72.	29	1994	diagnostic	Raynaud´s phenomenon
Wigley et al. Ann Intern Med 120: 199-206	30	1994	outcome	Raynaud´s phenomenon
In: Ammer&Ring. Uhlen, 1995 , 237-240	5	1995	diagnostic	Raynaud´s phenomenon
Teh et al; Br J Rheumatol;34:636-641	31	1995	outcome	Raynaud´s phenomenon
Ammer, Skin Research and Technology 2; 182-185,	32	1996	diagnostic	Raynaud´s phenomenon
Chetter et al, Cardiovas Surg 5(Sept) 45	33	1997	diagnostic	Hand-Arm-Vibration Syndrome
Howell et al.; Eur J Thermo; 7(4):132-13	34	1997	diagnostic	Raynaud´s phenomenon
Jayanetti et al, J Rheumatol, 25, 997-999	35	1998	diagnostic	Raynaud´s phenomenon
von Bierbrauer et al.; Vasa;27(2):94-9	36	1998	diagnostic	Hand-Arm-Vibration Syndrome
Boesinger et al, Thermology 3:191-198	37	1999	diagnostic	Raynaud´s phenomenon
Clark et al, J Rheumatol, 26, 1125-1128	38	1999	diagnostic	Raynaud´s phenomenon
Dziadzio et al.Arthritis & Rheumatism,42 (12) 2646-2655	39	1999	outcome	Raynaud´s phenomenon
Hayoz et al.; Rheumatology 39; 1132-1138	40	2000	outcome	Raynaud´s phenomenon
Schuhfried et al. Arch Phys Med Rehabil; 81:495-9.	41	2000	diagnostic	Raynaud´s phenomenon
Cherkas et al.; Rheumatology 4:1384–1387	42	2001	diagnostic	Raynaud´s phenomenon
Coughlin et al. Occup Med 2001, 51, 75-80	43	2001	diagnostic	Hand-Arm-Vibration Syndrome
Schilk I, Thesis 2001	44	2001	diagnostic	Raynaud´s phenomenon
Hirschl et al; Vasa 2002;31 :91-4.	45	2002	outcome	Raynaud´s phenomenon
Merla et al, IEEE Eng Med Biol Mag; 21: 86-92	46	2002	diagnostic	Raynaud´s phenomenon
Yamamoto et al.; Industrial Health, 40, 59–62	47	2002	diagnostic	Hand-Arm-Vibration Syndrome
Mason et al.; Occup. Med. 53:325-330	48	2003	diagnostic	Hand-Arm-Vibration Syndrome
Melhuish et al; Thermology international, 13;27-32	49	2003	diagnostic	Raynaud´s phenomenon
Hirschl et al. J Rheumatol 31 :2408-2412	50	2004	outcome	Raynaud´s phenomenon
Rasmussen & Mercer, Thermology international 14:68-74	51	2004	diagnostic	Raynaud´s phenomenon
Suizu et al. Industrial Health, 44, 577–583	52	2006	diagnostic	Hand-Arm-Vibration Syndrome
Anderson et al. Rheumatology 46:533–538	53	2007	diagnostic	Raynaud´s phenomenon
Foerster et al.; J Dermatol Sci. 45, 113—120	54	2007	diagnostic	Raynaud´s phenomenon
Stefañczyket al.; Med Sci Monit. 13(Suppl 1): 121-128	55	2007	diagnostic	Raynaud´s phenomenon
Ammer, Thermology international, 18; 81-88	56	2008	diagnostic	Raynaud´s phenomenon
Chikura det al. Rheumatology 47;219–221	57	2008	diagnostic	Raynaud´s phenomenon
Jankovic et al; J Occup Health, 50; 473	58	2008	diagnostic	Hand-Arm-Vibration Syndrome
Traynor & MacDermid; Hand (2008) 3:212–219	59	2008	diagnostic	Raynaud´s phenomenon

Table 2
Patient preparation, measuring device, body part of which temperature was measured

Reference	body position	dressing	room temperature	acclimatisation. time	device	body part of which temperature was measured
9	sitting	?	24	30	thermography	dorsal, both hands
10	sitting	bare forearms	20	10	thermography, radiometer	dorsal, both hands
11	?	?	20	10	thermography	dorsal, both hands
12	?	?	?	?	thermography	dorsal, both hands
13	sitting	bare forearms	20	10	thermography, radiometer	dorsal, both hands
14	?	?	?	15	thermography	both hands
15	sitting	ß	23-26	30	thermocouple	affected finger of the left hand
16	sitting		23	10	thermistor	middle finger of the dominant hand
17	?	?	20	15	thermography	right hand
18	?	?	?	15	radiometer	dorsal, both hands
19	supine	?	22	30	thermistor	most affected finger
20	sitting	bare forearms	20	10	thermography,radiometer	dorsal, both hands
4	?	?	24	?	thermography	both hands
21	?	?	22±1	?	thermography, thermistor	dorsal, both hands
22	sitting	?	22,7-23, 23,2(3)-23,5	20	thermography	1 hand
23	sitting	?	23-25	20	thermography	palmar, both hands
24	?	?	20	0	thermography	dorsal, both hands
25	sitting	bare forearms	19- 21	15	thermography	dorsal, both hands
26	?	?	22.5-23.5	20	thermography	right hand
27	?	?	24	?	thermography	both hands
28	?	?	22-24	30	thermography	dorsal & palmar, both hands
29	?	?	24	20	thermography	both hands
30	supine	?	20-22	30	thermistor	right hand
5	sitting	?	22	15	thermography	both hands in front of chest
31	sitting	?	22.5-23.5	20	thermography	dorsal, both hands
32	?	bare forearms	24	15	thermography	dorsal, both hands
33	?	?	?	?	thermography	dorsal, both hands
34	sitting	bare legs	23±1	156	thermography	dorsal feet
35	sitting	?	22.5-23.5	15	thermography	dorsal, both hands
36	?	?	?	?	thermography	dorsal, both hands
37	?	bare arms	25±0,5	30	thermography	dorsal, both hands
38	?	?	23	20	thermography	dorsal, both hands
39	sitting	?	22.5-23.5	15	thermography	dorsal, both hands
40	supine	?	22	60	thermistor	palmar
41	sitting	bare forearms	24	20	thermography	dorsal, both hands
42	sitting	light clothing	23	15	thermography	palmar, both hands
43	?	?	25	45	thermography	palmar, both hands
44	?	?	?	?	thermography	palmar, both hands
45	sitting	bare forearms	24	15	thermography	dorsal, both hands
46	sitting	?	23±0.5	20	thermography	dorsal, both hands
47	sitting	?	23	30	radiometer	left hand
48	?	?	?	?	thermocouple	both hands
49	sitting	bare hands	20	15	thermography, radiometer	dorsal, both hands
50	sitting	bare forearms	24	15	thermography	dorsal, both hands
51	sitting	bare forearms	26-28	30	thermography	right hand, left foot
52	sitting	?	?	15	thermistor, thermography	palmar, both hands
53	?	?	23	20	thermography	dorsal, both hands
54	?	?	21	30	thermography	1 finger
55	sitting	?	20-25	20	thermography	right hand
56	sitting	bare forearms	24	15	thermography	dorsal, both hands
57	?	?	22-24	15	thermography	both hands
58	?	?	21- 23	?	thermography	palmar, both hands
59	?	?	18-22	15	radiometer	dominant hand

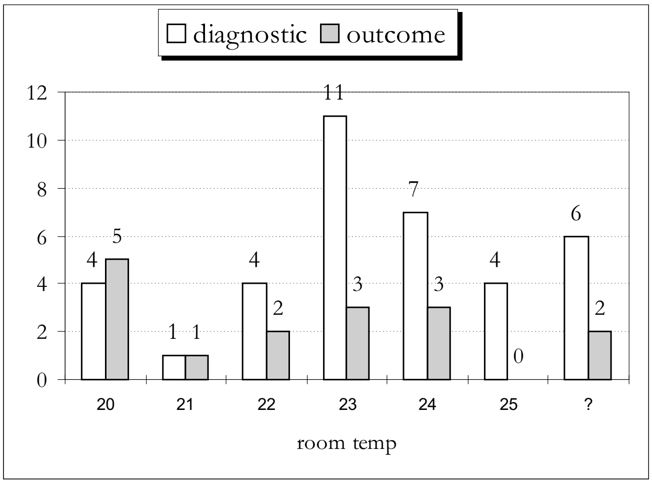

Figure 1
Room temperature for acclimatisation in studies using the cold challenge test for diagnosis or as an outcome measure.

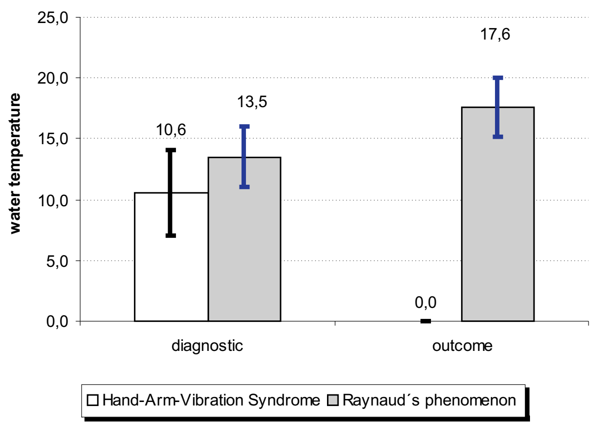

Figure 2
Mean values±standard deviation of water temperature in studies on hand-arm-vibration syndrome or Raynaud´s

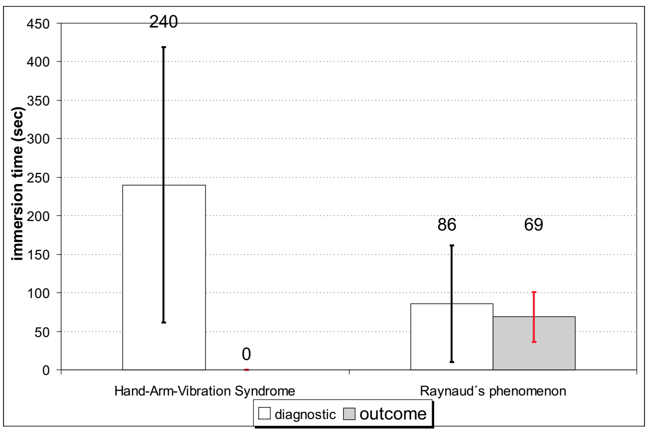

Figure 3
Mean values±standard deviation of immersion time in studies on hand-arm-vibration syndrome or Raynaud´s phenomenon

lications. A deviation of 0.2, 1.5, 2,0 or 2.5 from mean room temperature was indicated in 4 papers.

Device

Infrared thermography was used in 37 studies, 4 papers reported the combined use of infrared thermal images and a hand held radiometer, and 2 studies applied thermistors simultaneously with an infrared camera. In 5 publications thermistors were used for diagnostic measurements and for treatment evaluation in patients with Raynaud´s phenomenon. One study applied thermocouples for the evaluation of diagnostic temperature criteria in suspected hand-arm vibration syndrome.

Body parts of which temperature was measured

In the majority of studies measurements were taken from both hands, predominately from the dorsal surface. 8 papers reported measurements from just one hand and in 2 publications the measurement site was a single finger. Only two studies investigated the cold challenge test for toes.

Cold challenge test (table 3)

Gloves

70% of the studies immersed hands or feets with gloves. 13 papers reported a cold bath without protective clothing. In the remaining 3 publications information on protection against wetness was not available.

Water temperature

All but 2 studies(16, 30) used a water bath for the cold challenge. Freedman & Gianni (16) used a Pelletier element as cold stimulus, whose temperature decreased from 30°C to 20°C at a rate of 1°C/min and was then maintained at 20'C for six minutes. In the study by Wigley et al (30) the patients' hands were placed in a cold-air chamber (4 °C) for a maximum of 10 minutes. The times at which the finger temperatures reached 18 °C were recorded. If the finger temperatures did not reach 18 °C, the finger temperatures were recorded at 10-minute intervals after being placed in the chamber.

4 papers used more than one temperature level for provocation. Traynor & MacDermid started the cold challenge with immersion of the hand in water bath of 12 degrees C for 3 minutes, followed by immersion in ice water for 5 minutes. A group in Cambridge immersed the hands in warm water (37° C) for 3 min prior to the immersion in cold water (20° C) for 1 minute [17, 24, 25].

Figure 2 shows the mean values of water bath temperature in diagnostic and in outcome studies. The predominant water temperature value was 20 degrees followed by 15 degrees. More variety of water temperature was found in diagnostic studies than in studies that used the cold challenge as an outcome measure.

Immersion time

2 studies immersed the hand as long as the fingers reached a predefined temperature, which was 21°C in one paper [37] and 18°C in the other publication [30]. The mostly applied immersion time was 60 seconds, followed by 300 seconds.

Table 3
Condition of cold challenge test

Reference	gloves	water temperature	immersion time (sec)	interval (min)
9	yes	0 (ice water)	60	1.-45.
10	yes	20	60	4
11	yes	20	60	4, 10
12	yes	18	60	1,3,5,10,15,30,60
13	yes	20	60	4, 10
14	?	20	60	4, 10
15	no	0 (ice water)	20	60 seconds until recovery or for 30 Min
16	no	30 to 20 in 1 min steps, than 20	960	immediately after
17	yes	37, followed by 20	180 + 60	5,10,15,20
18	?	20	60	10, 15, 30
19	no	no	no	20,40,60
20	yes	20	60	10
4	yes	20	60	10
21	yes	14-15	120	1,2,3,4,5,6,7,8,9,1,15,20,25,30
22	yes	10	60	20 sec until recovery
23	yes	10	60	20 sec until recovery
24	no	20, after 3min at 37	60	1,5,10,15,20
25	no	20, after 3min at 37	60	5,10,15,20
26	yes	15	60	15 sec for 15 min
27	yes	50	60	5 to 60
28	no	15	60	60 sec for 12 Min
29	yes	16	60	1,2,,3,4,5,6,7,
30	no	4-cold air,(until finger temp=18°)	600	1,2,5,7,10
5	yes	29	60	10 min
31	yes	15	60	15 sec for 15 min
32	yes	20	60	5,10,15,20
33	yes	5	60	30 sec for 15 Min
34	yes	15	60	5, 10
35	yes	15	60	15 sec for 15 min
36		12	180	5,10,15, 20,30
37	yes	14	until finger temp=21°	until rewarming
38	yes	15	60	?
39	yes	15	60	60 sec for 10 min
40	no	15	180	10,20,32
41	yes	16	60	1,2,3,4,5,6,7,10,15,20
42	yes	15	60	10,20,30
43	yes	5	60	30 sec for 10 min
44	no	12	180	5,10,15,20,25,30
45	yes	20	60	20
46	yes	10	120	30 sec for 20 min
47	no	10	600	5, 10
48	?	15	300	60 sec for 10 min
49	yes	20	60	10, 20
50	yes	20	60	20
51	yes	10	120	30 sec for 7 min
52	yes	15	300	60 sec for 10 min
53	yes	15	60	15 sec for 15 min
54	no	12	90	60 sec for 30 min
55	no	0 (ice water)	12	1,3,6,12
56	yes	20	60	5,10,15,20
57	yes	15	60	10
58	yes	8	300	30 sec for 30 Min
59	no	12, followed by 0	180 + 300	2,4,6,8,10

Table 4
Measuring points and method of evaluation

REFERENCE	MEASURING POINTS	METHOD OF EVALUATION
9	percentage recovery	percentage recovery
10	all fingers	combined gradient finger-dorsum
11	dorsum, finger	combined gradient finger-dorsum
12	dorsum, finger 2-5 bil	temperature gradient
13	all fingers	combined gradient finger-dorsum
14	all fingers	combined gradient finger-dorsum
15	pulp of affected finger	recovery time
16	middle finger	absolute temperature decrease
17	finger	temperature gradient
18	wrist, MCP, fingertip	temperature gradient
19	dorsal between DIP and nail	absolute temperature
20	dorsum, finger	combined gradient finger-dorsum
4	dorsum, finger 2-5 bil	Combined gradient fingertip - dorsum
21		Recovery time
22	fingers	percentage recovery
23	fingers	percentage recovery
24	?	percentage recovery
25	?	temperature gradient
26	DIP 2,3,4,	temperature change in time
27		recovery time
28	DIP ,metacarpales	negative temperature gradient>0.5
29	DIP 2.3,4, PIP 3, RC	temperature change in time, temperature gradient, precentage recovery. Absolute temperature
30	fingertip middle finger	average rate of temperature decrease
5	dorsum, finger 2-5	gradient fingertip - dorsum
31	dorsum, finger 2,-5 bil	percentage recovery
32	MCP, fingertip	negative temperature gradient>0.5
33	fingertip, finger base	temperature gradient
34	each toe	percentage recovery
35	DIP 2,3,4,	lag time, maximum temperature recovery, percentage recovery
36	?	absolute temperature, recovery time
37	?	temperature change in time
38	?	lag time, maximum temperature recovery, percentage recovery
39	fingertips 2-5 , bil	mean finger temperature
40	Fingertips	absolute temperature
41	wrist, fingertip 2,3,4 bil	temperature change in time, temperature gradient, precentage recovery., absolute temperature
42	fingertip, 2,-5	absolute temperature, change of temperature. percentage recovery
43	fingertip, finger base	temperature gradient
44	?	recovery time, maximum temperatur change
45	dorsum, finger 2-5 bil	gradient fingertip - dorsum
46	each finger	recovery curve, tau-image
47	fingertip 2-4	maximum recovery, lag time, thermal gradient
48	volar fingertips	time to recovery by 4 degrees
49	dorsum, fingers2-5bil	combined gradient finger-dorsum
50	dorsum, finger 2-5 bil	gradient fingertip - dorsum
51	dorsum, DIP 1, PIP 3,DIP 4 finger	time to 80% rec0very
52	volar fingertip, finger base 2-5 bil	time to recovery by 4 degrees, temperature gradients, absolute temperatures
53	dorsum. Fingertip	maximum recovery, lag time, thermal gradient
54	fingertip	log of recovery time
55	nail middle finger, wrist	maximum recovery, lag time, thermal gradient
56	fingertip, metacarpals 1-5	gradient fingertip - dorsum
57	fingers	gradient fingertip - dorsum
58	?	rewarming rate, absolute temperature decrease
59	fingertip 2 and 5	percentage recovery

The mean value of immersion time in studies for Raynaud´s phenomenon was 80 ± 68 (95% confidence interval 60 to 100) seconds and 240 ±179(95% confidence interval 91 to 289) seconds for hand-arm-vibration syndrome. Figure 3 shows that the mean immersion time was slightly shorter studies reporting treatment effects on in patients with Raynaud´s phenomenon than in diagnostic investigations.

Interval between measurements

The time interval between the measurements varied between 15 seconds and 20 minutes. 5 and 1 minutes were the most frequently used intervals. 12 studies reported more than one time interval.

The observation time after the cold challenge ranged from immediately after the immersion up to 1 hour. 3 studies measured until temperature recovery. The observation time was 20 or 30 minutes in 65% of the studies. The mean of the observation time 20 ± 14 minutes for Raynaud´s phenomenon and 18 ± 10 in studies for hand-arm- vibration syndrome.

The number of measurements varied between 1 and 60, no preference was detected for the number of measurements.

Definition of measurement sites (table 4)

In 10 studies no information was available on which sites of the hand measurements were taken. In hand-arm-vibration syndrome, measurements were taken from the fingertips, and in 3 studies also from the base of the fingers. In most studies related to Raynaud´s phenomenon the measurements from fingers excluded the thumb, but determined the temperature also at the dorsum or palm of the hand. Complete information on which sites the measurements have been pefcormed, was not available from most of the publications.

Method of evaluation

22 ways of temperature evaluation were reported for the cold challenge test (table 5). Percentage temperature recovery and temperature gradients were the predominant methods. Diagnostic thresholds for temperature values have been reported in few studies only.

Discussion

There is a wide variety of cold challenge tests for diagnosing vasospastic disease of fingers. For hand-arm vibration syndrome national standards for the cold challenge test has been developed (48). The European Association of Thermology installed a working group on thermographic evaluation of Raynaud´s phenomenon, but the report from this group does not provide information about standardised proceduresof a cold challenge test or recommedations for the evaluation of thermal images recorded from patients with vasospastic disease[4]..

For detecting Rayaud´s phenomenon a milder cold challenge is suggested than for the identification of hand- arm vibration syndrome. Although early studies used ice water as cold challenege, most of the studies used a water bath temperature of either 15 or 20 degrees and an immersion time of 1 minute, particularly in studies which used the response to the cold challenge test as an outcome measure.

The predominante method of evalution was base on temperature gradients. The combined Thermal Index, pro-

Table 5
Methods of evaluation

method of evaluation	frequency	percentage	cumulated percentage
mean finger temperature	1	2,08	2,08
time to 80% recovery	1	2,08	4,17
absolute temperature	4	8,33	12,50
absolute temperature decrease	1	2,08	14,58
absolute temperature, recovery time	1	2,08	16,67
average rate of temperature decrease	1	2,08	18,75
combined gradient finger-dorsum	6	12,50	31,25
gradient fingertip - dorsum	6	12,50	43,75
lag time, maximum temperature recovery, percentage recovery	2	4,17	47,92
log of recovery time	1	2,08	50,00
maximum recovery, lag time, thermal gradient	1	2,08	52,08
percentage recovery	7	14,58	66,67
recovery time	3	6,25	72,82
recovery time, tau-image	1	2,08	75,90
rewarming rate, absolute temperature decrease,	1	2,08	77,98
temperature change in time	2	4,17	79,17
temperature gradient	6	12,50	91,67
time to recovery by 4 degrees	1	2,08	95,83
time to recovery by 4 degrees, temperature gradients, absolute temperatures	1	2,08	97,92
time to recovery, maximum temperatur change	1	2,08	100,00

posed by Ring in 1980 [11] , seems to have some advantages in comparison to other evaluation methods. The temperature gradient calculated from distal and proximal sites of the hand, relies on the obviously cold fingers in vasospastic disease. Combining the gradients prior to the cold challenge with the gradient 10 or 20 minutes after the cold provocation takes account of the fact, that some patients with negative gradients before the cold challenge may present with normal gradients after the cold provocation and other patient will present with the opposite finding [32]. A combined thermal gradient of an individual finger is diagnostic if the gradient is negative (i.e. the distal temperature is lower than the proximal temperature) and its absolute value is equal or greater than 1. Summarising small negative gradients between 0.5 and 0.9 will also result in combined gradients of diagnostic magnitude. Placement of measurement areas for the calculation of the combined thermal index affects the diagnostic sensitivity of the method [56]. Occasionally, patients were seen in which negative gradients 10 minutes after the cold challenge resolve within the following 10 minutes. These patients should be labelled as delayed temperature recovery, but not as Raynaud´s phenomenon [18, 32].

Medical physicists had promoted the rate of rewarming as the recommended method of evaluation for temperature measurements in Raynaud´s patients [37, 46]. However, more measurements are necessary to define the rewarming curve than for the calculation of the combined thermal gradients. For the rate of recovery. percentage of recovery, time until begin of rewarming (lag time) and maximum temperature decrease, measurement of finger and hand temperature must be conducted immediately after cold challenge which may be difficult due low thermal contrast of the fingers to the background. The determination of the time for full recovery is time consuming in routine evaluation of Raynaud´s patients. In addition, the diagnosis can not rely on the fact, that the temperature has recovered to the baseline value, because this temperature reading may have been taken from the distal part of a finger which has already presented with a marked negative temperature gradient. The drop of finger temperature is dependent from the temperature of the water bath and the duration of the immersion, and may not reflect a pathological response to a cold stimulus.

This review is intended to serve as basic information for the discussion of developing standard procedures for performing the thermographic evaluation of patients with sus- pected Raynaud´s phenomenon. Such a proposal for a standard must address patient´s preparation, temperature of the examination room, temperature and duration of the immersion bath, position of hands, time of follow-up after the cold challenge and method of evaluation. This standard may differ in diagnostic testing or in treatment monitoring. Procedures which are unclear or appear to be ambiguous in the literature, should be further investigated.

Finally, the approved standard should be applied in an epidemiological study which aims to investigate the co-incidence between clinical and thermographic signs of Raynaud´s phenomenon. For a better understanding of thermal imaging applied for treatment monitoring, measures of the severity of vasospastic disease of the hand must also compared with the thermographic findings. Comparison of temperature measurements with other methods of evaluation such as laser Doppler imaging or plethysmography are also of high interest.

References

1. Silman A, Holligan S, Brennan P, Maddison P. Prevalence of symptoms of Raynaud's phenomenon in general practice. Br Med J 1990; 301: 590-2

2. Chetter IC, Kent PJ, Kester RC. The hand arm vibration syndrome: a review. Cardiovascular Surg 1998, 6(1): 1-9

3. Ammer K. Thermal imaging as an outcome measure. Thermology international 2006; 16: 123

4. Ring EFJ, Aarts N, Black CM., Boesiger P. et a.l. Raynaud's Phenomenon: Assessment by Thermography. Thermology. 1988; 3:69-73

5. Ring EFJ.Cold Stress test for the hand In. Ammer K, Ring EFJ (eds) The Thermal Image in Medicine and Biology, Uhlen-Verlag, Wien 1995, pp. 237-240

6. Laskar S, Harada N. Different Conditions of Cold Water Immersion Test for Diagnosing Hand-Arm Vibration Syndrome. Environl Health Prevent Med 2005; 10, 351–359,

7. Herrick AL, Clark S Quantifying digital vascular disease in patients with primary Raynaud's phenomenon and systemic sclerosis. Ann Rheum Dis 1998; 57:70–78

8.Lindsell CJ. Test Battery for Assessing Vascular Disturbances of Fingers. Environ Health Prevent Med 2005 10, 341–350.

9. Chucker F, R.C. Fowler, C. W. Hurle,. Raynaud's Disorders Revisited. Am Fam Physician 1974; 10(2):70-78.

10.Ring EFJ; Owens CWI, Cosh JA, Eghiedari A.Infra-red techniques in the assessment of peripheral temperature response to antihypertensive drugs. In Birley DM (ed) The clinical impact of beta-adrenoceptor blockage. Horsham, UK. 1980, p.267-275

11. Ring EFJ: A thermographic index for the asssessment of ischemia. Acta thermographica 1980, 5:35-38

12.Ströbel G, Engel J-M. Dynamische Thermographie bei peripheren Zirkulationssstörungen. Thermographische Fachberichte 1980, 1: 46

13.Ring EFJ, Porto L, Bacon PA. Quantitative thermal imaging to assess inositol nicotinate treatment for Raynaud's syndrome. J Int Med Res 1981; 9: 393-400.

14. Martin MF, Dowd PM, Ring EF, Cooke ED, Dieppe PA, Kirby JD. Prostaglandin E1 infusions for vascular insufficiency in progressive systemic sclerosis. Ann Rheum Dis 1981;40: 350-354

15.Carroll GJ, Withers K, Bayliss CE. The prevalence of Raynaud's syndrome in rheumatoid arthritis Ann Rheum Dis 1981; 40:567-570.

16 Freedman RR, Ianni P. Role of cold and emotional stress in Raynaud's disease and scleroderma. BMJ 1983, 287: 1499-1502

17. Kyle MV,.Parr G..Salisbury R,.Page Thomas P, Hazleman BL: Thermography and Raynaud' s Syndrome. In.: Ring EFl, B.Phillips (eds): Recent Advances in Medical Thermology. Plenum Press, 1984, New York. London, pp.355-360

18 Bosmansky K, Tauchmannova H, Lukac J, Zitnan D. Auswertung der Panergontherapie bei Raynaud-Syndrom im Rahmen einer progressiven Sklerodermie. Z.Rheumatol 1985, 44: 242-245

19. Mohrland JS, Porter JM, Smith EA, Belch J,Simms MH A multiclinic, placebo-controlled, double-blind study of prostaglandin El in Raynaud's syndrome.Ann Rheum Dis 1985; 44: 754-760

20. McHugh NJ, Csuka M, Watson H, Belcher G, Amadi A, Ring EF, Black CM, Maddison PJ. Infusion of Iloprost, a prostacyclin analogue, for treatment of Raynaud's phenomenon in systemic sclerosis. Ann Rheum Dis 1988;47;43-47

21. Dupuis H. Thermographische Diagnostik des vibrationsbedingten vasospastischen Syndroms (VVS). ThermoMed 1989, 5:70-74

22. Darton K. Black CM. The Use Of Infra-Red Thermography In A Rheumatology Unit. .Br J Rheumatol 1990; 29: 291-292

23. Darton K. Black CM. Pyroelectric Vidicon Thermography and Cold Challenge Quantify the Severity of Raynaud's Phenomenon. Br J Rheumatol 1991; 30: 190-195

24. Shawket S, Dickerson C, Hazleman B, Brown MJ. Prolonged effect of CGRP in Raynaud's patients: a double-blind randomised comparison with prostacyclin. Br. J. clin. Pharmac. 1991, 32, 209-213

25. Kvle MV, Belcher G., Hazleman BL.: Placebo Controlled Study Showing Therapeutic Benefit of Iloprost in the Treatment of Raynaud's Phenomenon. J Rheumatol 1992; 19: l403-1406.

26. O'Reilly D, Taylor L, el-Hadidy K, Jayson MI. Measurement of cold challenge responses in primary Raynaud's phenomenon and Raynaud's phenomenon associated with systemic sclerosis. Ann Rheum Dis 1992;51;1193-1196

27. Tauchmannova H: Beitrag der Thermographie zur Diagnose und Therapieverlaufskontrolle bei systemischer Sklerodermie. Thermologie Österreich 1992: 2(2): 61-64.

28. Zurak N,Brzovic Z, Brinar V,. Vukadin S. Sequential Dynamic Computerized Telethermography in the Assessment of Raynaud's Syndrome Neurologia Croatica 1993, 42(2) 93-106

29Vacariu G, Schuhfried O, Korpan M.. Resch K, Fialka V. Normwertermittlung der thermographisch bestimmten Hand. temperatur. Thermologie Österreich 1994: 4(2): 66-72.

30. Wigley FM, Wise RA, Seibold JR et al. Intravenous Iloprost Infusion in Patients with Raynaud Phenomenon Secondary to Systemic Sclerosis A Multicenter, Placebo-controlled, Double-Blind Study. Ann Intern Med, 1994; 120: 199-206

31. Teh LS, Manning J, Moore T, Tully MP,. O'Reilly, Jayson MIV. Sustained-release transdermal glyceryl trinitrate patches as a treatment for primary and secondary Raynaud's phenomenon. Br J Rheumatol 1995; 34: 636-641

32. Ammer K. Diagnosis of Raynaud's phenomenon by thermography. Skin Research and Technology 1996; 2:182-185.

33. Chetter IC, Spark JI, Mercer K, Kent PJ, Berridge DC, Scott DJA, Kester RC. The Utilization of Cold Provocation Thermography in Upper Limb Vasospastic Conditions. Cardivascular Surgery 1997 September, 5: 45

34. Howell KJ, Kennedy LF, Smith RE, Black CM. Temperature of the toes in Raynaud's phenomenon measured using infra-red thermography. Eur J Thermol 1997, 7: 132-137

35. Jayanetti S, Smith CP, Moore T, Jayson MIV, Herrick AL. Thermography and Nailfold Capillaroscopy as Noninvasive Measures in Children with RP. J Rheumatol 1998, 25, 997-999

36. von Bierbrauer A ; Schilk I ; Lucke C ; Schmidt JA Infrared thermography in the diagnosis of Raynaud's phenomenon in vibration-induced white finger, Vasa. 1998; 27(2):94-9

37. Boesinger P, Geser HM. A Thermodynamic Model for thermographic Analysis of Tissue Perfusion and Its Regulation. Thermology 1999; 3: 191-198

38. Clark S, Hollis S, Campbell F, Moore Jayson M, Herrick A. The "Distal-Dorsal Difference" as a Possible Predictor of Secondary Raynaud´s Phenomenon. J Rheumatol 1999, 26, 1125-1128

39. Dziadzio M,. Denton CP, Smith R, Howell K, Blann A, Bowers E, Black CM. Losartan Therapy For Raynaud's Phenomenon And Scleroderma. Arthritis & Rheumatism, 1999, 42 (12) 2646-2655

40. Hayoz D, Bizzini G, Noel B, Depairon M, Burnier M, Fauveau C, Rouillon A, Brouard R, Brunner HR. Effect of SR 49059, a V1a vasopressin receptor antagonist, in Raynaud´s phenomenon. Rheumatology 2000, 39; 1132-1138

41 Schuhfried O, Vacariu G, Lang T, Korpan M, Kiener HP, Fialka-Moser V. Thermographic parameters in the diagnosis of secondary Raynaud's phenomenon. Arch Phys Med Rehabil 2000;81:495-9.

42.Cherkas LF, Howell K, Carter L, Black CM, MacGregor AJ. The use of a portable radiometry to assess Raynaud´s phenomenon; a practical alteranative to thermal imaging. Rheumatology 2001;40:1384–1387

43. Coughlin PA, Chetter IC, Kent PJ, Kester RC. The analysis if sensitivity, specificity, positive predictive value and negative predictive value of cols provocation thermography in the ob- jective diagnosis of hand-arm-vibration syndrome. Occup Med 2001, 51, 75-80

44. Schilk I. Die Wertigkeit unterschiedlicher Untersuchungsverfahren zur Beurteilung der peripheren Zirkulation in der apparativen Diagnostik des Raynaud-Phänomens. Dissertation Marburg, 2001

45. Hirschl M, Katzenschlager R. Ammer K. Melnizky P. Rathkolb O, Kundi M. Double-blind, randomised placebo controlled low level laser therapy sludy in patients with primary Raynaud's phenomenon. Vasa 2002;31 :91-4.

46. Merla A, . Di Donato L, Di Luzio S; Luca Romani G.. Quantifying the Relevance and Stage of Disease with the Tau Image Technique. IEEE Engineering In Medicine and Biology Magazine 2002; 21: 86-92

47. Yamamoto H, Zheng K-C, Ariizumi M. A Study of the Hand-Arm Vibration Syndrome in Okinawa, a Subtropical Area of Japan. Industrial Health 2002, 40, 59–62

48. Mason HJ, Poole K, Saxton J. A critique of a UK standardized test of finger rewarming after cold provocation in the diagnosis and staging of hand–arm vibration syndrome,Occup Med 2003; 53:325-330

49. Melhuish JM, Krishnamoorthy L, JR Harding, Wertheim DF, Williams RJ, Harding KG. Diagnosis of Raynauds Phenomenon Using a Hand Held Infra-red Scanner Compared to thermal Imaging. Thermology international 2003, 13: 27-32

50. Hirschl M, Katzenschlager R, Francesconi C, Kundi M. Low level laser therapy in primary Raynaud's phenomenon-results of a placebo controlled, double blind intervention study. J Rheumatol, 2004; 31: 2408 - 2412

51. Rasmussen LK, Mercer JB. A comparison of thermal responses in hands and feet of young and elderly subjects in response to local cooling as sertmined by infared imaging. Thermology international 2004, 14: 71-76

52. Suizu K, Inoue M, Fujimura T, Morita H, Inagaki J, Kan H, Harada N. Influence of Waterproof Covering on Finger Skin Temperature and Hand Pain during Immersion Test for Diagnosing Hand-arm Vibration Syndrome. Industrial Health 2006, 44, 577–583

53. Anderson ME, Moore TL, Lunt M; Herrick AL The 'distal–dorsal difference': a thermographic parameter by which to differentiate between primary and secondary Raynaud's phenomenon. Rheumatology 2007;46:533–538

54. Foerster J, Kuerth A, Niederstrasser E, Krautwald E, Pauli R, Paulat R, Eweleit M, Riemekasten G, Worm M. A cold- response index for the assessment of Raynaud's phenomenon J Dermatol Sci 2007; 45, 113—120

55. Stefañczyk L, Woyniakowski B, Pietrzak P, Majos A, Grzelak P. Comparison of thermography and Doppler sonography in the evaluation of the cold immersion test in women with excessive vasospastic reaction Med Sci Monit, 2007; 13 (Suppl 1): 121-128

56. Ammer K. The sensitivity of infrared imaging for diagnosing Raynaud´s phenomenon and for Thoracic Outlet Syndrome is dependent on the method of temperature extraction from thermal images. Thermology international 2008, 18, 81-88

57. Chikura.B, Moore TL, Manning JB, Vail A, Herrick.AL Sparing of the thumb in Raynaud's phenomenon. Rheumatology 2008; 47: :219-22

58. Jankovic S, Stankovic S, Borjanovic S), Tenjovic L, Bogdanovic M. Cold Stress Dynamic Thermography for Evaluation of Vascular Disorders in Hand-Arm Vibration Syndrome. J Occup Health 2008, 50; 473

59. Traynor R, MacDermid JC. Immersion in Cold-Water Evaluation (ICE) and Self-reported Cold Intolerance are Reliable but Unrelated Measures Hand 2008; 3:212–219

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An investigation into the effect on skin surface temperature of three cryotherapy modalities.

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ABSTRACT

OBJECTIVE: To investigate the comparative cooling effect at the knee, of Crushed Ice and two commonly used commercial cryotherapy modalities, following a clinically relevant application of 20 minutes.

DESIGN: Within subjects, randomised cross over design.

SETTING: University Laboratory

PARTICIPANTS: Eleven healthy male participants

MAIN OUTCOME Measures: Skin temperature over the anterior knee measured by thermal imaging camera.

RESULTS: Mean absolute baseline skin surface temperature (Tsk) was 28.4ºC (±1.2 ºC). The greatest reduction in Tsk was produced by Crushed Ice Δ14.6 ºC (±3.7 ºC) resulting in an absolute Tsk of 13.8 ºC; followed by Ice Man Δ12.3 ºC (±2.4 ºC) resulting in an absolute Tsk of 16.1ºC and then Arctic Flow Δ4.9 ºC (±1.3 ºC) resulting in an absolute Tsk of 23.5ºC. One-way ANOVA revealed significant differences ($p<.05$) between modalities for change in Tsk.

CONCLUSIONS: Crushed Ice and Ice Man produced very similar results following a 20 minute application to healthy adult male knees, however only Crushed Ice resulted in a skin temperature in the desired 10-15°C therapeutic range, results for Ice Man were just above this range. The resultant skin temperature following a similar application of Arctic Flow was well above the therapeutic range.

KEY WORDS: Cryotherapy, Skin Temperature, Thermal Imaging, Knee

EINE UNTERSUCHUNG ÜBER DIE BEEINFLUSSUNG DER HAUTTEMPERATUR DURCH DREI MODALITÄTEN DER KRYOTHERAPIE

ZIEL DER STUDIE: Vergleich des Kühleffektes von zerstosssenem Eis und zweier kommerziell verfügbarer Formen der Kältebehandlung am Kniegelenk bei ein klinisch relevanten Anwendungsdauer von 20 Minuten.

DESIGN: randomisierte Cross-over innerhalb derr Teilnehmer.

SETTING: Universitäts-Labor

TEILNEHMER: 11 gesunde Männer

HAUPTERGEBNISPARAMETER: Die mit einer Infrarotkmera bestimmte Hauttemperatur an der Knievorderseite.

ERGEBNISSE: Der Durchschnittwerte der mittleren Ausgangswertes der Hauttemperatur (T_h) betrug 28.4ºC (±1.2 ºC). Die größte Verminderung der Hauttemperatur wurde durch zerstossenes Eis im Ausmaß von Δ14.6 ºC (±3.7 ºC) erzielt, was zu einer absoluten T_h von13.8 ºC; geführt hatte. Es folgten "Ice Man" mit einer Temperaturdifferenz von Δ12.3 ºC (±2.4 ºC) und einer absolute T_h von 16.1ºC und "Arctic Flow" mit einer Δ4.9 ºC (±1.3 ºC) und einer resultierenden T_h von 23.5ºC. Hinsichtlich der Änderung der T_h fand eine einfache ANOVA signifikant Unterschiede ($p<0.05$) zwischen den Modalitäten.

SCHLUSSFOLGERUNG: Zerstossenes Eis und "Ice Man" führten nach 20 Minuten Anwendung an den Kniegelenken gesunder Männer zu ähnlichen Ergebnissen, obwohl nur zerstossenes Eis die gewünschte Hautemperatur im therapeutischen Bereich zwischen 10-15°C erzielt, während die Werte nach "Ice Man" knapp über diesen Bereich lagen Die erzielte Hauttemperatur nach der Anwendung von "Arctic Flow" lag deutlich über den gewünschten Bereich.

KEY WORDS Kryotherapie, Hautemperatur, Thermographie, Knie

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Introduction

Cryotherapy is a popular treatment modality for the immediate care of soft tissue injury, despite occasional reports of the complication of ice burn [1,2,3,4,5,6]. Although these reports are relatively infrequent and small in number relative to the frequency of application of cryotherapy they do continue to occur periodically over time. This indicates that clinicians need to remain vigilant for any adverse reactions when applying cryotherapy modalities; underpinning this is the requirement for a good understanding of the effects of the particular modality utilised. In particular in scenarios where clinicians have a choice between a number of modalities it is important to know what different cooling effects may occur.

Although the skin is rarely the target tissue for cryotherapy, the superficial nature of application dictates that it is unavoidably the tissue that will be cooled first due to its immediate proximity to the cooling modality. Therefore an understanding of the effect of cryotherapy on skin temperature (Tsk) is important. On a practical level in most clinical scenarios it is also the only tissue where temperature can actually be monitored and recorded. The optimum Tsk needed to gain beneficial therapeutic physiological changes, within deeper target tissues has been reported as being in the range of 10-15°C [7,8]. There is some debate over how much cooling takes place in the subcutaneous tissues during and following cryotherapy applications; MacAuley [7] and Merrick [9] provide comprehensive reviews of the evidence that supports that superficially applied cryotherapy modalities have beneficial physiological effects in deeper subcutaneous effects. Recently Hardaker et al [10] were able to demonstrate a strong relationship between Tsk and intramuscular temperature at 3cm sub-adipose depth in the quadriceps in adult male subjects during and after cryo- therapy.

According to Von Nieda & Michlovitz [11] the magnitude of tissue temperature change and the physiological response to cryotherapy depend on the interplay of four factors

- Temperature difference between cryotherapy and target tissue (Fourier's Law)
- Length of exposure
- Thermal conductivity and specific heat capacity of the area being cooled
- Thermodynamic properties of the cooling agent

Table 1 presents Tsk data from a number of cryotherapy studies, in order to assist comparability lower limb studies only have been included.

Table 1.
Studies comparing different cryotherapy modalities applied to the lower limb
* indicates where T*sk* lies within desired therapeutic range of 10-15°C

Authors, length of application, body part	**Cryotherapy Modality**	**Resultant absolute T*sk***
Belitsky, Odam, & Hubley-Kozey [23] 15 minutes: Gastrocnemius	Wet ice Dry ice Gel pack	17.9°C 20.1°C 22.1°C
Oosterveld, Rasker, Jacobs, & Overmars [24] 30 minutes: Knee	Ice chips Nitrogen-cold air	11.5°C * 13.8 °C *
Merrick, Knight, Ingersoll, & Potteiger [25] 30 minutes: Quadriceps	Compression & Crushed ice Crushed ice	4.94°C 7.24°C
Chesterton, Foster, & Ross [13] 20 minutes: Quadriceps	Gel pack Frozen peas	14.4°C * 10.8°C *
Kim, Baek, Choi, Lee, & Park [12] 5 minutes: Knee	Cold air	9.7°C
Merrick, Jutte, & Smith [26] 30 minutes: Quadriceps	Ice bag Wet ice Gel Pack	6.47°C 6.24°C 9.86°C
Warren, McCarty, Richardson, Michener, & Spindler [27] 30 minutes: Knee	Ice Cryo/Cuff	8°C 14.8°C *
Kanlaynaphotporn & Janwantanakul [28] 20 minutes: Quadriceps	Ice pack Gel pack Frozen peas Water and Alcohol	10.2°C * 13.9°C * 14.4°C * 10.0°C *
Hardaker, Moss, Richards, Jarvis, McEwan, & Selfe [10] 15 minutes: Quadriceps	Crushed ice	13.9°C *
Kennet, Hardaker, Hobbs, & Selfe [29] 20 minutes: Ankle	Crushed Ice Water Immersion Frozen Peas Gel Pack	11.2°C * 13.2°C * 15.0°C * 17.4°C

A brief review of table 1 shows that no clear picture emerges as to the optimum cryotherapy modality for reducing lower limb Tsk to the therapeutic target range of 10-15ºC. Despite only lower limb studies being selected there are a number of confounding factors which make interpretation of the data in Table 1 difficult from a clinical perspective; these are related to the four factors highlighted earlier [11]. The first factor is related to Fourier's law which states that; "per unit area the transfer of heat in a given direction is proportional to the temperature gradient", this suggests that a cryotherapy modality with a lower temperature offers greater opportunity for heat energy transfer, which should then result in a lower Tsk. In the study by Kim, Baek, Choi, Lee, & Park [12] cold air at a temperature of -30ºC was used resulting in a temperature gradient of 61.8ºC whereas Chesterton, Foster, & Ross [13] used frozen peas at 0.31ºC resulting in a temperature gradient of approximately 30.2ºC. Despite the large difference in magnitude of the temperature gradients the resultant Tsk are not actually very different from each other, in the Kim, Baek, Choi, Lee, & Park [12] study absolute Tsk was 9.7ºC and in the Chesterton, Foster, & Ross [13] study the absolute Tsk was 10.8ºC;. The reason for this lack of difference despite the very large differences in temperature gradients relate to the length of exposure to the modality. Kim, Baek, Choi, Lee, & Park [12] used 5 minutes whereas Chesterton, Foster, & Ross [13] applied the modality for 20 minutes. The differences in the anatomy and physiology of the target body parts under the skin i.e. joint or muscle, in terms of their thermal conductivity and their specific heat capacity are also important even though all the studies presented are in the lower limb. The specific heat capacity of muscle is 3.75 j/g/ºC compared to that of 1.59 j/g/ºC for bone [14]. Tissue with a higher specific heat capacity will retain more heat than tissue with a lower specific heat capacity when the same cryotherapy modality at the same temperature is applied. There are also striking differences in the thermodynamic properties of the modalities studies. For example ice will undergo phase change, absorbing a large amount of heat energy as it changes physical state melting from ice to water, whereas a gel pack or a Cryo/Cuff will not undergo phase change so will therefore not absorb as much heat energy. The studies in Table 1 that compared crushed ice with other modalities consistently report lower Tsk following crushed ice compared to the other modalities studied, highlighting the importance of the effect of phase change in cryotherapy.

Commercial cryotherapy products are widely available and are popular, yet their comparative efficacy and their efficiency remain under investigated. Reviewing Table 1 supports the view of Merrick [9] who states that there are few data indicating which form of cryotherapy is most effective. The aim of this study was to investigate the comparative cooling effect at the knee, by measuring Tsk, following a clinically relevant application of 20 minutes of Crushed Ice and two commonly used commercial cryotherapy modalities Ice Man and Arctic Flow.

Methods

Participants

The study received ethical approval from the Faculty of Health Research Ethics Committee, University of Central Lancashire (UCLan), Preston, England, it also conformed to the World Medical Association Declaration of Helsinki [15]. Written informed consent was gained from all participants prior to participating in the study. Eleven healthy male participants mean age 29.6 (±9.3) years were recruited from staff and student populations at UCLan, Preston, England. Male participants only were selected due to the gender differences found in females in response to local cooling [16]. A within subjects randomised cross over design [17] was used where all participants were required to attend 3 separate testing sessions, at the same time of day, one for each of the modalities, at least 24 hours apart from each other.

Prior to testing participants were screened for eligibility for participation in the study, exclusion criteria were; referred pain to the knee from any other lower limb or spinal joint, increased temperature of the knee joint, sensory deficit, cold intolerance/hypersensitivity and any skin lesions. Pre- testing participants were requested to adhere to the following standardised thermal imaging data collection protocol; no caffeine consumption, cigarettes or exercise 2 hours before and no alcohol for 24 hours before testing [18, 19, 20]. Ambient room temperature was recorded using a thermometer, throughout each test session to ensure a thermally stable environment; mean ambient room temperature was 23.3ºC ±1.9ºC.

Equipment

Exposed lower limbs were given a 15 minute acclimatisation period, away from heat sunlight and draughts to allow stabilisation to room temperature [18, 19, 20]. Participants were seated comfortably in a chair with knees at an angle of 45°. A ThermoVision, A40M, Thermal Imaging camera (Flir systems, Danderyd, Sweden) was positioned 0.91m from the right knee, on a tripod, at an angle of 45° in parallel with the anterior surface of the knee.

Cryotherapy Application

An Anatomical Marker System was applied to the skin surface of the anterior knee to facilitate defining a region of interest (ROI) in subsequent thermal data analysis. This consisted of small thermally inert anatomical markers placed in 4 positions; tibial tubercle, medial and lateral border of patella tendon at the level of the tibiofemoral joint line and centre of the base of the patella [21]. A baseline thermal image of the knee was taken prior to cryotherapy application. Each cryotherapy modality was applied to the right knee in all participants for 20 minutes in accordance with the PRICE guidelines which suggest an application time of 20-30 minutes for ice [22].

The order of application of the 3 different cryotherapy modalities was randomised using a computer generated randomisation schedule, the modalities were;

1. One litre of Crushed Ice (Scotsman Ice Machines, Milan), contained within a plastic bag, and placed over a damp towel.

2. Arctic Flow (DJO, Guildford, Surrey, England), consists of a flask containing crushed ice mixed with water connected to a knee sleeve. The flask is raised above the level of the knee sleeve to allow gravity to feed the cold water to the knee sleeve.

3. Ice Man (DJO, Guildford, Surrey, England), consists of a reservoir for crushed ice mixed with water connected to a knee sleeve. An electric pump circulates the cold water continuously through the knee sleeve.

A thermal image to record the temperature of each treatment modality was taken immediately pre and post application. Immediately following the removal of the cryotherapy application a second thermal image of the knee was taken.

Thermal data analysis

Quantification of thermal images was facilitated by computer linked to the thermal camera and was carried out using Thermacam Researcher 2.8 (Flir systems, Danderyd, Sweden) software, and then processed in Microsoft Excel. The ROI was the anterior knee as defined by the anatomical markers; mean temperature for the ROI was taken from each thermal image. The ROI was drawn using the polygon tool within the computer software.

Statistical analysis

One way repeated measures analyses of variance (ANOVA) at a 95% confidence interval was used to determine differences between modalities for temperature change, the mean absolute Tsk immediately following cryotherapy application and the effect of the modality on change in mean Tsk pre to post application. Pairwise comparisons with Bonferroni adjustment were used to highlight specific significant differences between the modalities.

Results

Modality temperature

Crushed Ice had the lowest absolute pre-application modality temperature 3.9°C (±0.9°C), followed by Ice Man 7.6°C (±3.5°C) and Arctic Flow 8.3°C (±4.5°C). All modalities demonstrated an increase in temperature post application.The greatest temperature increase post application was demonstrated by Arctic Flow Δ10.6°C (±3.6°C); Ice Man increased the least Δ0.7°C (±1.2°C); Crushed Ice increased by Δ1.08°C (±1.2°C). One-way ANOVA revealed significant differences ($p<0.05$) between modalities for temperature change. Post-hoc testing with Bonferroni correction highlighted that the rise in temperature in the Arctic Flow was significantly more than that of Crushed Ice ($p <0.01$) and Ice Man ($p <0.01$). However, no significant differences were found between Crushed Ice and Ice Man.

Skin surface temperature

Mean absolute baseline skin surface temperature was 28.4ºC (±1.2 ºC). The greatest reduction in Tsk was produced by Crushed Ice Δ14.6 ºC (±3.7 ºC) resulting in an absolute Tsk of 13.8 ºC. This was followed by Ice Man Δ12.3 ºC (±2.4 ºC) resulting in an absolute Tsk of 16.1ºC and then Arctic Flow Δ4.9 ºC (±1.3 ºC) resulting in an absolute Tsk of 23.5ºC. One-way ANOVA revealed significant differences ($p<0.05$) between modalities for change in Tsk. Post-hoc testing with Bonferroni correction highlighted that the differences were between; Crushed Ice and Arctic Flow ($p<0.01$), and between; Ice Man and Arctic Flow ($p<0.01$); there was no significant difference between Crushed Ice and Ice Man ($p>0.05$).

Discussion

All three modalities were applied according to the manufacturer's instructions for a clinically relevant period of time [22], as predicted the temperature of each of the modalities increased and the Tsk decreased in all experimental conditions, as the modalities and the skin moved towards a state of thermal equilibrium during the period of application. However the results for the Arctic Flow were significantly different to Crushed Ice and Ice Man which produced very similar results to each other.

Modality temperature

Ice Man and Arctic Flow both had very similar baseline temperatures 7.6°C and 8.3°C respectively which would have produced similar temperature gradients with the skin. These two modalities would therefore be predicted to have similar effects; however the results from these two mo- dalities were significantly different to each other, Ice man absolute Tsk 16.1ºC: Arctic flow absolute Tsk 23.5ºC. The baseline temperatures were similar as both modalities consist of iced water systems however it is their mode of operation that produced the significant difference in Tsk, as the pump system in Ice Man ensures a constant cir- culation of cold water to the knee sleeve therefore in- creasing the cooling effect. In the Arctic Flow no cir- culation of the water takes place and the temperature of the skin and the water in the knee sleeve move towards a state of thermal equilibrium, this is highlighted by the large Δ10.6 ºC rise in temperature of the Arctic Flow during the experiment.

In contrast the temperature of Ice Man and Crushed Ice increased very little Δ0.7°C and Δ1.08°C respectively and results reveal no significant difference in temperature between these two modalities. As stated previously Crushed Ice will have undergone phase change, as the ice closest to the skin melted, fresh ice will have replaced it promoting further phase change. A similar mechanism will have occurred in the Ice Man due to the pump circulating the cold water through the reservoir of iced water.

Skin surface temperature

Following application the resultant absolute Tsk for each modality was Crushed Ice 13.8°C, Ice Man 16.1°C and Arctic Flow 23.5?C, this is consistent with the data from the studies presented in Table 1 where the application of Crushed Ice consistently produces the lowest skin temperatures when compared to other cryotherapy modalities.

As previously stated the desired temperature range of the skin temperature is reported as 10-15°C in order to produce beneficial physiological effects within sub-cutaneous tissues [7, 8]. The results of this study suggest that when applied for 20 minutes, only Crushed Ice would be capable of producing a positive therapeutic effect. However, although the mean absolute Tsk of 16.1°C for Ice Man falls just above, the therapeutic range, when considering the standard deviation of ±2.4 °C it becomes apparent that this modality is capable of reducing Tsk to fall within the desired range. Further studies may wish to investigate if a longer application time for this modality would result in a skin temperature within the therapeutic range.

Application of Arctic Flow resulted in an absolute Tsk of 23.5°C which falls well outside the therapeutic range, the reasons for this have been discussed above. However, this modality should not be discounted as it could still have a useful role in those patients that are unduly sensitive to cold and who would benefit from a mild cooling effect. Alternatively clinicians who require stronger cooling effects when using this modality should ensure that periodically the knee sleeve is drained and then refilled with fresh cold water from the flask in order to maintain the desired temperature in the knee sleeve, further work would be required to define the optimal time interval between draining and refilling.

Conclusion

Crushed Ice and Ice Man produced very similar results following a 20 minute application to healthy adult male knees, however only Crushed Ice resulted in a skin temperature in the 10-15°C therapeutic range, results for Ice Man were just above this range. The results demonstrated that the resultant skin temperature following a similar application of Arctic Flow was well above the therapeutic range, reasons for this and the clinical implications have been discussed.

This study adds to the body of knowledge that provides a scientific underpinning of clinical practice. When there is a choice the physical characteristics and performance capability of different cryotherapy modalities should be understood and used to inform clinical reasoning processes. Additionally it is also important to remember that applying the same cooling stimulus to different anatomical regions will provoke a different cooling response dependent on the local anatomy and physiology. Although the physiological responses to cryotherapy modalities requires further investigation, it is useful to remember that a skin temperature range of 10-15°C should be aimed for when applying cryotherapy modalities.

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Conflict of Interest

The authors would also like to thank DJO who supplied the Arctic Flow and Ice Man, however DJO had no role in the design, analysis or interpretation of the study or its findings.

References

1.Cipollaro VA. Cryogenic injury due to local application of a reusable cold compress. Cutis. 1992; 50: 111-112.

2.Fye K H, Denkler K. Gangrene as a complication of topical ice therapy. Journal of Rheumatology. 1993; 20: 1808-1810.

3.O' Toole G, Rayatt S. Frostbite at the gym: A case report of an ice pack burn. British Journal of Sports Medicine. 1999; 33: 278-279.

4.Graham C A, Stevenson J. Frozen chips: An unusual cause of severe frostbite injury. British Journal of Sports Medicine. 2000; 34: 382-384.

5.Cuthill J A, Cuthill G S. Partial thickness burn to the leg following application of a cold pack: Case report and result of a questionnaire survey of Scottish physiotherapists in private practice. Physiotherapy. 2006; 92: 61-65.

6.Selfe J, Hardaker NJ, Whittaker J, Hayes C. Ice burn to the knee: A case report Physical Therapy in Sport. 2007; 8: 153-158.

7.MacAuley D C. Ice Therapy: How good is the evidence? International Journal of Sports Medicine. 2001; 22: 379-384.

8.Bleakey C, McDonough S, MacAuley D. The Use of ice in the treatment of acute soft-tissue injury. The American Journal of Sports Medicine. 2004; 32: 251-261.

9.Merrick MA. Physiological basis of physical agents. In: Magee DJ, Zachewski JE, Quillen WS. (Eds). Scientific foundations and principles of practice in musculoskeletal rehabilitation. Saunders, Misouri. 2007.

10.Hardaker N, Selfe J, Richards J, Sullivan I, Moss A, Jarvis S. Relationship Between Intramuscular Temperature and Skin Surface Temperature as Measured by Thermal Imaging Camera. Thermology International. 2007; 17: 45-50.

11.Von Nieda K, Michlovitz SL. Cryotherapy. In: Michlovitz SL (Ed). Thermal agents in rehabilitation 3rd Edition. F.A. Davies Company, Philadelphia. 1996.

12.Kim Y, Baek S, Choi K, Lee S, Park S. The effect of cold air application on intra-articular and skin temperatures in the knee. Yonsei Medical Journal. 2002; 43: 621-626.

13.Chesterton LS, Foster NE, Ross L. Skin Temperature Response to Cryotherapy. Archives of Physical Medicine and Rehabilitation. 2002; 83: 543-549.

14.Cameron MH. Physical agents in rehabilitation. W.B. Saunders Company, Philadelphia. 1999.

15. World Medical Association. Declaration of Helsinki. http://wma.net. 1964.

16.Cankar K, Finderle Z. Gender differences in cutaneous vascular and autonomic nervous response to local cooling. Clin Auton Research. 2003; 13: 214-220.

17.Sim J, Wright C. Research in Health Care. Nelson Thornes, Cheltenham. 2000.

18.Ben-Eliyahu DJ. Infrared thermographic imaging in the detection of sympathetic dysfunction in patients with patellofemoral pain. J Manip Physiol Therapeutics. 1992; 15: 164-70.

19.Mayr H. Thermographic evaluation after knee surgery. In Ammer K, Ring E FJ (Eds). The Thermal Image in Medicine and Biology . Uhlen-Verlag, Wien. 1995.

20.Sherman RA, Woerman AL, Karstetter KW. Comparative effectiveness of videothermography, contact thermography and infrared beam thermography for scanning relative skin temperature. Journal of Rehabilitation Research and Development. 1996; 33: 377-386.

21.Selfe J, Hardaker NJ, Thewlis D, Karki A. An accurate and reliable method of thermal data analysis in thermal imaging of the anterior knee for use in cryotherapy research. Archives of Physical Medicine and Rehabilitation. 2006; 87: 1630-1635.

22.ACPSM. Guidelines for the management of soft tissue (musculoskeletal) injury with protection, rest, ice, compression and elevation (PRICE) during the first 72 hours. Chartered Society of Physiotherapy, London. 1999.

23.Belitsky RB, Odam SJ, Hubley-Kozey C. Evaluation of the effectiveness of wet ice, dry ice, and cryogen packs in reducing skin temperature. Physical Therapy. 1987; 67: 1080-1084.

24.Oosterveld F G J, Rasker JJ, Jacobs JWW, Overmars HJA. The effect of local heat and cold therapy on the intraarticular and skin surface temperature of the knee, Arthritis and Rheumatism. 1992; 35: 146-151.

25.Merrick M A, Knight KL, Ingersoll CD, Potteiger JA. The effects of ice and compresion wraps on intramuscular temperatures at various depths. Journal of Athletic Training. 1993; 28: 236-245.

26.Merrick M A, Jutte L S, Smith M E. Cold modalities with different thermodynamic properties produce different surface and intramuscular temperatures. Journal of Athletic Training. 2003; 38: 28-33.

27.Warren TA, McCarty EC, Richardson AL, Michener T, Spindler KP. Intra-articular knee temperature changes : Ice versus cryotherapy device. The American Journal of Sports Medicine. 2004; 32: 441-445.

28. Kanlaynaphotporn R, Janwantanakul P. Comparison of skin surface temperature during the application of various cryotherapy modalities. Archives of Physical Medicine and Rehabilitation. 2005: 86; 1411-1455.

29.Kennet J, Hardaker N, Hobbs S, Selfe J. A comparison of four cryotherapeutic modalities on skin temperature reduction in the healthy ankle. Journal of Athletic Training. 2007; 42: 343-348.

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General Assembly of the European Association of Thermology (EAT) held on September 17th, 2009 in Mannheim

James B. Mercer, Anna Jung, Kurt Ammer

European Association of Thermology, Vienna, Austria

The General Assembly took place on September 17th, 2009, commencing at 18:30 hrs, at the Hotel Wartburg in Mannheim, Germany. The President Prof. Anna Jung opened the General Assembly. Delegates from 6 of the 8 Member Societies and 2 individual members were present.

As more than half of all members with voting rights were present, the General Assembly was entitled to make decisions without delay. The Agenda included: a report from the president; a report from the general secretary and treasurer; a statement from the auditors; election of a new board; and any other business.

President's Report EAT 2006-2009

Prof. Anna Jung reported the main events of the EAT in the period from 2006 to 2009. The tenth European Congress of Thermology was held in Zakopane Poland, and was successful in bringing together colleagues from Europe, Russia, Australia and the USA with a full programme of lectures. Across Europe, annual meetings have continued in Poland, the United Kingdom, Austria and Germany.

Prof. Benko and colleagues in Budapest have continued the long running series of meetings entitled "Thermogrammetry". These conferences are held under the auspices of the Thermal Engineering and Thermogrammetry organisation in Hungary, and included a technical exhibition. The 15th THERMO conferences was organised in June 2007, the 16th conference took place this year in July, and the next meeting has been announced for 2011.

Prof. B. Wiecek, delegate of the Polish Association of Thermology in the EAT Council, was responsible for or-ganising the 9th QIRT 2008 conference in Krakow. This well attended conference had a number of papers on bio-medical applications. Almost all of these papers were pre-sented by members of the EAT.

The activity of the training course on the theory and practice of thermal imaging in medicine has continued at the University of Glamorgan., although a full Glamorgan course was only held once, in 2007. Compressed 1 day versions of the course were held at the International Thermology Conference in Auburn, Alabama in 2007 and at the QIRT 2008 Congress in Krakow. The short course in Auburn was attended by 25 people, while about 40 people registered for the course in Krakow. Last year a full time course was organised by the Romanian Society of Thermology in co-operation with the EAT, the University of Glamorgan and University of Medicine "Carol Davila" and partly funded by a grant from the Romanian Ministry of Education and Research. The course was held in Bucarest, Romania, and attracted more than 60 participants.

Prof. James Mercer from the University of Tromsø in Norway, continued with his activities to promote the technique of infrared thermal imaging. This year he launched a web site for the EAT at www.europeanthermology.com. It is hoped that this site will become a major platform of communication between thermologist in Europe and around the World.

Prof Mercer and Prof Ring have been members of a special committee of the International Standards Organisation that has drawn up a standard for the correct use of infrared cameras as a fever screening tool. The final standard was just recently released. For the first time in a long time, the EAT published a position paper on the evolving application of infrared thermal imaging for fever screening. The statement can be found on the EAT web site and also in our journal, Thermology international. EAT members have also acted as referees or invited editors for journal submissions related to the topic of fever screening with infrared imagers and as referees for grant applications related to research in thermology.

The journal Thermology International now serves as an official publication organ for 6 national and 1 international Thermology Association. The Brazilian Society of Thermology joined the journal in October 2007. Prof. M. Brioschi, President of the Brazilian Society of Thermology, Prof. H. Usuki, President of the Japanese Society of Thermology, and Prof J.B. Mercer became members of the editorial board.

Finally President Prof Jung expressed her thanks to the members of the EAT board and the EAT Council of National Delegates, and especially to Prof James Mercer, whose effort to design, launch and maintain the EAT website was highly appreciated.

Report of the general secretary and treasurer

Currently the EAT has 7 affiliated National Societies and 4 individual members. The two German Societies are still in the process of merging, the continuing German Society of Thermography & Regulation Medicine has 108 members, the Italian Society has 8 members and 10 thermographers are organised in the Medical Group of the UK Thermography Association (UKTA). There are 18 members in the national society in Romania. The Austrian Society comprises 25, the Polish Association 30 and the Hungarian Thermology International Society 40 members. In total, 253 Europeans hold either individual or associated membership (through an affiliated society) in the EAT.

Most of the membership fees were paid prior to the General Assembly 2009, the remaining unpaid fees were received during the 11th European Congress of Thermology. The balance of the EAT account as per September 17th. 2009, had a surplus of 2456.50-Euro.

The treasurer Prof. Kurt Ammer reported that the main expenses of the EAT are production costs for the journal Thermology International. A balance in the EAT account was only achieved as a result of a private donation of approximately 1100.-Euro from the treasurer.

In order to increase the financial means of the society, the treasurer suggested the following

- oto increase the annual membership fee for member societies from 40.-Euro/per member in the member society to 50.-Euro.
- oto increase the annual subscription fee for the journal to 50.-.Euro for members, and to 60.-Euro plus 18.-Euro for mailing outside Austria for non EAT- members.
- oto increase the number of subscriptions to the journals from the national societies
- oto increase the membership numbers in the EAT

Statement of the Auditors

Dr Plassmann reported on behalf of both auditors, that both auditors had checked the accountancy of the EAT, without finding any irregularities. Dr Plassmann finally asked the General Assembly to accept the finance report and to relieve the board members from their responsibilities. The General Assembly agreed unanimously.

Election of a new board

After that, the board members resigned and Prof. Ammer asked Dr Plassmann to conduct the elections for the new board. Prior to the General Assembly the following nominations had arrived within the time limit set by the EAT:

- President: Prof. James B. Mercer, Ph.D. Norway
- Vice-President; Prof. Dr. med Anna Jung, Poland
- General Secretary/Treasurer:
  Prof. Dr. med Kurt Ammer, PhD Austria.

The majority of the General Assembly agreed with the nominations. President, Vice-President and General Secretary/Treasurer were unanimously elected with one abstention.

They newly elected Board of the EAT graciously accepted their positions on the Board and promised to fulfil their duties to the best of their abilities.

The following nominations for membership in the Council of National Delegates were received. Nominees, who were unable to attend the General Assembly, had sent a written statement expressing their willingness to be nominated.

- Prof Dr. R.Berz, Germany
- Dr. H.Sauer, Germany
- Prof Dr B.Wiecek, Poland
- Prof. Dr. E.F.J.Ring; UK
- Mr. Kevin Howell, UK
- Prof. Dr. I.Benkö, Hungary
- Prof.Dr.A.Nica, Romania
- Prof Dr.J.Demmink, Norway
- Dr. G.Dalla Volta, Italy

There were no objections to these nominations and the General Assembly unanimously agreed with their election as members of the Council of National Delegates.

Finally, the newly elected president Prof J Mercer conducted the General Assembly.

Any other business

Prof Mercer discussed future directions of the EAT and possibilities to improve the finances of EAT. Ways of less expensive production of the journal were discussed, particularly the possibility of producing the journal as an internet journal only. It was agreed that the journal should continue as a printed publication, but an additional web publication was suggested. Dr Plassmann offered to investigate the printing costs for the journal at the printing facility of the University of Glamorgan.

Decision on membership fees and other financial matters will be made at the next board meeting of the EAT.

Prof. Mercer closed the General Assembly at 19:40.

Infrared Centenary, October 2010

Francis J Ring

Fellow of the Royal Photographic Society; Fellow of the Royal Astronomical SocietyUniversity of Glamorgan UK

The Royal Photographic Society of Great Britain is coordinating a series of events in 2010 to commemorate the first publication of an infrared photograph. In October 1910 Professor Robert Wood, (fig1) visited the UK to present his paper on infrared photography to the Royal Photographic Society in London. It was also published in The Journal of Photographic Science at that time[1. Using Eastman film sensitive to the near infrared he showed unique images of natural objects including trees in a format that had never been seen before. The technique was later applied to medical applications, and was particularly useful to make permanent images of the network of blood vessels near the human skin surface (fig.2).

The modern developments in electronic infrared sensors did not occur until the 1940's and now have reached a high level of performance, and provide us with radiometric temperature measurements by infrared thermal imaging.

One main event in 2010 will be a two day con- ference in London in October. The first day will discuss the early work of Wood and others, the emergence of infrared imaging with electronic sensors, and applications in medicine and industry. The second day will be devoted to infrared astronomy, and will include the current infra- red studies of our universe with data from the Herschel Space telescope launched in 2009 by the European Space Agency from Europe's spaceport at Kourou in French Guiana. This new telescope has been named after Sir William Herschel, who first discovered the presence of infrared radiation in 1800.

The far-infrared space observatory is ESA's latest mission designed to study the formation and evolution of stars and galaxies. Herschel has the largest telescope ever flown in space, giving astronomers their best view yet of the cold and most distant objects in the universe. It is collecting very long infrared wavelengths, peeking into star-forming regions, galactic centres and planetary systems. Inside the cryostat the sensitive instru- ment detectors are cooled down to about -273 ºC (0.3 degrees above absolute zero). This low tem- perature is achieved using super fluid helium (at about -271 ºC) and an additional cooling stage inside the focal plane units. This is why the spacecraft's brain – or its payload module – hosts a cryostat, a cryogenic module inside which the cold components of the scientific instruments are mounted. The service module is the spacecraft's heart, which keeps the spacecraft going by monitoring all its vital functions. It also carries the 'warm' components of the instruments – those that do not require cooling with the cryo- stat. (Figure 3) This new era in

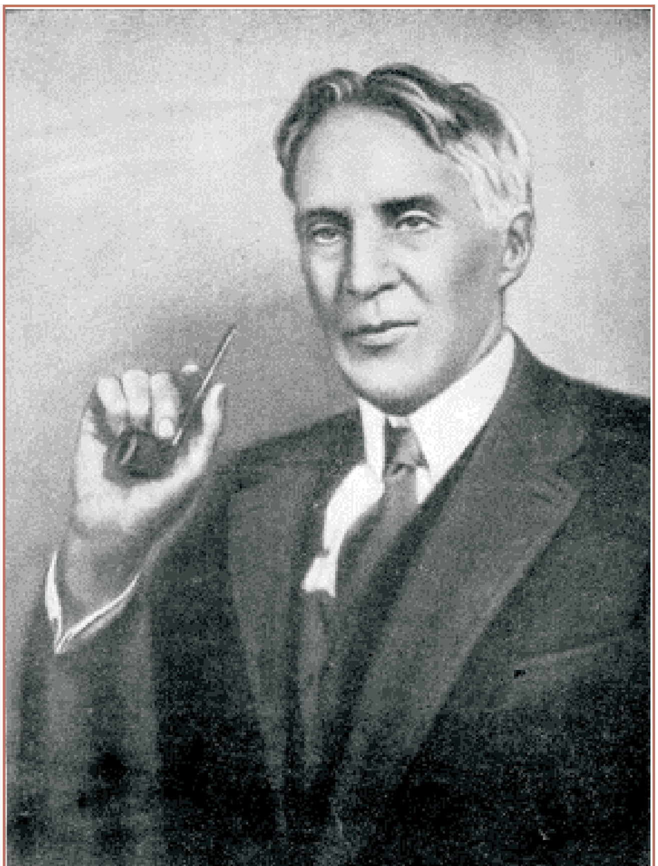

Figure 1
Prof Robert Wood, 1910

Figure 2
Infrared photography of superficial blood vessels

infrared imaging in space will be aptly timed to coincide with the commemorations of Robert Wood.s innovative photography.

Professor Wood was an accomplished American scientist who also did much work in the ultraviolet, his name is also given to the safety filter used for many years with ultraviolet lamps used in treatment of some skin conditions [1].

References

1 Wood R Photography by invisible rays. Photogr. J 1910, 50 (Oct) 329-338

2. Ring EFJ. The historical development of thermometry and thermal imaging in medicine. Thermol Int. 2003; 13(2): 53-57.

3. http:/ esamultimedia.esa.int/multimedia/publications/BR-262

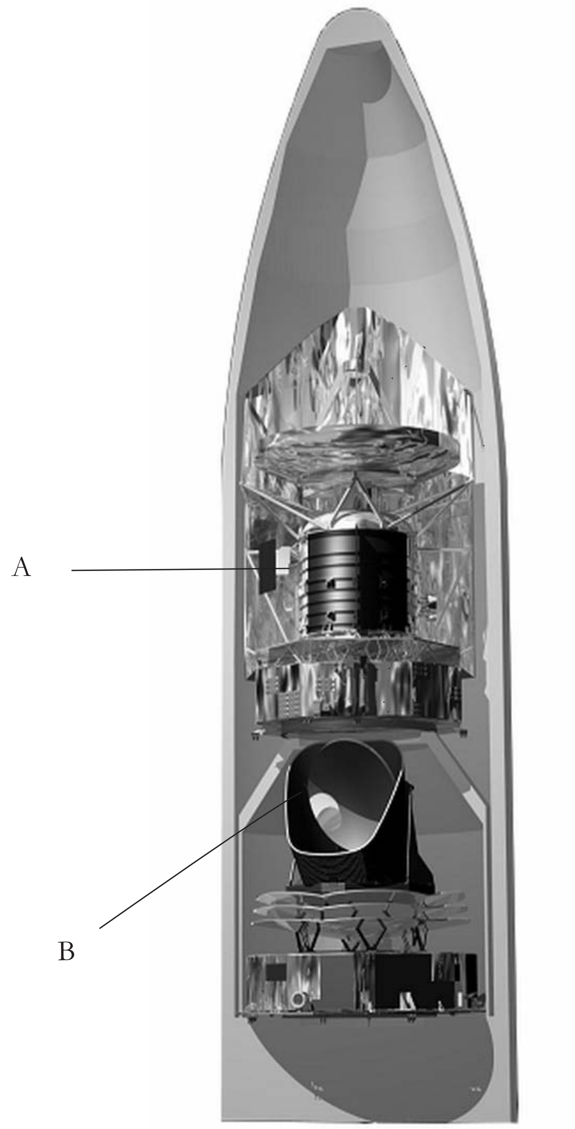

Figure 3
Ariane Rocket Launch Vehicle
A: Herschel Space Telescope
B: Plank Space Craft

TTP 2009 Conference Report

The 8th Conference on Thermography and Thermometry in Practice was held on 22nd-24th October 2009 at Ustron in South Poland. A half day pre-conference course was attended by some 50 delegates. The speakers were Prof. Ammer, and Prof. Ring who presented four short lectures from the "Glamorgan University Course on Thermal Imaging in Medicine" followed by Prof. Minkina and Dr. Dudzic on Infrared Thermography, "Errors and uncertainties". Prof. Van de May (Belgium) and Prof. Wiecek from Lodz University, who was the organiser and President of the conference, presented a lecture on "An Introduction to Heat Transfer, the practical use of thermal time constants".

The main conference programme began on Friday morning. Prof. Ring presented the opening lecture on The New ISO Standard for Fever Screening, followed by Dr Rogalski on Latest Developments in Microbolometer, and Multi Spectral Infrared Detector Arrays for Thermal Imaging. This included interesting material from Dr Tissot of ULIS France, the main European manufacturer of infrared detectors. We saw exceptional high definition thermograms with 1064 x 768 /17um detectors that give an NETD of better than 50 mK (figure A). Prof. De May presented a paper on the use of thermal impedance for characterization of electronic devices.

The majority of papers given were by engineers and covered a range of different applications of temperature monitoring and thermal imaging. A medical session on Saturday morning chaired by Dr Kalicki from Warsaw included four papers. Prof. Ammer spoke on "Temperature gradients of fingers with Raynaud's Phenomenon, Comparison of young and elderly adults". Marzec et al presented "Automatic temperature measurement on thermograms for headache diagnosis". Barjorek and Nowakowski from Gdansk gave a paper on "Possibility of using thermal tomography for diagnostics of burn wounds" and Kaczmarek and Zajaczkowska presented a paper on the "Analysis of sequential thermograms in dynamic thermography". A number of the papers have already been published in the current issue of the Polish journal "Measurement Automation and Monitoring" 2009 no.11.

Figure A
High definition IR 1024 by 768 image

In total 32 oral papers and 23 posters made up this interesting programme, and the presence of three companies with thermal imaging equipment from FLIR, VIGO and Infratec added to the considerable amount of information contained within the conference. A book of proceedings, with a CD of all papers in colour was produced, and Prof. Wiecek and his colleagues should be complemented on such an excellent conference, attended by about 100 delegates (figure B).

Figure B
Delegates at the TTP 2009 conference Ustron, Poland

News in Thermology

Meeting of the Polish Association of Thermology in Zakopane 2010

The 14th National Congress of the Polish Association of Thermology will take place in Zakopane from 26-28th March 2010. March in Zakopane is very attractive, being surrounded by the Tatra Mountains covered with snow. The international airport of Krakow, is a 2 hours journey away. There is good connection from Krakow airport by railway to busstation in direct Zakopane.

Registration fee is 200 Euro, for accompaning persona 150.- Euro. Registration includes welcome dinner Saturday 27th, lunch and accomodation. Prize for an extra night plus breakfast on Monday is 50.-Euro.

Registration fee for non Polish participants will be paid in cash on arrival at the conference. Registratrion by email is rquired before March 1 to ensure hotel reservation After the registration number is issued, delegates are commited to pay their fee.

Deadline for Abstracts is January 15th, 2010. Abstracts should be submitted electronically to ajung@wim.mil.pl or a.jung@spencer.com.pl. Accepted abstracts will be published in Thermology international and in Acta Bio-Optica et Informatica Medica.

Local organising committee

Prof Anna Jung (Chair), Dr Janusz Zuber (Deputy Chair) Dr Boleslaw Kalicki, Mgr inz. Piotr Murawski

International Scientific Committee

Prof A. Jung (Poland) Prof EF.J. Ring (UK), Prof J. Mercer (Norway), Prof. I.Benkö (Hungary), Prof K Ammer (Austria) Prof.B.Wiecek (Poland), ProfA.Nowakowski (Poland)

10th QIRT Conference in Quebec

The **Quantitative Infrared Thermography** (**QIRT**) conference is an international forum which brings together specialists from industry and academia, who share an active interest in the latest developments of science, experimental practices and instrumentation, related to infrared thermography. Following conferences in Paris (1992), Sorrento (1994), Stuttgart (1996), Lodz (1998), Reims (2000), Dubrovnik (2002), Brussels (2004), Padova (2006) and Krakow (2008), the *10th Quantitative Infrared Thermography Conference, QIRT 2010,* will take place on July 27-30th, 2010 at Université Laval, Québec City, Canada.

Scientific Committee

Chairman of QIRT

D. Balageas, ONERA, France

QIRT Steering Committee

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H. Wiggenhauser (Germany)
V. Vavilov (Russia)
Th. Zweschper (Germany)

The 10th International Conference QIRT 2010 will emphasize the following topics:

- State of the art and evolution in the field of infrared scanners and imaging systems allowing quantitative measurements and related data acquisition and processing.
- Integration of thermographic systems and multispectral analysis. Related problems like calibration and characterization of infrared cameras (mono and multidetector systems), emissivity determination, absorption in media, spurious radiations, three dimensionality of observed objects, certification and standardization.
- Thermal effects induced e.g. by electromagnetic fields, elastic waves or mechanical stresses.
- Application of infrared thermography to radiometry, thermometry and physical parameters identification in all fields such as (and not limited to): industrial processes, material sciences, structure and material non destructive evaluations, medicine, and biomedical science, fluid mechanics, cultural heritage, environment, food production. of papers for publication in the ***QIRT Journal***, after a subsequent review by experts.

How to submit an abstract and paper

Authors are kindly invited to submit both the abstracts and the full papers via the website. The procedure requires the registration of the user (main author) when sending the full paper. The registration form and all necessary information are available on the QIRT 2010 website:

http://qirt2010.gel.ulaval.ca

PDF format for abstract and full paper files is recommended. Optionally, the documents in *Adobe Frame Maker* or *Microsoft Office Word* formats are accepted as well.

Conference fees

Regular participants (*)
• Early rate (deadline: May 20th 2010): 700 $
• Late rate (deadline: July 10th 2010): 800 $
• Desk registration rate: 900 $

Students
• Early rate (deadline: May 20th 2010): 350 $
• Late rate (deadline: June 25th 2010): 400 $
• Desk registration rate: 450 $

Fees cover: Conference Proceedings, Welcome reception, Conference dinner, 3 lunches and coffee breaks. Accomodation is not included. For regular participants only, fees includes also a free subscription to the **QIRT Journal** for 2 years.

Accompanying persons
• Rate (deadline: June 25th 2010): 225 $

• It is not possible to book after June 25th 2010.

This amount includes only the Welcome reception and Conference dinner.

(*) All amounts in CAD$, plus the taxes: Québec's Province resident add Provincial (7.5 %) and GST tax (5%). Others (Canada's resident and non-resident), add only the GST tax (5 %).

Course offer before the conference (*):

• A - Basic Thermography,
• B - Application to Fluids,
• C - Application to Solids,
• D - Cultural Heritage and buildings.

The Courses are scheduled on Monday, July 26th, 2010. The tuition fees are 250 $ for one or more courses. Two courses will be presented in parallel, in the morning (A and B) and afternoon (C and D).

Deadlines

• December 15th, 2009 - Abstact submission
• February 20th, 2010 - Acceptance Notification
• May 20th, 2010 - Full-paper submission
• May 20th, 2010 - Advance registration

Abstracts and papers

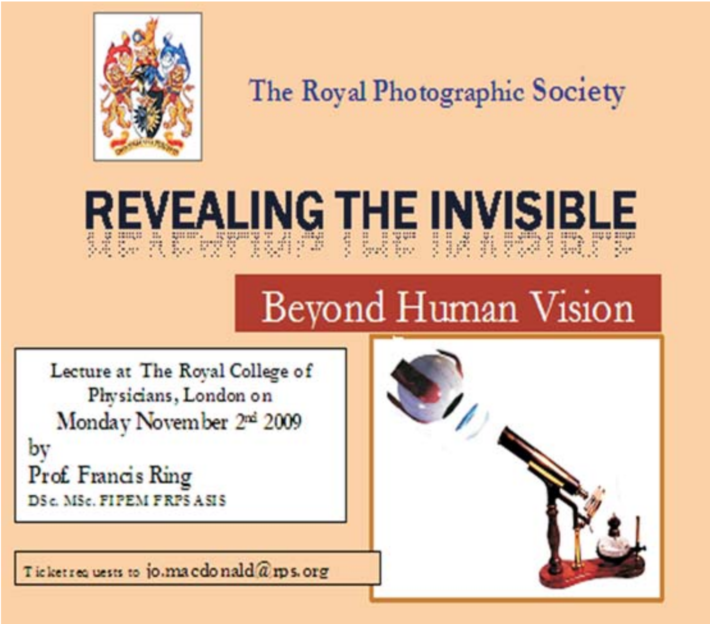
The participants are invited to submit to the *QIRT 2010 Secretariat* by December 15th, 2009 an extended abstract of 2 pages (letter size / A4 format) either for oral or poster presentation, including the key figures and main results. Following acceptance notification, camera ready, full paper of 6-10 pages including color figures should be submitted to the *QIRT 2010 Secretariat* by May 20th, 2010.

The proceedings, printed in black and white, containing the full text papers will be delivered at the beginning of the conference. Authors are requested to indicate the thematic section in which the paper should be included, as well as their preference (oral presentation or poster). A color version of aIl presented papers will be later included in the "Open Archives of the QIRTConferences" part of the QIRT web site: **http://qirt.gel.ulaval.ca**

In parallel, all the papers presented at the conference will be screened by the International Scientific Committee in charge of proposing a selection

Meetings

2009



This lecture will trace the rapid development of medical imaging, the impact of computing on our use of imaging, and major on infrared thermal imaging. Developed at the Royal National Hospital for Rheumatic Diseases in Bath since 1958, quantitative methods have been used to monitor and assist in clinical trials of new anti-inflammatory treatments.

Prof. Ring received the Medal of the Society's Medical Group awarded jointly with the Royal College of Surgeons, Royal College of Physicians and Royal College of Obstetrics and Gynaecology, London in 2008. Prof. Ring is also part of the International Standards Organisation , which has been developing guidelines for the use of this technology in fever screening and now being implemented in some countries during the current pandemic H1N1 infection.

2010

23rd March, 2010

Inauguaral Professorial Lecture

Graham Machin (Visiting Professor, Faculty of Advanced Technology)

Is temperature measurement necessary?

This event will be held in the Glamorgan Business Centre from 5:30 p.m. - 7:30 p.m.

Refreshments will be available from 5.30pm and following the lecture a buffet will be served.

To book a place please contact June Landeg in the Research Office on +044144348 2788 or researchoffice@glam.ac.uk

26th-28th March 2010

XIV National Congress of the Polish Association of Thermology in Zakopane

Abstract deadline: January 15th, 2010

Deadline for hotel reservation; March 1st, 2010

Registration fee: 200 €

Further information

Prof Dr. Anna Jung

ajung@wim.mil.pl or a.jung@spencer.com.pl

5th -9th April 2010

Thermosense XXXII- Part of program track on IR Sensors and Systems at SPIE DSS

Venue: Orlando World Center Marriott Resort and Convention Center – Orlando, FL United States

Conference Chairs: Ralph B. Dinwiddie, Oak Ridge National Lab.; Morteza Safai, The Boeing Co.

Program Committee
Andrea Acosta, Colbert Infrared Services; Nicolas P. Avdelidis, National Technical Univ. of Athens (Greece); Pierre G. Bremond, Cedip Infrared Systems (France); Jeff R. Brown, Hope College; Douglas Burleigh, La Jolla Cove Consulting; Antonio Colantonio, Public Works and Government Services Canada (Canada); Fred P. Colbert, Colbert Infrared Services; K. Elliott Cramer, NASA Langley Research Ctr.; Ermanno G. Grinzato, Consiglio Nazionale delle Ricerche (Italy); Sheng-Jen Hsieh, Texas A&M Univ.; Herbert Kaplan, Honeyhill Technical Co.; Timo T. Kauppinen, VTT (Finland); Kathryn M. Lee, United Space Alliance, LLC; Dennis H. LeMieux, Siemens Power Generation, Inc.; Robert P. Madding, FLIR Systems, Inc.; Xavier P. Maldague, Univ. Laval (Canada); Jonathan J. Miles, James Madison Univ.; Gary L. Orlove, FLIR Systems, Inc.; G. Raymond Peacock, Temperatures.com, Inc.; Piotr Pregowski, Pregowski Infrared Services (Poland); Andrés E. Rozlosnik, SI Termografía Infrarroja (Argentina); Takahide Sakagami, Osaka Univ. (Japan); R. James Seffrin, Infraspection Institute; Steven M. Shepard, Thermal Wave Imaging, Inc.; Gregory R. Stockton, Stockton Infrared Thermographic Services, Inc.; Vladimir P. Vavilov, Tomsk Polytechnic Univ. (Russian Federation); Lisa West Åkerblom, FLIR Systems AB (Sweden)

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John R. Snell, Snell Inrared

Information: http://thermosense.org

19th – 21th July 2010

7th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics-HEFAT2010 Antalya, Turkey

Important dates

Abstract submission closing date: 31. October 2009
Acceptance of Abstracts: 2 November 2009
Final paper submission: 21 December 2009
Final paper acceptance feedback: 1 March 2010
Early bird registration deadline: 10 March 2010
Final registration deadline: 10 May 2010

Further Information:
Prof Josua P Meyer
Chair: School of Engineering
Head: Department of Mechanical and Aeronautical Engineering, University of Pretoria, Pretoria

Tel: (012) 420 3104, Fax: (012) 362 5124
E-mail: josua.meyer@up.ac.za

Conference website: http://www.hefat.net

27-30th,July 2010

QIRT 2010 The 10th Quantitative Infrared Thermography Conference at Université Laval, Québec City, Canada

Important dates

December 15th, 2009 - Abstact submission

February 20th, 2010 - Acceptance Notification

May 20th, 2010 - Full-paper submission

May 20th, 2010 - Advance registration

Topics:

- State of the art and evolution in the field of infrared scanners and imaging systems allowing quantitative measurements and related data acquisition and processing.
- Integration of thermographic systems and multispectral analysis. Related problems like calibration and characterization of infrared cameras (mono and multidetector systems), emissivity determination, absorption in media, spurious radiations, three dimensionality of observed objects, certification and standardization.
- Thermal effects induced e.g. by electromagnetic fields, elastic waves or mechanical stresses.
- Application of infrared thermography to radiometry, thermometry and physical parameters identification in all fields such as (and not limited to): industrial processes, material sciences, structure and material non destructive evaluations, medicine, and biomedical science, fluid mechanics, cultural heritage, environment, food production.

Further information

QIRT 2010 Secretariat

Electrical and Computer Engineering Dept.
Université Laval, Québec (Québec)
CANADA G1V 0A6

http://qirt2010.gel.ulaval.ca

Infrared 100 Events

RPS Exhibition (Bath, October 2010)

Science Museum lecture (London, October 2010)

Medical and Industrial Infrared conference
(London, October 8th 2010)

Astronomical Infrared conference
(London, October 9th 2010)

2011

6-8 July, 2011

17th International Conference on Thermal Engineering and Thermogrammetry (THERMO)

at the Budapest University of Technology and Economics (BME), Budapest, XI .Müegyetem rkpt.3., Hungary

THE CONFERENCE ORGANIZER:
Branch of Thermal Engineering and Thermogrammetry (TE and TGM),
Hungarian Society of Thermology (HST) at MATE,
European Association of Thermology (EAT),

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- Dr. B. Wiecek Technical University of Lodz, Lodz, Poland (QIRT)

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- LOVÁK, István ENMECO (Budapest), (Editorial),
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- RIMASZOMBATI, Sándor m VEIKI ZRt. (Budapest), (Exhibition)
- PHILIP, János BME (Budapest),(web,photo).

About the Conference

Since 1977 a successful series of Symposia has been organised by our Society every year. At the beginning these events were named "Symposium on Thermogrammetry" after a newly developed branch of thermal mapping methods which played a significant role in the program. As the scope of the symposia widened in 1982 they received the new name "Symposium on thermo technical measurements".

Due to the broad and increasing interest shown by the international thermal engineering and physician communities, in 1987 it was already organised as the International Conference on Thermal Engineering and Thermogrammetry (THERMO). This conference is a series of biennial meetings. The Conference is intended to be an event worthy of the attention of all engineers, scientists, physicians and researchers who are involved in the solution of thermal or energy related problems, as well as in the applications of thermal imaging.

Objectives

The developments of measurement theory and technologies help the energy- conscious design of thermal engineering equipment and processes as well as the better understanding of thermal phenomena in living organisms.

The Conference will cover topics both the field of theory and application including new measurement concepts; transducer technique; thermal mapping; contact, optical and IR imaging; biomedical and biotechnological applications; thermal informatics, automatic methods and systems for industrial energy management and process control; heat loss detection and analysis; heat and mass transfer; utilization of alternative energy; thermophysical properties as well as the common practice of thermal engineering.

This Conference will provide the latest information on the above topics together with a good opportunity for personal discussions among experts in the fields of energy conservation, control of energy release and loss, protection of human environment, medical and veterinary applications, remote control through infrared sensors.

Main Topics

The structure of the sessions will be fixed after receiving the papers, but the topics will cover the following fields:

General thermal engineering; theory of measurements; thermal informatics, thermo-CAD and its applications; industrial energy management and process control systems; practice of thermal engineering; infra-red imaging science & technology: thermogrammetry, micro- and nanoscale thermal phenomena and sensing techniques, thermal defectometry; applied thermo optics; thermophysical properties; heat and mass transfer; cooling of electronic components; heat exchangers; combustion; thermophysics of the environment; building services; environmental aspects of energy use; thermo-ergonomy and thermo-psychology; thermo diagnostics; system analysis in thermo-biology; IR- imaging in biomedical and bio-engineering applications; remote sensing through IR-imaging, multidisciplinary topics.

We are awaiting (on the basis of the 16thTHERMO) speakers from :

Canada, Czech Republik, France, Greece, Hungary, India, Iran, Italy, Japan, Morocco, Poland, Portugal, Romania, Spain, Sweden, Tajikistan, Tunisia, Turkey, Ukraine, U.S.A

Technical Issues

The language of conference and abstracts is English. Together with oral presentation of papers a poster session will be organized.

Duration of each presentation will be limited to 15 minutes and additional time for discussion will also be provided. The English translation of lectures not read in English should be submitted at the registration desk on the spot. LCD projector and computer with Windows OS for Microsoft Power Point format presentations is available. (Please note, that using your own computer is not allowed.)

Those intending to attend the conference are kindly invited to send a registration form to the address listed later, under "Information".

Exhibition

During the conference an exhibition of scientific and industrial instru-mentation will be organised. Exhibitors from the field of temperature measurement and control, thermal properties, IR imaging, anemometry, industrial energy control, heat loss detection equipment etc. are welcome.

Venue

The conference is hosted by the Budapest University of Technology and Economics (BME, Budapest, XI. Müegyetem rkpt.3.,Hungary) located near the Hotel 'Gellért' and the Danube. More information about the conference place and hotel accommodation will be sent after the arrival of the Registration Form.

CALL FOR PAPERS

The photocopy-ready papers(for CD-ROM presentation) of max. ten A4 format pages to be presented on the conference are to be submitted before 15 February, 2011. To assist the work of the Scientific Committee the authors are kindly requested to point out the aim, method and results of their work in the summary to be provided according to the typing instructions.

Notification of the acceptance of abstracts will be forwarded to the authors until 30 November, 2010. The full text of all accepted papers will be included the CD-ROM Proceedings to be presented to the participants at the Conference

Information

Prof. Dr. Imre BENKÖ,

Budapest University of Technology and Economics (BME),
Faculty of Mechanical Engineering,
H-1521 Budapest, Muegyetem rkp. 7 / D.301. Hungary

Phone/fax: +361-310-0999.

E-mail: ibenko@freestart.hu

Correction

In the article by *David D Pascoe & Gordon Fisher* on *Comparison of Measuring Sites for the Assessment of Body Temperature Thermology international 2009, 19: 35-42* a layout error occured

The table in figure 3 B repeated data shown already in the table of figure 3 A. The correct table of figure 3B is printed below.

We regret this error.

Ambient Temp(°F/°C)	Axillary	Forehead	Temporal	Canthi
60/15.5	36.7±0.9	34.9 ± 2.3	35.9 ± 1.1	35.7 ± 1.0
70/21.1	36.7 ± 0.8	35.5 ± 1.4	37.3 ± 0.7	36.7 ± 0.6
80/26.6	36.8 ± 0.7	37.1 ± 0.9	37.2 ± 0.7	37.6 ± 0.6

Thermology international

Dr. Kurt Ammer
- Österreichische Gesellschaft für Thermologie
-
- Hernalser Hauptstr.209/14
- A-1170 Wien
- Österreich

- This journal is a combined publication of the Austrian Society of Thermology and the European Association of Thermology (EAT)
- It serves as the official publication organ of the the American Academy of Thermology, the Brazilian Society of Thermology tthe UK Thermography Association (Thermology Group) and the Austrian Society of Thermology.
- An advisory board is drawn from a panel of international experts in the field. The publications are peer-reviewed.
-

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