The 17th International Conference on Environmental Ergonomics ICEE2017

November 12 – 18, 2017
Kobe, Japan

Editors:
ICEE2017 Local Organising Committee

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BOOK OF ABSTRACTS

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The proceedings in this publication have been reviewed by at least one independent reviewer and have subsequently been revised by the author(s) before inclusion.

Environmental Ergonomics XVII / editors Local organising committee. International Society for Environmental Ergonomics.

PREFACE

It is a great pleasure to introduce the 17th International Conference on Environmental Ergonomics (ICEE) held in Kobe, Japan from November 12th to 18th 2017. This is the second time that the ICEE has been held in Japan, where previously it was held in Fukuoka in 2002. The host city of Kobe is a vibrant port city and hub for people, information and goods from around the world. Kobe's location nestled between the mountains and sea gives the city beautiful natural diversity and is convenient to visit other attractive cities such as Kyoto, Osaka, Nara, Himeji in Kansai. In addition, Kobe has a laid-back and open atmosphere, which can be enjoyed all throughout the year. The month of November should be especially beautiful for viewing the autumnal colors around the city and mountainside. We trust that you will have a fruitful and pleasant visit to Kobe and Kansai area in Japan.

We are pleased to announce that over 200 people have registered for the conference, coming from 27 countries. ICEE is a small, single session, family type meeting that always provides a great opportunity for researchers to come together and discuss relevant topics in our field of research. The conference attracts researchers throughout all stages of their research career and has been particularly keen on supporting the next generation. This year has been no exception as we have awarded 67 free student places. In addition we have created two Early Career Research Symposiums to continue our support post PhD graduation. We have three fantastic sessions from senior scientist, including a special symposium focused on Asian populations. The calibre of the research continues across a total of 91 oral presentations and 93 poster presentations. The International and Local Organizing Committee reviewed all papers.

In total 23 sponsors have supported ICEE2017, Kobe. We are very grateful for the support of all sponsors, with special thanks for the continued support from WL Gore & Associates for funding the presenting students. In addition, we are grateful to Experimental Physiology and The Physiological Society for their generous donation towards the best student oral and poster presentation prizes. We would like to take this opportunity to thank all participants and the ICEE Executive Committee for entrusting us with such a fantastic opportunity to organize ICEE2017. We warmly welcome you all and hope that you have a great time for science and social activities in ICEE2017, Kobe.

ICEE2017 Local Organising Committee

ICEE2017 Local Organising Committee

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ICEE2017 Conference Website:

http://icee2017.h.kobe-u.ac.jp/ICEE2017_c/Welcome.html

An introduction to the history of the International Conference on Environmental Ergonomics:

http://www.environmental-ergonomics.org/

Location: Ikuta Shrine Hall

1-2-1 Shimo Yamate Dori Chuou ku, Kobe 650-0011, Japan

Floor map

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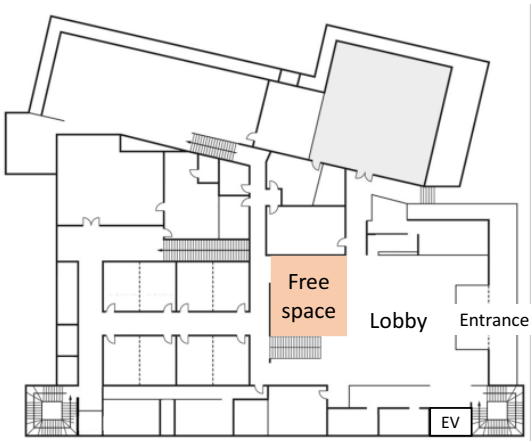

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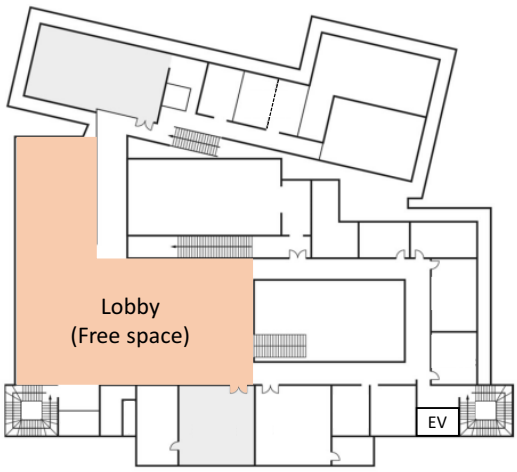

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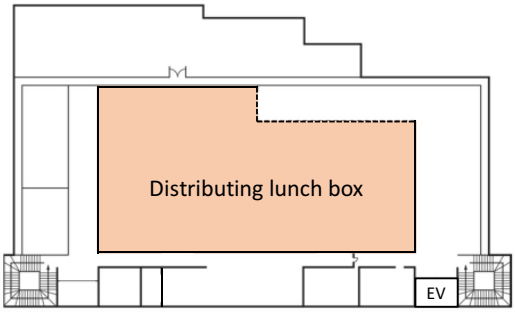

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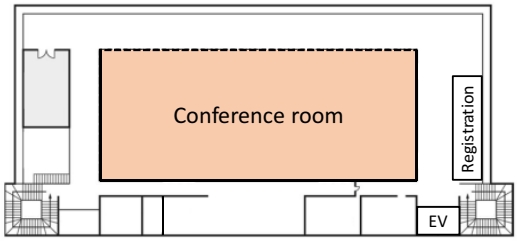

ICEE 2017 Week Schedule

Date/Time	Sunday 12th November
16:00-18:00	Registration

Date/Time	Monday 13th November
7:30-8:30	Registration
8:30-8:50	Welcoming address: Prof Kondo
8:50-9:30	Keynote speaker: Prof Morimoto
9:30-10:20	Oral presentation 1: **Temperature regulation 1** (x4)
10:20-11:00	Coffee break & poster presentations 1 (x20)
11:00-12:15	Oral presentation 2: **Occupation** (x6)
12:15-13:35	Lunch, Experimental Physiology announcement by Dr. Tipton
13:35-15:05	Symposium 1: Early Career researchers 1 : **Heat loss response**
15:05-15:45	Coffee break & poster presentations 1 (x20)
15:45-16:40	Oral presentation 3: **Perception 1** (x3)
16:40-17:10	JSPS announcement
17:10-17:50	Meeting adjourned for the day. Announcements. Group Photo
18:00-20:00	Welcome reception

Date/Time	Tuesday 14th November
7:30-8:00	Registration
8:00-9:15	Oral presentation 4: **Physiology and Exercise Physiology** (x6)
9:15-9:55	Coffee break & poster presentations 2 (x20)
9:55-10:45	Oral presentation 5: **Materials and design 1** (x4)
10:45-12:00	Oral presentation 6: **Materials and design 2** (x6)
12:00-13:20	Lunch
13:20-15:20	Symposium 2: **Aging in a Hotter World**
15:20-16:10	Oral presentation 7: **Temperature regulation 2** (x4)
16:10-16:50	Coffee break & poster presentations 2 (x20)
16:50-17:30	Oral presentation 8: **Heat Exposure 1** (x3)
17:30-18:10	Oral presentation 9: **Heat exposure and Adaptation** (x3)
18:10-18:20	Meeting adjourned for the day. Announcements
18:45-late	Student party

Date/Time	Wednesday 15th November
7:30-8:00	Registration
8:00-9:15	Oral presentation 10: **Exercise performance** (x6)
9:15-9:45	Poster presentations 3 (x20)
9:45-10:35	Oral presentation 11: **Fire fighters** (x4)
10:35-11:15	Coffee break & poster presentations 3 (x20)
11:15-12:45	Symposium 3: **Clothing assessment and Development**
12:45-14:05	Lunch
14:05-14:15	Meeting adjourned for the day. Announcements

Date/Time	Thursday 16th November
7:30-8:00	Registration
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9:05-10:10	Oral presentation 13: **Heat adaptation** (x5)
10:10-10:50	Coffee break & poster presentations 4 (x20)
10:50-11:50	Oral presentation 14: **Temperature regulation 3** (x5)
11:50-13:10	Lunch
13:10-14:40	Symposium 4: **Thermoregulation in Asians**
14:40-15:20	Coffee break & poster presentations 4 (x20)
15:20-16:25	Oral presentation 15: **Modeling and design** (x5)
16:25-17:15	Oral presentation 16: **Temperature regulation 4** (x4)
17:15-17:25	Meeting adjourned for the day. Announcements

Date/Time	Friday 17th November
7:30-8:00	Registration
8:00-8:50	Oral presentation 17: **Temperature regulation 5** (x4)
8:50-9:55	Oral presentation 18: **Sports Clothing** (x5)
9:55-10:35	Coffee break & poster presentations 5 (x19)
10:35-11:15	Oral presentation 19: **Heat exposure 2** (x3)
11:15-11:55	Oral presentation 20: **Body morphology** (x3)
12:00-13:20	Lunch
13:20-14:50	Symposium 5: Early Career researchers 2: **Adaptation**
14:50-15:30	Coffee break & poster presentations 5 (x19)
15:30-16:00	Closing ceremony and Awards
18:30-21:30	Conference Banquet

Date/Time	Saturday 18th November
9:00-12:00	Interesting Group Meeting for Environmental Ergonomics (Kobe University)

ICEE2017 Abstracts

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Moran	Physiological and logistic considerations in the integration of females in the IDF combat units	145	9
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ABSTRACT

1 KEYNOTE

Environmental Physiology in Japan -Past and present-

Taketoshi Morimoto

Kyoto Prefectural University of Medicine, Kyoto, Japan

With the advance of global warming, many scientists are working on environmental issues including the prevention of heat illness. At the annual meeting of Japanese Physiological Society, the Environmental Physiology Interest Group meet every year to discuss these problems. The Japanese Society of Physical Fitness and Sports Medicine, and the Japan Society for Occupational Health have similar interest groups, and discuss environmental issues, too.

Lately, the main interest of the Japanese Society of Biometeorology is the analysis of the effects of global warming on human health and they have published “A Guidebook for the Prevention of Heatstroke During Everyday Life”.

Extensive activity in this field in Japan was seen as far back as the 1930s, when Dr. Yas Kuno started his studies on sweating. He published his work as a monograph titled “Human Perspiration” in 1956[1)]. Many research scientists worked together with him, who formed the first generation of thermal physiologists in Japan. These investigators recruited qualified investigators, forming the second and third generations of thermal physiologists. At present, the third and fourth generations of investigators are actively engaged in research, expanding their interests to neurophysiology, chronobiology and exercise physiology[2)]. They are serving to cope with environmental issues.

References

1) Kuno, Y: Human Perspiration. Charles C. Thomas, Springfield, Illinois, 1956.

2) Morimoto, T: History of thermal and environmental physiology in Japan**:** the heritage of Yas Kuno. Temperature2-3, 1-6, 2015.

2. ORAL 1: Temperature regulation 1

Internal and external cooling methods and their effect on body temperature and manual dexterity

Ian Stewart, Matthew Maley, Aaron Bach, Stephanie Zietek, Geoffrey Minett

Queensland University of Technology, Brisbane, Australia

Cooling an individual prior to working in protective clothing in the heat may reduce thermal strain. Many investigations assessing the effect of pre-cooling on body temperature are limited by the number of cooling methods compared. Further, cooling methods such as arm immersion may compromise manual dexterity. As the present study focuses on those who may utilise pre-cooling in an occupational setting, the opportunity to assess a potentially novel internal cooling method, Heliox inhalation, is investigated. The aim of the present study is to investigate both internal and external cooling methods and their effect on body temperature and manual dexterity.

In a randomised order, separated by 24-hours, ten healthy male participants attended the laboratory on eight occasions. Each session consisted of 30 min sat in a warm environment (34 °C, 58 % rh), followed by 30 min of cooling or control of no cooling (CON). One of seven cooling methods were applied per session: ice-based cooling vest (CV_0); non-ice-based cooling vest with a melting temperature of 14 °C (CV_{14}); evaporative cooling vest (CV_{EV}); arm immersion in 10 °C water (AI); portable water-perfused suit (starting inlet water temperature: 11 °C [WPS]); heliox inhalation (79 % helium, 21 % O_2 [HE]); slushy ingestion (-2 °C [SL]). At the end of baseline (pre) and cooling (post), participants were asked to perform a Perdue pegboard task, with higher scores corresponding to greater dexterity. Rectal (T_{rec}) and mean skin temperature (ISO 9886, 2004 [T_{sk}]) were recorded throughout. Data presented as mean and SD.

At baseline, T_{rec} (CON: 37.3 [0.2] °C) and T_{sk} (CON: 34.8 [0.4] °C) were similar between trials ($P>0.05$). At the end of 30 min of cooling, only SL had lowered T_{rec} compared with CON ($P=0.012$). All external cooling methods, except CV_{EV}, lowered T_{sk} compared with CON ($P<0.05$). Pegboard scores were lower following AI only ($P=0.001$).

Variable	Time	CON	CV_0	CV_{14}	CV_{EV}	AI	WPS	HE	SL
Delta T_{rec} (°C)		-0.01 (0.11)	0.02 (0.11)	0.00 (0.06)	0.03 (0.06)	-0.12 (0.11)	0.10 (0.05)	-0.09 (0.09)	-0.27 (0.12)*
Delta T_{sk} (°C)		0.20 (0.09)	-4.27 (0.89)*	-2.05 (0.68)*	-0.52 (0.31)	-1.03 (0.37)*	-0.94 (0.80)*	0.23 (0.20)	0.69 (0.24)
Pegboard score	Pre	67 (5)	62 (4)	64 (11)	62 (6)	66 (4)	67 (5)	66 (5)	65 (6)
	Post	64 (8)	65 (3)	66 (9)	62 (5)	49 (5)*	66 (5)	64 (4)	66 (5)

* Significantly different from CON ($P < 0.05$).

The different cooling methods used in the present study appear to have varied effects on body temperature. Considering work tolerance time is governed, in part, by high deep body temperatures, the cooling method that has the greatest effect on deep body temperature would appear the most optimal choice. The present study showed that SL, CV_0 and AI were the more aggressive forms of cooling, providing the greatest cooling effect compared with WPS, CV_{14} and CV_{EV}. The use of HE would not be recommended for workers with breathing apparatus, due to increased financial cost with no associated benefit. Individuals requiring fine manual dexterity should opt for an alternative cooling method to AI due to the reduction in performance. The use of SL or CV_0 and their combination as a pre-cooling method should be tested for its effectiveness for those working in the heat in protective clothing.

3 ORAL 1: Temperature regulation 1

The effects of separate and combined forearm and face heating on hand temperatures and dexterity during cold exposure

John Castellani, Beau Yurkevicius, Myra Jones, Courtney Cowell, Jiyo Torres, Fernando Gonzalez, Timothy Driscoll, Laurel Smith, Catherine O'Brien

US Army Research Institute of Environmental Medicine, Natick, MA, USA

Reduced dexterity is a major problem in cold weather, whether directly due to tissue cooling and reduced function or limitations imposed by protective handwear (e.g., bulk, tactile sensation). A countermeasure that maintains finger temperature and dexterity without the need for protective handwear could improve performance in the cold. The purpose of this study was to determine whether direct heat applied to the forearm and/or face increases hand/finger temperatures and improves manual dexterity during cold exposure (COLD), compared to no heating. Six volunteers (5 men, 1 woman; 24 ±10 yr; 169 ± 5 cm; 75 ± 12 kg; 15 ± 6 % fat) completed 4 separate, 120-min, experimental trials in 0°C air. Trials were: forearm heating (ARM, both forearms from distal elbow to proximal wrist); face heating (FACE, forehead and both cheeks); combined arm and face heating (ARMFACE), and no heating (NOHEAT). The ARM and FACE devices used resistive heating elements and temperature set points of 42°C. Volunteers wore cold-weather clothing (2 clo), and were seated and bare-handed throughout COLD. Skin temperatures (forearm (T_{arm}), forehead (T_{head}), cheek (T_{cheek}), hand (T_{hand}), and finger (T_{fing})) were measured before (BASE) and throughout COLD. Measures of manual dexterity, (Purdue Pegboard tests (PP) and a militarily-relevant magazine loading task (MAGLOAD)), were measured at BASE, and after 90 min COLD. Data were analyzed using repeated measures analysis of variance; significance was set at $p < 0.05$. Application of direct heat maintained T_{arm} at 38.5°C during ARM and ARMFACE vs. NOHEAT and FACE (28.5°C) and T_{head} and T_{cheek} both at 37.9°C during FACE and ARMFACE vs. ARM and NOHEAT (T_{head} 29.1°C, T_{cheek} 22.8°C). During ARM and ARMFACE, T_{hand} was warmer at min 80 (18.9 ± 2.2°C) and 100 (17.7 ± 2.0°C), vs. NOHEAT and FACE (16.5 ± 1.8; 14.4 ± 1.6°C, respectively). There was a main effect for trial for T_{fing}, with higher values during ARMFACE (12.2 ± 1.4°C) compared to FACE (10.4 ± 1.6°C, $p = 0.02$); ARM and NOHEAT values for T_{fing} were 11.6 ± 1.4 and 10.9 ± 1.2°C, respectively. PP assembly was the same at BASE for all trials (7.8 – 8.7); at min 90, PP assembly was higher ($p < 0.05$) in ARMFACE (7.3 ± 2.1) vs. NOHEAT (5.5 ± 2.3) and FACE (5.3 ± 2.7). For MAGLOAD, the decrease from BASE in the number of ammunition rounds loaded was less ($p < 0.01$) at min 90 in ARMFACE (-6.8 ± 5.7) vs. NOHEAT (-14.3 ± 2.8). In conclusion, direct heating using ARMFACE, compared to NOHEAT, reduced the decline in fine and gross manual dexterity by 20-50%. These data suggest that direct forearm and face heating is a potential countermeasure for limiting cold-induced dexterity losses.

Author views not official US Army or DOD policy.

4 ORAL 1: Temperature regulation 1

Rescue and survival in Arctic sea regions

Hilde Færevik[1], Øyvind Roland Persson[2]

[1]SINTEF, Trondheim, Norway, [2]DNV, Harstad, Norway

A majority of shipping goes through Norwegian Arctic waters which covers a huge geographical area with little infrastructure and few accessible resources. Search and rescue operations in this area is therefore especially challenging. The IMO's Polar Code for ships operating in arctic waters entered into force on 1 January 2017 (1). The Polar code requires life-saving appliances to enable survival for a minimum of five days. The aim of this study was to carry out a review of available studies, regulations and published reports to provide a knowledge status on hypothermia and other cold related disorders and the preventive use of personal rescue equipment. This provided a basis for identification of gaps and recommendations to meet the five-day survival requirement. The results from the review showed that survival in cold climate will be highly dependent on the nutritional and health status of the deceased, whether the person are exposed to sea, land or ice, wearing a life jacket, suit or other protection against cold (clothing, other thermal protection) and if evacuated to a lifeboat or fleet. Central to the issue of surviving for five days is the human capacity to produce heat over longer periods. Our current knowledge of the physiological processes of shivering for over 24 hours is limited. Conventional lifeboats will probably not offer sufficient physiological support to enable survival for five days (2). The existing performance-based requirements of emergency rations can be a cause of, or contributing factor to, reduced survival time. One study has shown that the current nutritional content and size of emergency rations can be sub-optimal for ensuring a sufficient shiver response if the body temperature drops (3). From a physiological perspective, more prolonged studies and better knowledge of nutritional requirements and heat production from shivering over time is necessary, improvements in existing survival prediction tools is also suggested. To meet the five-day survival requirement, the use of life-saving appliances in Arctic Regions will also require an adaptation of the operation to reflect the specific ice and weather conditions. All of the challenges associated with maintaining life-saving appliances for a minimum of five days must also be included as part of the obligatory training.

1. IMO Polar Code 2015 MEPC 68-21. International code for ships operating in polar waters.
2. Mak, L., Kuczora, A., Farnworth, B., Brown, R. & Ducharme, M. 2010. Assessment of Thermal Protection and Microclimate In SOLAS Approved Lifeboats.
3. Haman, F. 2006. Shivering in the cold: from mechanisms of fuel selection to survival. J Appl Physiol 100 (5), 1702-8.

Financial supported by The Ministry of Foreign Affairs in Norway

5 ORAL 1: Temperature regulation 1

Greater contribution of glycolytic metabolism during exercise in cold water with hypothermic skeletal muscle

Hitoshi Wakabayashi[1], Ke Li[2], Hiroyuki Sakaue[2], Yasuo Sengoku[2], Hideki Takagi[2]

[1]Hokkaido University, Sapporo, Japan, [2]University of Tsukuba, Tsukuba, Japan

The purpose of this study was to investigate the metabolic response during submaximal exercise in cold water with hypothermic skeletal muscle in human. It was hypothesized that greater anaerobic contribution would be observed during exercise in cold water. Six healthy males participated in this study. They conducted the experimental protocol as below at three water temperature conditions (12, 18 and 33°C) on different day. Following resting baseline on land, they immersed their lower body for 30 min, and then performed 30-min cycling exercise in each water temperature at lactate threshold intensity, which was pre-determined in 33°C water. During the experiment, oxygen uptake (VO_2), carbon dioxide output (VCO_2) and haemoglobin oxygenation (oxy- and deoxy-haemoglobin concentration) in the vastus lateralis was continuously measured. Blood lactate concentration was measured every 5 min during exercise. The vastus lateralis muscle temperature after 30-min lower body immersion was 22.0, 24.8, 33.9°C in average, in 12, 18 and 33°C conditions, respectively. In 12°C condition, 3 of 6 participants could not continue exercise more than 15 min. The blood lactate concentration during exercise in 12°C condition was above lactate threshold level and significantly higher than that in 33°C condition from 10 to 15 min ($P<0.05$). VCO_2 and respiratory exchange ratio was significantly higher in 12°C condition than in 33°C condition till 15 min ($P<0.05$), though no significant difference was observed in VO_2. During the first 15 min of exercise, percent change in oxy-haemoglobin concentration from the resting baseline was significantly lowered in 12°C condition than in 33°C condition ($P<0.05$). The percent change in the tissue oxygen saturation was significantly lowered in 12°C condition than in 33°C condition during the first 10 min of exercise ($P<0.05$). These results suggested that anaerobic glycolytic energy pathway was more activated during exercise in cold water. The less oxygenated condition of hypothermic skeletal muscle might induce the greater anaerobic contribution. Similarly, we previously reported muscle temperature dependent suppression of skeletal muscle aerobic metabolism during isometric hand grip [1]. Additionally, fast-twitch fibers might be recruited more to compensate for the impairment of each muscle fibers function, since in general, the slow twitch fibers were more sensitive to cold, and faster muscle fibers were recruited at relatively lower intensity than in the thermoneutral condition.The cold-induced muscle fatigue would be one of the limitation factors for maintaining exercise intensity in cold.

[1] Wakabayashi et al. (2017) Effect of repeated forearm muscle cooling on the adaptation of skeletal muscle metabolism in humans. Int J Biometeorol 61: 1261-7.

6 POSER SESSION 1

Estimation method of air flow in microenvironment inside clothes using a tracer gas.

Rui Miyazawa, Tomonori Sakoi, Satoshi Hosoya

Shinshu University, Ueda, Japan

The purpose of this research is to propose a method for estimating airflow in microenvironment inside clothes. This method estimates airflow in this space from the relationships among the tracer gas supply location, supply rate, air sampling points and the tracer gas concentration of the sampled air. Because textile has air permeability, the tracer gas diffused from the supply location is diluted by the air coming from the outside the cloth. The tracer gas concentration of the sampled air becomes higher as the tracer gas supply rate increase and the distance between the supply location and the sampling location decreases. Considering these facts, we proposed one-dimensional analytical model to estimate the airflows in the microclimate. We applied this model for detecting the airflow inside sportswear of a runner exposed to the airflow blowing from front to back. Subjects wore gym clothing and ran on the treadmill at 8 km / hr. Air was blown from the front at 8 km / hr by electric fans. With regard to the locational relationship between tracer gas supply point and the sampling points, the tracer gas was supplied uniformly on the line that crossed in the right angle with the assumed airflow from front to back. The sampling points was set at three points, x0, x1, and x2 (-2cm, 2cm and 5cm) downward from the gas supply line. The center of the tracer gas supply line was fixed at the position of 20 cm below the armpit and 20 cm from the median sagittal plane. Gas concentration was measured for each sampling point for 10 minutes. Figure.1 shows the increased tracer gas concentration of the sampled air compared with the ambient air at x0, x1, and x2 when gas supplied rate was 0.0625ml/(cm·s). Two runners participated in the experiments as the subjects.

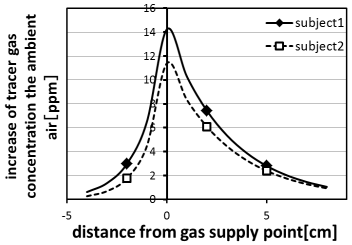

Figure 1 Gas concentration at each air sampling point

When comparing the tracer gas concentration at two points (x0 and x1) locating at the same distance from the gas supply line, the downward gas concentration for the assumed airflow at x1 was higher than that the upward concentration at x0. The flow rate from front to back for unit skin length was estimated to be 16cm^3/(s·cm) for subject 1 and 24cm^3/(s·cm) for subject 2 from our estimation model and the distribution of tracer gas.

In this study, we succeeded to estimate airflow in microenvironment inside sportswear. The proposed method is useful for evaluating the body cooling effect of a newly developed sportswear by ventilation .

7 POSER SESSION 1

Effect of traits of microclimates in protective clothing on thermal protective performance: A review

Meng Deng[1,2], Yunyi Wang[1,2]

[1]College of Fashion and Design, Donghua University, Shanghai, China, [2]Key Laboratory of Clothing Design & Technology, Donghua University, Shanghai, China

The evaluation of thermal protective performance is based on the amount of heat that transfers to the skin through the air layers under clothing and within the fabrics. Therefore, the air layer between the protective suit and the skin is one of the crucial factors which determine the clothing's thermal protective performance offered by the clothing. After reviewing both experimental and numerical analysis in previous researches, the parameters of air layers are concluded as thickness, locations, heterogeneity, orientation and dynamic in this paper.

Stagnant air in clothing microclimates provides significant amount of thermal resistance because of its low thermal conductivity. With lower thickness microclimates in which heat conduction and radiation are the primary modes of heat transfer, the thermal insulation of microclimates increases as the thickness increases. Should the thickness be large enough that convection occurs, the insulating effect of microclimates will be weakened.

Clothing microclimates not only exist between the clothing and human skin, but also between the fabric layers. Studies have shown that microclimates in different locations would cause different effects on the protective performance.

Most previous studies considered the microclimates to be horizontal. However, the orientation of microclimates can be horizontal, vertical and titled depending on the location of the body and posture.

In this paper, the heterogeneity of microclimates is defined as non-uniform thickness over the body and contact area with the body. The most severe burn usually occurs in area where clothing is in direct contact with the skin.

As a matter of fact, clothing microclimates can be in dynamic change due to thermal shrinkage of fabrics or human body motion instead of being stationary or fixed.

Further studies should be conducted to develop clothed numerical models to simulate the 3D heat transfer in clothing microclimates. Also, the changing traits of microclimates should be considered. New technologies may be used in the future to characterize the clothing microclimates more exactly.

8 POSER SESSION 1

Comparison of air gap behaviour at partial saturation using microclimate sensors with a sweating thermal manikin and guarded hotplate

Richard Burke

Thermetrics, LLC, Seattle, WA, USA

Sweating thermal manikins and guarded hotplates are commonly applied to measure thermal R_c and evaporative R_e resistance of garment systems. As defined in standard test methods ASTM F2370 and ASTM F1868, R_e measurements are performed with a fully wetted, heated skin surface and microclimate vapour pressure estimated by saturation pressure at skin temperature. The aim of this study was to evaluate the impact of varying degrees of skin saturation as compared to traditional full saturation results.

A wireless temperature/relative humidity (T/RH) sensor was developed for precise measurement of local vapor pressure. By locating an array of these T/RH sensors over the skin surface beneath the garment, the actual microclimate vapor pressure can be determined at very high resolution.

Two stages of experiments were performed. Initially, measurements were performed with a Newton thermal manikin fitted with an array of microclimate T/RH sensors over the manikin torso. A two-layer garment ensemble was tested using an experimental protocol beginning with a dry manikin and stepwise increasing the sweat rate to create partial saturation conditions beneath the garment. The complex results from this experiment necessitated a second more controlled protocol with a sweating guarded hotplate. In this second stage, the array of microclimate T/RH sensors was spatially arrayed within a 11mm air gap between the hotplate sweating surface and a single layer Nomex fabric. The test protocol began dry, increasing sweat to full saturation, and then allowed to dry out. The vapor pressure in the microclimate gap was monitored continuously.

While microclimate measurements from the thermal manikin were largely inconclusive due to high spatial variation, guarded hotplate results showed a highly uniform vapor pressure during full saturation and fully dry phases with a spatial variation of less 2% or less across the hotplate surface. However, during the 30 minute dryout phase, vapor pressure varied spatially by up to 70% corresponding to local wetness of the hotplate surface. In the depth plane, the vapor pressure varied linearly with the distance from the hotplate surface. The study concludes that garment microclimate conditions are dominated by the local skin wittedness, and lateral diffusion does not sufficiently equalize the vapor pressure.

9 POSER SESSION 1

Modelling the effects of air gap size on human physiological and psychological responses in chemical protective clothing

Jie Yang, Liwen Wang, Rui Li, Chunhui Xiang, Guowen Song

Iowa State University, Ames, Iowa, USA

The air gap size greatly affects the heat and mass transfer in the microclimate environment between human skin and chemical protective clothing (CPC), thereby influencing the human thermoregulation and thermal comfort. Previous studies mainly focused on the determination of air gap size and distribution as well as the effects of air gap size on fabric properties. However, the relationship between garment fit and human thermoregulation is still unclear. Therefore, investigation of the effects of air gap size on human physiological and psychological responses is necessary to improve the apparel design and reduce heat-related issues. A typical CPC (level D) was selected to measure the thermal insulation and evaporative resistance through a sweating hot plate. Two different spacers of thickness 3 mm and 6 mm were used in the experiment. A human thermal model was applied to predict the physiological (core and mean skin temperatures) and psychological (thermal comfort) responses. The human thermal comfort was evaluated by the 11-point scale thermal sensation index (TSENS). The metabolism rate was assumed as 300 W/m^2 and exposure conditions were set as 35 ^oC, 70% RH, and 1.0 m/s wind speed, respectively. The thermal insulation, evaporative resistance, and moisture permeability index significantly increased with an increase in air gap thickness. The fabric thermal insulation and evaporative resistance with the air gap thickness of 6 mm were 7.33 times and 2.26 times as high as that without the air gap, respectively. The simulated mean skin temperatures and thermal comfort indexes with the air gap thickness of 3 mm and 6 mm were slightly higher than those without the air gap. Additionally, the core temperatures with the air gap thickness of 3 mm were higher than those without the air gap throughout the exposure. The mean skin temperature and thermal comfort index showed a positive correlation with the air gap size. Reducing the air gap size would be a physiological and psychological benefit to the wearer, especially in hot environments where the heat burden might occur.

10 POSER SESSION 1

Assessment and improvement of thermal-physical properties on 3D printed bionic body armor

Mengqi Yuan, Jingjie He

Beijing Institute of Technology, Beijing, China

Stab resistance body armor (SRBA) is a defensive equipment to protect body from stabbing. The existed SRBA has weaknesses such as heavy weight; poor flexibility herein leads to low wearing frequency. Therefore, based on the theory of bionics, the model of crocodile armour was applied. And structured SRBA was designed and manufactured using 3D Printing technology.To investigate the thermal-physical properties of the new type of SRBA, thermal insulation and vapour resistance were assessed via conducting the thermal manikin experiment in a climate chamber with temperature ranges from 25-40 ℃ and humidity ranges from 40-70%. Thermal insulation of structured SRBA in 25℃, 30℃, 35℃, 40℃ was 0.15, 0.15, 0.24 and 0.10 $m^2 \cdot K/W^{-2}$. The results show that thermal insulation of structured SRBA is lower than conventional SRBA. On the other hand, vapour resistance of structured SRBA was higher under normal conditions. But under high temperature and humidity conditions (40℃, 70%), it was 40%-50% lower than conventional SRBA, which was 110.10 $Pa \cdot m^2/W$. Indicating that 3D-printed SRBA can improve diathermancy generally and improve vapour permeability in high temperature and humidity.Therefore, investigations and experiments were performed to achieve the optimal method of drilling micro holes on the SRBA. Different micro-hole distributions were studied, stab resist experiments were performed, and the optimal distribution was achieved. Than the thermal manikin experiments were performed. Thermal insulation of structured SRBA with micro holes in 25℃, 30℃, 35℃, 40℃ was 0.17, 0.18, 0.15 and 0.08 $m^2 \cdot K/W^{-2}$ which was lower than that without micro holes under high temperature(35℃, 40℃). In terms of vapour resistance, the structured SRBA with micro holes is less than or about equal to the structured SRBA without micro holes in most cases (considering the experimental error, vapour resistance difference within 5% are considered equal) as shown in Table 1. So the design of the micro holes is more conducive to the spread of heat and improve thermal-physical properties. To testify the thermal manikin results, volunteers were recruited to complete exercises with different intensities when wearing different kinds of SRBA, and factors such as body core temperature and skin temperature were recorded and analysed. This study shows the first effort in investigating the thermo-physical properties of 3D-printed bionic stab resistance body armor.

Table 1: Comparison of vapour resistance

	Vapour resistance（Pa·m2/W）	
	structured SRBA without micro holes	structured SRBA with micro holes
25℃,40%	210.46	180.22
25℃,55%	144.09	151.39
25℃,70%	110.25	106.32
30℃,40%	211.89	224.31
30℃,55%	213.12	143.91
30℃,70%	173.89	146.16
40℃,40%	140.88	142.64
40℃,55%	126.10	106.33
40℃,70%	110.10	113.54

11 POSER SESSION 1

Relationships between yachting characteristics and the PPE usage features

JuYoun Kwon

Ulsan National Institute of Science and Technology, Ulsan, Republic of Korea

Yachting requires sailors to use some Personal protective equipment (PPE) for ensuring their safety and health. The aim of this study was to investigate the relationships between yachting characteristics and the features of PPE usage. A survey of 190 club or elite sailors was conducted with a paper-based questionnaire which was comprised of the yachting characteristics, the number of PPE owned, the frequency in PPE usage, and the satisfaction for PPE etc. Chi-square test and independent t-test were conducted. Most types of PPE showed the relationships between PPE owned and yachting characteristics. The relationships between age and some PPE owned were significant, and they tended to be owned as ages increased. Operating license holders tended to own most of PPE except harness, impactvest, helmet and insulation. However, operating license holders or not showed the significant differences in the usage frequency only for life vest, wetsuit, harness, impactvest and helmet but no significant differences in the satisfaction for all PPE ($P<0.05$). Interestingly, no license holders tended to wear them more frequent than license holders. PPE possession or not showed the significant differences in the usage frequency for the most of PPE and in the satisfaction only for long T-shirts, hats, shoes, impactvest and helmet ($P<0.05$). 'Neutral or dissatisfied' tended to be answered for the satisfaction without the PPE possession but 'satisfied' tended to be answered with the PPE possession. PPE possession or not showed no differences in the frequency and satisfaction for life vest and wetsuit ($P<0.5$), and 'always or often' and 'satisfied' for life vest and 'often or occasionally' and 'satisfied or neutral' for wetsuit were answered. Sunglasses only showed significant differences in satisfaction of the most of PPE ($P<0.05$), and 'very satisfied or satisfied' tended to be answered. However, 'satisfied or neutral' tended to be answered for the others. In conclusion, PPE for yachting tended to be owned as the age and operating experience increased. No operating holders showed higher usage frequency especially in the yachting specialised PPE like life vest etc than license holders. It would be necessary to pay attention to wearing life vest etc for license holders and to find out how to increase using them. Long T-shirts, hats, shoes, impactvest and helmet, which showed the difference in satisfaction by PPE possession or not, would be required in the aspects of conformance with human body, yachting activity and yachting environment. Those aspects would be meaningful to be considered for developing PPE. It would be desirable to find influential factors for satisfaction on particular PPE through further research.

12 POSER SESSION 1

Immediate effects of shoes for the treatment inducing a slightly high heel and the special bottom structure during challenging walking gaits

Masanori Takmeura[1], Kenichi Ichihashi[1], Junzo Tsujita[2]

[1]Ichihashi Clinic, Kobe, Japan, [2]Institute of Health & Sports Medical Science, Osaka, Japan

The influence of heel heights on lumbar lordosis and thoracic kyphosis remains controversially discussed. We think that the high-heeled shoes of the moderate height change gait pattern and improve a posture. This study aimed to investigate whether shoes for the treatment inducing a slightly high heel and the special bottom structure improve the posture of the elderly person whom lumbar lordosis. Five volunteers (66±16.7 years of age, foot size 26.1±0.37 cm) were participated in this study. Participants were requested to walk at a comfortable, self -selected pace across walkway (about 10m) for six trials under each of two conditions: wearing general low-heeled running shoes (heel height; less than 1 cm) and wearing the treatment shoes (heel height; 4 cm). In order to obtain the kinematics data, a Vicon motion capture system using a Plug-in Gait Full Body Marker set with six cameras (100Hz) was used. Paired T-test was used for within-group comparisons (α=0.05). The results of data analysis showed that the treatment shoes can decrease the hip flexion angle during the mid-stance ($p<0.05$). But, trunk flexion angle was not affected by footwear. It is thought that the decrease in hip joint flexion angle during the mid-stance phase was related to the posture that trunk does not become the bending forward like a lumbar lordosis.

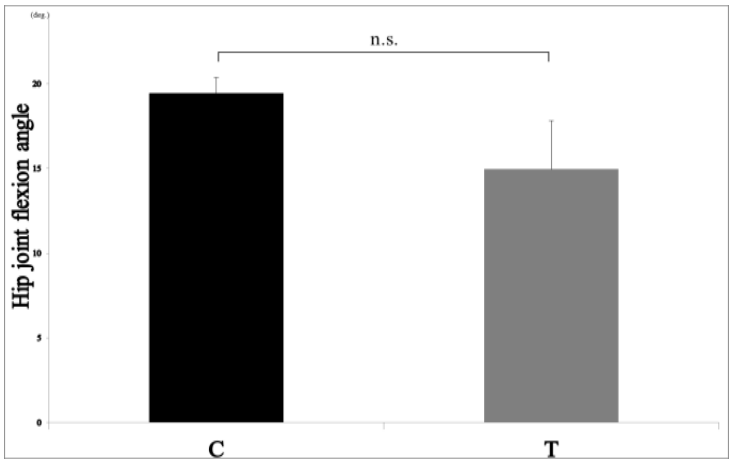

Figure 1: The comparison of hip joint flexion angle during the mid-stance phase of gait. C; wearing a general low-heeled running shoes. T; wearing the treatment shoes (n=5).

13 POSER SESSION 1

Thermal and vapour resistance of different triathlon suits

Nazia Nawaz, Olga Troynikov, Chris Watson

RMIT University, Melbourne, VIC, Australia

Triathlon consists of multiple-stage competition involving swimming, biking, and running in consecutive order to test the endurance of its participants, much more than swimming, biking, or running alone at ambient temperatures 14°C – 28°C. As a result of this endurance activity and climatic conditions of triathlon (14°C – 28°C), body temperature tends to rise considerably with the high potential of heat stress occurring and this may hinder the athlete's performance. Therefore, triathlon suit must enable and support thermoregulation of the body within varied range of environmental climates and physical activities. For the present study, 7 commercially available triathlon suits of the same size and construction were investigated for their performance attributes relevant to the physiological comfort of the competing athlete wearing these suits. A 20 zone sweating thermal manikin Newton was used to determine their thermal resistance and evaporative resistance. The results of the study showed that whilst the suits are similar overall to each other in terms of their thermal regulation and breathability performance; the results for individual zones of the suits display significant differences in a number of cases. These differences are related to garment construction and materials and the results identify opportunity for garment construction and fabric performance improvement. For example, reduction in the number of panels that have double layers of fabric in the current designs will improve both thermal and breathability performance of the suits. Further, results showed that fabric construction can influence performance of the suits.

14 POSER SESSION 1

Characterization of PCM textiles by a heat release tester and subject trials

Martin Harnisch, Miriam Scheffelmeier, Bianca-Michaela Woelfling, Edith Classen

Hohenstein Institut fuer Textilinnovation, Boennigheim, Germany

Phase change materials (PCM) can absorb or release additional amounts of heat, respectively, at their temperature of phase change. This effect is used in textile applications, where weight is not of importance, e.g. space suits, insulation of buildings. Due to low weight of clothing fabrics, amount of incorporated PCM in clothing is limited. Therefore, the effect of such textiles on perceived temperature, thermoregulation and thermal wear comfort is unclear and needs to be investigated.

Several manufactured textiles incorporating PCM as well as textiles, which were especially coated in the laboratory, were tested. Heat uptake of pre-acclimatised PCM textiles was characterised by means of a heat release tester. Trials were performed in a climatic chamber. Furthermore, subject trials were performed to look on human thermal perception and thermoregulation of the same textiles. Four subjects wore different arm sleeves and judged temperature differences. In each trial a pair of pre-acclimatised samples was put on right and left arm, respectively, for ten minutes. Skin temperature, subjected feedback on temperature and perceived temperature difference between pair of samples was recorded.

The heat release tester is able to show differences in heat storage between PCM and control sample as well as between different PCM samples. Furthermore, results show that the amount of stored heat is related to the amount of incorporated PCM and the effect is just a temporary one. Depending on the amount of a pre-cooled PCM a cooling effect lasts from seconds to about ten minutes. These results are proven by subject trials. Depending on the amount of incorporated PCM subjects could perceive differences between samples with and without PCM. This effect lasted less than ten minutes. Skin temperature showed a decrease of less than 0.2 K and for durations shorter than two minutes with a highly dotted sample at max. At the end of the trial/after ten minutes, skin temperature was higher for all fabrics, independent on PCM or amount of PCM.

Clothing fabrics with incorporated PCM can absorb heat, but this amount of heat is small and duration is short. E.g. during running, it is not realistic, to put on a new pre-cooled shirt every five minutes. Therefore, it can be concluded, that intended benefit by PCM is not achieved for lightweight clothing worn close to skin (1^{st} and 2^{nd} layer).

15 POSER SESSION 1

The development of the specific requirements of energy-saving shirt in Taiwan

Li-Chu Wang[1], Tsung-Lin Liu[2], Chun-Ku Yeh[1], Yang-Ping Shih[1], Gwo-Tsuen Jou[1]

[1]Taiwan Textile Research Institute, New Taipei City, Taiwan, [2]Wiwynn Company, New Taipei City, Taiwan

The 311 tsunami in Japan raised highly concern about the safety of nuclear power plants, while the climate change has thrown impact on the power limitation more seriously. Taiwan government continuously launched the publicity of higher air conditioning temperature for energy-saving. The textile industry has been encouraged to develop a cool feeling "energy-saving" shirt for office workers. As a result, establishing a specific requirement of the energy-saving shirt for the textile manufacturers to comply with has become necessary for the evaluation of its performances. Among numerous methods of evaluating physiological thermal comfort, a numerical analysis may be the most efficient way. We set up a thermal comfort model based on ISO 7730. A simulation with two kinds of clothing ensemble in various climates was compared to prove the reliability of the model. Next, some shirts were collected and measured carefully by a thermal manikin in accordance with ISO 15831 to determine the total thermal insulation, I_{cl} (m^2·K/W), of the clothing ensemble with the manikin in a stationary condition and further brought in the model to calculate PMV and PPD.

By measuring of more than 30 summer shirts, the results showed the range of I_{cl} was between 0.411and 0.584 m^2·K/ W and the range of inferred PMV and PPD were between 0.67~0.97 and 14.5~24.7% respectively. These shirts can be considered as representative since they were collected from different markets with different brands, materials and even fitness (sizes). The I_{cl} data couldn't be lower for office usage, while the environmental elements of the model for "energy-saving" were set as 28°C, 60%RH, and 0.25 m/s air speed, and the PMV results were beneath "slightly warm" (+1) in a thermal scale from -3 (cold) to +3 (hot). The mean of PPD was 19.5 and the 75th percentile was 20.3. By several turns of discussion of "Committee of Conformity Assessment of

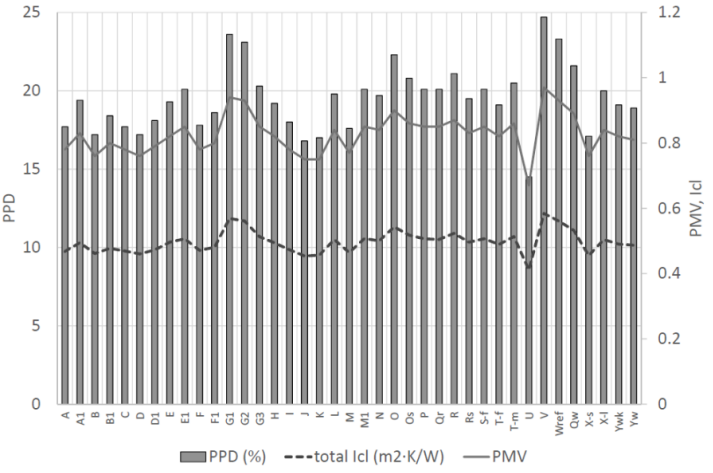

Figure 1: The PPD, PMV, and I_{cl} results of summer shirts

Accreditation and Certification on Functional and Technical Textiles", whose members are composed of textile manufacturers, textile-related R&D institutes and Universities, and governmental officers in Taiwan, the threshold of 20% PPD as a recognized "energy-saving shirt" was obtained. The next step, the ISO 7933 and dynamic simulation may be an approach to acquire a more practical application.

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16 POSER SESSION 1

Repeated L-Menthol application to the skin improves thermal perception and enhances cycling performance in the heat

Martin Barwood[1], Stuart Goodall[2], Jo Kupusarevic[2]

[1]Leeds Trinity University, Leeds, West Yorkshire, UK, [2]Northumbria University, Newcastle Upon Tyne, Tyne and Wear, UK

Sprayed L-Menthol applied to the skin acts on the transient receptor potential melastatin 8 (TRPM8) thermoreceptor. TRPM8 is also activated by temperatures ranging from 8 to 28°C thereby inducing cool sensations and improvements in thermal comfort when the skin is hot. L-Menthol has been added to various cooling products that claim to enhance exercise performance in the heat; however, evidence to support this using ecologically valid protocols is lacking. We aimed to examine if repeated spraying of L-menthol induces improvements in thermal sensation and comfort, initiating a reduced rating of perceived exertion (RPE) along with an ergogenic effect. Eight trained male cyclists volunteered (mean ± SD: age 22 ± 2 yrs; height 1.8 ± 0.1 m; body surface area 2.1 ± 0.1 m^2; powermax [P_{Max}] 363 ± 35 W). Participants completed two experimental trials in hot conditions (35°C, 20% relative humidity) where their t-shirt was sprayed with a 100 mL of Control-Spray (surfactants only) or Menthol-Spray (0.20% L-Menthol) after 20 and (i.e. when they were hot and uncomfortable) 40-minutes of a 45-minute fixed intensity (FI) period (55% P_{max}), which was followed by a test to exhaustion (TTE; 70% P_{max}). Thermal perception (thermal sensation & comfort; TS, TC), thermal responses (rectal temperature [T_{rec}], 8-site skin temperature [T_{skin}]), perceived exertion (RPE), heart rate, blood lactate and TTE duration were measured. Menthol-Spray made participants feel cooler (FI exercise end: 15.4 ± 1.6 cm - *warm* vs. 17.5 ± 1.8 cm - *hot*) and more comfortable (FI exercise end: 6.4 ± 3.2 cm – *just uncomfortable* vs. 5.1 ± 3.4 cm – *uncomfortable; p<0.05*), but the magnitude of the effect diminished with repeated application. RPE was only numerically lower after Menthol-Spray (FI exercise end: Menthol-Spray 16 ± 2 vs. Control-Spray 17 ± 2; *p>0.05*). TTE duration increased following Menthol-Spray (4.57 ± 1.7 min) vs. Control-Spray (2.39 ± 1.5 min; *p<0.05*). Following 45-minutes fixed intensity exercise core [T_{rec}] temperature was similar (Menthol-Spray 38.3 ± 0.3°C vs. Control-Spray 38.3 ± 0.3°C). Spraying L-Menthol repeatedly during exercise in the heat improved perception and performance. The diminished effects of L-Menthol on perception with increasing T_{rec} indicated an increasing influence of deep, by contrast to peripheral, thermoreceptors on thermoreception.

17 POSER SESSION 1

Children thermal comfort during physical activity: how to bridge the gap ?

Damien Fournet

DECATHLON SPORTSLAB, Villeneuve d'Ascq, France

Thermal comfort during physical activity has not been extensively studied. Most thermal comfort models come from the field of the automotive or building industry. Adaptations of the PMV,PPD model from Fanger (1970) have been applied for sport enthusiasts and sport-related equipment in connection with occupational standards such as IREQ (ISO 11079). The knowledge is limited for adults and close to non-existent for children.

On the other hand, children thermal responses during exercise have been well studied since the pioneering work of Bar-Or in the 1970's highlighting that children are not small adults. Physical and physiological differences between children and adults exposed to thermal stress have been reviewed by Falk (1994, 2008). Regarding body characteristics, the larger surface area-to-mass ratio, the lower adiposity in most cases, the smaller blood volume may either be beneficial or detrimental for children during exercise in the heat or in the cold. Regarding physiological specificities in children are related to the higher oxygen cost of locomotion, the lower cardiac output, the lower sweat output per gland, which can also be advantageous or disadvantageous depending on the environment.

Thermal comfort is usually considered as dependent upon 3 main physiological parameters with their absolute values and/or derivatives: core temperature (T_c), skin temperature (T_{sk}) and sweating (SW). During exercise in the heat, T_c and T_{sk} are usually higher in children whilst in the cold T_c is similar compared to adults and T_{sk} is lower with SW lower in both environments. The largest gap in the literature lies in the absence of connection between these physiological parameters and subjective variables (thermal comfort and sensation). There is also much to be discovered on children thermal preference and own behaviour towards their body, clothing and environment during exercise.

Lastly, it seems that the clothing factor has never been studied in children thermal comfort during exercise. Some predictions have been performed for cold applications using an adapted heat balance equation (McCullough, 2009) with limitations in manikin measurements and no validation with children perceptual responses.

Many questions remain on how to address this large topic: What is preferred way of matching individuals between maturation or body dimension? What is the heat production of children in normal physical activities ? What is the difference between boys and girls? When does wetness perception become a cognitive construct and a source of discomfort?

18 POSER SESSION 1

Arteriovenous anastomoses (AVAs) modeling study

Allen Curran, Mark Hepokoski

ThermoAnalytics, Inc., Calumet, MI, USA

Subcutaneous arteriovenous anastomoses (AVAs) are specialized vascular structures that result in enhanced heat transfer with the environment. AVAs are only present in glabrous skin, most notably the palms of the hands and the soles of the feet. Our AVA model is based on the published work of Hensley et al. (Hensley et al., "50 Years of Computer Simulation of the Human Thermoregulatory System," J. Biomech. Eng., 2013.). Hensley et al. state that it may be possible to withdraw several times the basal metabolic heat generation rate from the palms and soles under very specially controlled cooling conditions. Despite this claim, most thermophysiological models (including our model, TAITherm) do not account for AVA blood flow, which was the motivation for this modeling study. As shown in Figure 1, the TAITherm AVA model predicts core temperatures that are very close to what Hensley et al. reported. In this simulation, the subject was clothed in summer clothing but with no socks or shoes.The ambient temperature was 23° C, and the surface of the palms and soles were held at 22° C to match the conditions in Hensley et al. The metabolic rate was 1.0 met.The skin blood flow for the palms and soles was set to be between two and twenty percent of the basal cardiac output (%CO). To illustrate the potential impact of AVAs on human thermal comfort predictions., we ran the same simulation but with the palms and soles held at 34.4° C, both with and without AVAs. After 90 minutes the model without AVAs predicted an overall comfort (OC) = −0.95 on Berkeley's 9-point scale, while the model with AVAs predicted OC = −0.52, a difference that may be significant.

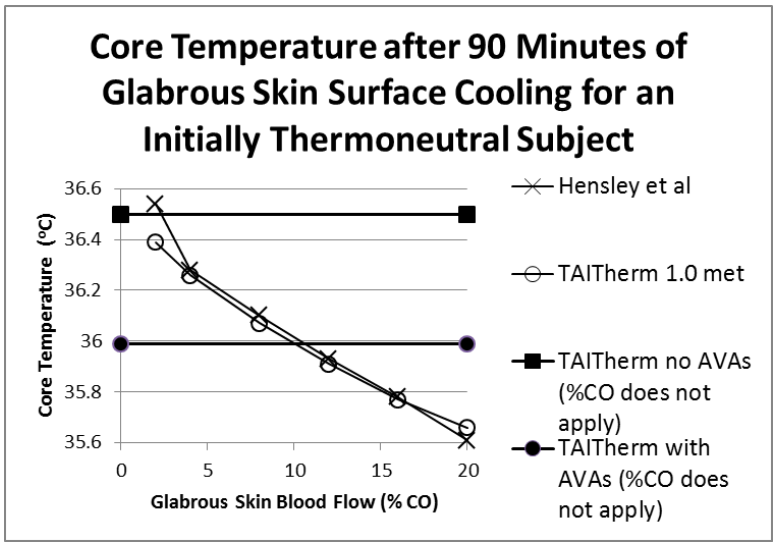

Figure 1: A comparison of TAITherm results to Hensley et al. TAITherm predictions without AVAs and with physiologically-controlled glabrous skin blood flow are shown for comparison.

19 POSER SESSION 1

Effects of cryotherapy on diabetic peripheral neuropathy symptoms: a case study

Paraskevi Gkiata[1], Stephen S. Cheung[2], Andreas D. Flouris[1]

[1]FAME Laboratory, Department of Physical Education and Sport Science, University of Thessaly, Trikala, Greece, [2]Department of Physical Education and Kinesiology, Brock University, St. Catharines, Ontario, Canada

Peripheral neuropathy (PN) is one of the most common complications in diabetes mellitus. It is characterized by neuropathic pain and loss of pain and temperature sensation. Cryotherapy (CR) may be neuroprotective in peripheral nerve ischemia and pain by attenuating immune responses to skin temperature and blood flow changes. The purpose of this case study was to examine the effects of CR on peripheral neuropathy symptoms on a female type 1 diabetes mellitus patient (age: 32 years, weight: 97 kg, height: 169 cm). The experimental protocol involved: (i) one day of baseline measurements, (ii) CR for 2 consecutive days, (iii) an acute post-CR period (days 1, 2, 3 post CR), and (iv) a medium-term post-CR period (days 5, 7, and 9 post CR). The CR included immersion of the leg (up to knee height) in 12°C water for 60 minutes per day. At the baseline and post-CR periods, neuropathy symptoms were evaluated using the Neuropathy Symptom Score (NSS) and the Therapy Efficacy Neuropathy Symptom Score (TENSS). Also, neuropathy disability was estimated through vibratory displacement and percentile thresholds as well as cooling perception thresholds. Finally, heat flow and temperature at the skin surface were recorded during 20 minutes of rest on the foot and the calf. Compared to baseline, the TENSS was significantly decreased during the medium-term post-CR period ($p<0.05$). Vibratory displacement and percentile thresholds were increased during the acute post-CR period (40.59±19um, 94.33±4.7%) and decreased during the medium-term post-CR period (23.04±2.36um, 90.33±2.3%) demonstrating small and medium effect sizes, but the results were not statistically significant ($p>0.05$). No significant differences ($p>0.05$) as well as low and medium effect sizes were found on the NSS score and cooling thresholds, respectively. Compared to baseline (calf: 34.91±0.22; foot: 33.81±0.23), one-way ANOVA with Bonferroni post hoc test showed a significant increase of skin temperature in day 5 post-CR (calf: 36.01±0.22˚C; foot: 34.58±0.26˚C) and significant decreases in days 7 (calf: 31.25±0.24˚C; foot: 31.34±0.23˚C) and 9 (calf: 32.70±0.22˚C; foot: 32.53±0.20˚C) post-CR ($p<0.05$; all effect sizes being large). The CR improves PN symptoms (as measured by TENSS) as well as vibratory sensation during the medium-term post-CR period.

20 POSER SESSION 1

Comparison of endothelial function and sensory thermal thresholds in cold sensitive and control individuals

Clare Eglin, Joe Costello, Michael Tipton, Heather Massey

University of Portsmouth, Portsmouth, UK

Individuals who have low peripheral skin temperatures in a warm environment and a slow rate of rewarming following a local cold stimulus are considered to be cold sensitive (CS). Therefore, CS may represent a subclinical non-freezing cold injury. The mechanisms underpinning CS have not been determined, therefore this study compared endothelial function and thresholds for warm and cold sensation in individuals with CS to matched controls.

Nine participants (5 men) with CS and nine control participants (5 men) undertook a CS test of the foot involving cooling in 15 °C water for 2 minutes with spontaneous rewarming in 30 °C air. Endothelial function was assessed at the forearm, finger and foot by iontophoresis of 1% w/w acetylcholine. Cutaneous vascular conductance (CVC) was calculated from laser Doppler flux and corrected for mean arterial pressure. Sensory thermal thresholds to heating and cooling of the fingers and foot were also determined.

There was no difference between groups for age, height, mass, BMI, skinfold thickness, foot volume or physical activity. Compared to the control group, mean [SD] toe skin temperature was significantly lower in the CS group prior to immersion (30.3 [0.9] °C v 34.8 [0.8] °C; $P<0.001$) and after 5 min of rewarming (27.9 [0.8] °C v 34.3 [0.9] °C; $P<0.001$). This was associated with a reduced CVC in the Great toe in the CS group (pre: 1.08 [0.79] flux.mmHg^{-1} v 3.83 [1.21] flux.mmHg^{-1}; 5 min: 0.79 [0.52] flux.mmHg^{-1} v 3.46 [1.07] flux.mmHg^{-1} $P<0.001$). The CS group had a lower sensory threshold to cold stimuli in their feet compared to controls (median [interquartile range]: 0.3 [0.4 – 0.7] °C v 0.5 [0.4 – 0.7] °C; $P=0.05$). Warm sensory thresholds in the feet and cold and warm sensory thresholds in the fingers were similar between groups. No differences in the responses to acetylcholine in the forearm, finger or foot were observed between groups.

Although CS individuals had lower toe CVC and temperatures in a warm environment and rewarmed more slowly following brief cold exposure of the foot, their endothelium-dependent vasodilation was comparable to that of controls. CS individuals were able to perceive smaller changes in foot skin temperature during cooling than controls, although the numerical difference between the groups was small. This indicates that the sensory cues for behavioural responses to the cold are unlikely to be compromised. Further research, possibly focusing on vasoconstrictor pathways, is required to understand the mechanisms involved in CS.

21 POSER SESSION 1

Effects of odor stimulation with essential oil on muscle sympathetic nerves activity in humans

Eriko Kawai[1], Genta Hanno[1], Ryosuke Takeda[2], Akemi Ota[1], Emiko Morita[1], Daiki Imai[1,2], Yuta Suzuki[1,2], Hisayo Yokoyama[1,2], Kazunobu Okazaki[1,2]

[1]Department of Environmental Physiology for Exercise, Osaka City University Graduate School of Medicine, Osaka, Japan, [2]Reserch Center for Urban Health and Sports, Osaka City University, Osaka, Japan

We recently reported that inhalation of odor of Grapefruit essential oil increased blood pressure (BP) while inhalation of odor of Marjoram essential oil decreased BP by using a quantitative evaluation system of odor stimulation with essential oils. Regarding the mechanisms, previous studies reported increased or decreased sympathetic nerves activity by using power spectral analysis of the fluctuation of BP and R-R intervals in humans. It has been also reported in experimental animals that olfactory stimulation with grapefruit oil evokes an increase in sympathetic nervous activity to adrenal gland and brown adipose tissue in the anesthetized condition. We hypothesized that the changes in BP with the odor stimulation with essential oils in humans were associated with changes in muscle sympathetic nervous activity (MSNA).

The purpose of the present study was to investigate the effects of inhalation of the odor of Grapefruit or Marjoram essential oils on MSNA.

Seven healthy subjects participated in this study. All subjects had no known cardiovascular or pulmonary disorders, had no history of head injury, and were not taking any prescribed medication. The experiment was performed in the supine position. Subjects were breathing blank air through a face mask for 10 min as baseline. Then, the subjects inhaled the odor of Grapefruit essential oil or the odor of Marjoram essential oil from Douglas bags for 10 min, and then they were breathing blank air for 10 min as recovery. Throughout the trial, MSNA (peroneal nerve, microneurography) as well as beat-by-beat heart rate and BP, and breath-by-breath respiratory variables were recorded continuously.

By inhalation of the odor of Marjoram (n = 5), MSNA burst rate remained unchanged at 1 to 5 min of inhalation (17.7 ± 9.7 bursts/min), then tended to increase at 6 to 10 min of inhalation (20.4 ± 9.8 bursts/min) with decreased BP compared to baseline (18.0 ± 4.4 bursts/min). On the other hand, by inhalation of the odor of Grapefruit (n = 4), MSNA burst rate and also BP remained unchanged throughout the trial.

It was suggested that muscle sympathetic nervous activity was modulated by changes in BP, which are induced by the inhalation of the odor of essential oils, through baroreflexes.

22 POSER SESSION 1

Changes in lung function during exercise are independently mediated by increases in deep body temperature

Mike Tipton[1], Pippa Kadinopoulos[2], Dan Roiz de Sa[3,1], Martin Barwood[4,1]

[1]Extreme Environments Laboratory (EEL), Dept. Sport and Exercise Science, University of Portsmouth, Portsmouth, UK, [2]HMS Nelson, HM Naval Base Portsmouth, Portsmouth, UK, [3]Environmental Medicine & Science Unit, Institute of Naval Medicine, Gosport, UK, [4]Dept. Sport, Health and Nutrition, Leeds Trinity University, Leeds, UK

In contrast to skeletal muscle function and temperature, the contribution of change in respiratory muscle temperature is usually ignored when considering the changes in lung function during exercise. We examined whether an increase in deep body temperature, independently, contributes to increases in ventilatory flow indicative of bronchodilatation.

Using a within-participant repeated measures design, nine participants (mean [SD]: age 22 [3] years; height 177.7 [8.3] cm; mass 80.2 [19.1] kg) completed three conditions: Exercise (EXERC; 30 minutes cycle ergometry, 70 rpm, 70% of age-predicted max heart rate); 40 °C water immersion (IMM40; 30 minutes) to passively raise rectal temperature (T_{rec}); and 35 °C immersion (IMM35; 30 minutes) a thermoneutral control for IMM40. A forced vital capacity (FVC) manoeuvre was performed at the start of the test and every 10 minutes thereafter. Forced expiratory volume in one second [FEV_1] FEV_1/FVC, 25, 50 and 75 % maximal expiratory flow during FVC (FEF75, FEF50, FEF25) were also measured. Data were analysed using a repeated measures two-way ANOVA, with a 0.05 alpha level.

T_{rec} peaked after 30 minutes in the EXERC (mean [SD] 38.0 [0.3] °C) and IMM40 (38.2 [0.2] °C) conditions and were higher ($P<0.05$) than that those at the corresponding time in the thermoneutral condition (37.2 [0.2] °C). At this time mean (SD) FEV1 was 4.5 (0.6), 4.6 (0.3), and 4.4 (0.6) L respectively. T_{rec}, FEV_1, and FEV_1/FVC were greater in the IMM40 and EXERC conditions compared to the IMM35 condition. Interaction effects were evident for FEF50 and FEF75 ($P<0.05$), being higher in the IMM40 and EXERC conditions.

Raised deep body temperature, independently, contributes to the increased airflow ascribed to bronchodilatation when exercising.

23 POSER SESSION 1

Effect of food intake on the respiratory response to CO_2

Keiji Hayashi[1], Misato Suekuni[2], Koji Sugiyama[2]

[1]University of Shizuoka, Shizuoka, Japan, [2]Shizuoka University, Shizuoka, Japan

We previously showed that food intake influences respiratory responses. This may reflect the fact that food intake increases metabolism, which may in turn influence respiratory responses. However, we found that minute ventilation (VE) during exercise was not increased by food intake, though carbon dioxide output and end-tidal PCO2 were increased. Because ventilatory responses are strongly controlled by the respiratory chemoreflex, we examined whether respiratory chemosensitivity to CO2 is altered by food intake.

Eleven subjects (four males and seven females; mean (SD) age, 21 (2) years; height, 169.0 (7.4) cm; weight, 59.7 (8.5) kg) participated in the study. We measured respiratory chemosensitivity to CO2 using a rebreathing method. The subjects wore a mask connected to a closed one-way circuit with a rubber bag containing the test gas (7% CO2, 43% O2, 50% N2). Rebreathing was terminated when the inspired CO2 fraction reached 9.2%. This test was performed before food intake and 90 min after. Measurements were made twice with a 15-min interval between tests, before and after food intake. VE, tidal volume (Vt), and respiratory frequency (fR) measured during rebreathing were plotted as functions of end-tidal PCO2. We took the slopes of the linear regression lines as indexes of respiratory chemosensitivity to CO2. Test meals were designed for each subject and contained 117.6 ± 17.4 g of carbohydrate, 30.9 ± 8.8 g of protein, and 20.2 ± 5.4 g of fat. The total energy content was 3,332 ± 633 kJ.

Mean (SD) sublingual temperature after food intake was higher than before food intake [36.4 (0.3) °C vs. 36.1 (0.3) °C, $P < 0.05$]. VE and fR were also increased by food intake [VE: 11.0 (3.4) L· min-1 (after) vs. 9.7 (3.3) L· min-1 (before), $P < 0.05$; fR: 17 (3) breaths· min-1 (after) vs. 15 (4) breaths· min-1 (before), $P < 0.05$]. While subjects breathed the CO2-rich mixture, VE was 1.60 (0.62) L· min-1· mmHg-1 before food intake and 1.53 (0.77) L· min-1· mmHg-1 after. Vt was 54.3 (19.8) mL· mmHg-1 before food intake and 59.8 (32.9) mL· mmHg-1 after. There were no significant differences between VE or Vt before and after food intake. By contrast, fR chemosensitivity decreased from 0.47 (0.41) breaths· min-1· mmHg-1 (before) to 0.30 (0.39) breaths· min-1· mmHg-1 (after) ($P < 0.05$).

These results indicate that food intake decreases respiratory chemosensitivity to CO2, as reflected by fR, whereas VE and Vt are unaffected. This suggests chemosensitivity is not related to the suppression of ventilatory responses seen during exercise after food intake. Nonetheless, our findings suggest food intake suppresses the fR response to CO2 and may influence respiratory patterns.

Conclusion: Our findings suggest food intake suppresses the fR response to CO2, though food intake does not change the VE or Vt response to CO2.

24 POSER SESSION 1

Effect of pedal cadence on the calf venous compliance after moderate cycling exercise

Yasuhiro Iimura, Michiko Saito, Anna Oue

Toyo university, Gunma, Japan

We investigated previously the effect of short-term endurance training on venous compliance, resulting that the calf venous compliance tended to be increased by the interval training but not constant training. From our previous result, it is hypothesized that the adaptation of venous compliance with exercise might be influenced by the frequency of muscle pump activity in exercising limb. Thus, to clarify our hypothesis, we determined whether different pedal cadence during moderate cycling exercise influenced the calf venous compliance, since the frequency of muscle pump activity was thought to depend on the cycling cadence. Sixteen young healthy subjects (13 males, 3 females) participated in this study. Subjects performed the cycling exercise at 60%HRreserve for 32 minutes in 60 round/minutes (60 rpm) and 80 round/minutes (80 rpm), respectively. Calf venous compliance was assessed using by venous occlusion plethysmography and cuff deflation protocol before exercise, and 10, 30 and 60 minutes after the end of exercise. Pedal cadence (60 rpm; 60.4 ± 0.1 rpm, 80 rpm; 80.0 ± 0.2 rpm) differ between 60 rpm and 80 rpm during exercise. Heart rate (HR) (60 rpm; 161 ± 3 bpm, 80 rpm; 164 ± 4 bpm), mean arterial blood pressure (MAP) (60 rpm; 91 ± 3 mmHg, 80 rpm; 91 ± 3 mmHg) and work load (60 rpm; 97 ± 9 watt, 80 rpm; 95 ± 10 watt) did not differ between 60 rpm and 80 rpm during exercise. In addition, HR and MAP before exercise, and 10, 30 and 60 minutes after exercise were also similar between 60 rpm and 80 rpm. Calf venous compliance did not differ between before and after exercise in 60 rpm. On the other hand, calf venous compliance decreased after exercise in 80 rpm when compared with before exercise ($P < 0.05$). In addition, calf venous compliance after exercise in 80 rpm was lower than that in 60 rpm ($P < 0.05$). These results suggested that the increased pedal cadence might cause the decrease in venous compliance after moderate cycling exercise.

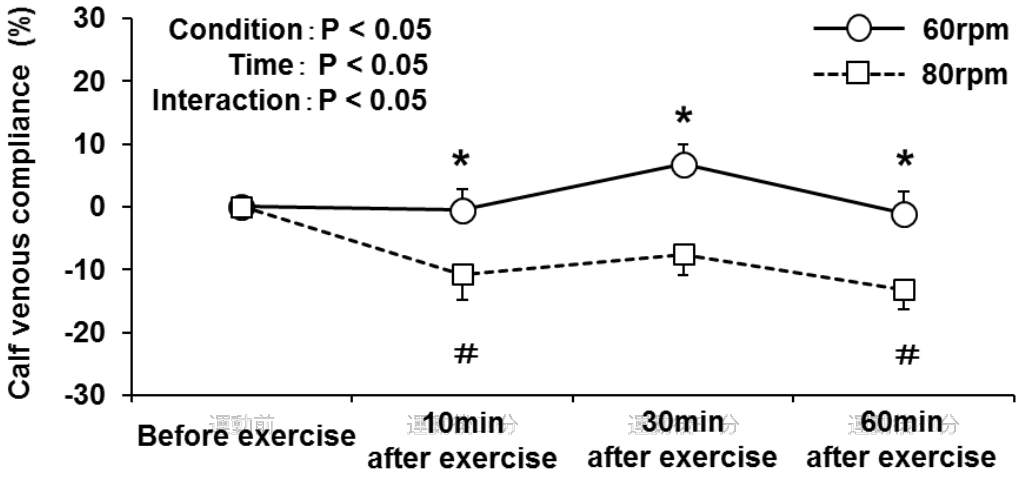

Figure 1: Changes in calf venous compliance before and after cycling exercise in 60rpm and 80rpm

Values are the mean ± SE. #: $P < 0.05$, vs. before exercise, *: $P < 0.05$, 60rpm vs. 80rpm

25 ORAL 2: Occupation

Performance of respiratory protective equipment in the cold environment

Sirkka Rissanen, Kirsi Jussila, Erja Mäkelä, Heli Kähkönen, Hannu Rintamäki

Finnish Institute of Occupational Health, Oulu, Finland

Respiratory protective equipment (RPE) is needed to protect airways from airborne particles and gases. The use of RPE is known to generally increase psychophysiological strain at work by increasing respiratory resistance, adding weight and hampering communication. RPE may increase risk of heat strain in warm and hot working environment. RPE is not well studied in the cold environment. Experiences from the outdoor workers indicate that low temperature causes special problems such as freezing of exhaled moisture. Especially powered air respirators are complained to cool excessively face. Cold may also harden RPE materials and impair its fitting on the face. A perfect fit of the RPE on the face is a crucial factor in the contaminated. The aims of this study were to evaluate the effects of cold temperature on protection properties of the RPE and to quantify the facial cooling problem. Filtering RPE and powered air respirators with half (HFP) and full face (FFP) pieces were studied. One of the powered air respirators adjusts the air flow in response to wearer's breathing while the others provide continuous air flow. Ten volunteers participated in the study. Exposure temperatures were +20 and -20°C. Fit-testing was performed by using TSI PortaCount method in both temperatures. Facial cooling experiments were performed in a separate protocol. Face skin temperatures and air temperature inside the face piece was measured. During the experiment the subjects were resting and exercising (moderate work load) for 40 min. According to the preliminary results the fit factor at -20°C was somewhat half of that at 20°C for filtering RPE. Use of filtering RPE with HFP resulted in appr. 15°C lower cheek temperature (uncovered) than that of FFP, which covers the whole face. Face skin temperatures were between 5 and 17°C and air temperature between 5 and -10°C while powered air respirator was used at -20°C. RPE with adjustable air flow diminished facial cooling rates compared to continuously blowing one. Preliminary results show that RPE with FFP may protect workers' face against cold compared to HFP. The continuous air flow in the face piece decreases skin temperatures to uncomfortable level in the cold. Poor fitting of the RPE in the cold may expose the user to serious health hazards. Condensation and freezing of moisture in filters and face piece attenuated the usability and convenience of RPE.

26 ORAL 2: Occupation

Heat shield project: The effect of a summer heat wave on the productivity in an automobile-parts manufacturing plant

Urša Ciuha[1], Mitja Gliha[1], Tjaša Pogačar[2], Lučka Kajfež Bogataj[2], Lars Nybo[3], Andreas Flouris[4], Tord Kjellstrom[5], Igor Mekjavic[1]

[1]Jozef Stefan Institute, Ljubljana, Slovenia, [2]University of Ljubljana, Ljubljana, Slovenia, [3]University of Copenhagen, Copenhagen, Denmark, [4]University of Thessaly, Trikala, Greece, [5]Center for Technology Research and Innovation, Limassol, Cyprus

A consortium of European researchers initiated the Horizon 2020 project: Heat Shield, with the goal of increasing the thermal resilience of EU workers in the context of global warming, in five key industries (manufacturing, transportation, agriculture, construction, tourism). The present study reports the variation in the temperature and humidity conditions within a factory producing automobile signal lights, as a function of the fluctuations in the surrounding conditions, particularly during heat waves. It also documents the changes in worker productivity as a function of the heat wave-induced changes in the conditions within the factory. A total of 40 sensor units (MSR, Switzerland) were mounted at workstations throughout the factory. Each unit had a sensor mounted at eye-level and 5cm above the floor. The units sampled the temperature and relative humidity at 15-minute intervals and automatically stored the information in a data cloud. A weather stations was installed on the factory grounds. Productivity was determined by standard company procedures.

During a normal weather period start of May 2017, the temperatures ranged from 20 to 29°C during the daytime, and from 19 to 25°C during the night time. During a subsequent heat wave in June 2017, temperature and relative humidity ranged from 27 to 37°C during the daytime, and from 25 to 37°C during the night time. During the heat wave, productivity evaluated as product-output by the company, decreased by 13%.

The present study demonstrates the significant impact of a heat wave on worker productivity in a manufacturing company.

This work was supported by the European Commission Horizon 2020 Research and Innovation action (project number 668786: Heat Shield)

27 ORAL 2: Occupation

Thermal strain during job-related tasks conducted by the National Ambulance Resilience Unit

Mark P. Rayson[1], Sam D. Blacker[2], Ella F. Walker[2], Jane Thompson[2], Carla Gallagher[2], Julianne Doherty[2], Stephen D. Myers[2]

[1]Mark Rayson Consulting Limited, Bristol, UK, [2]University of Chichester, West Sussex, UK

The National Ambulance Resilience Unit (NARU) undertakes special operations in the UK as the Hazardous Area Response Team (HART), Chemical Biological Radiological and Nuclear (CBRN) staff and Marauding Terrorist Fire Arms (MTFA) teams. Personnel wear personal protective equipment when completing physically demanding tasks in these roles and as a result could be at increased risk of thermal strain compared to their non-specialist counterparts. The objective of this study was to quantify that thermal strain.

Thirty-four NARU personnel volunteered (29 men, body mass 84 ± 14 kg, height 1.77 ± 0.08 m, estimated VO_2max 39 ± 7 ml·kg^{-1}·min^{-1}). Participants completed 11 job-related tasks undertaken by NARU operatives; Swift Water Rescue, Re-board Boat, Unload Vehicle and Set up Decontamination Unit, Clinical Decontamination, Movement in Gas Tight Suits, MTFA, Over Ground Rescue, Unload Incidence Response Unit Vehicle, Above Ground Rescue, Over Rubble Rescue and Subterranean Rescue. Deep body temperature (Tc), heart rate, subjective thermal ratings and urine osmolality were measured.

The most thermally challenging tasks were the MTFA (mean Tc of 38.1 ± 0.5 °C, 73 ± 11 %HRmax), Clinical Decontamination (peak Tc of 38.6 °C, 65 ± 11 %HRmax), Subterranean Rescue (equal highest mean thermal rating of 'very hot', 65 ± 9 %HRmax) and Over Ground Rescue (highest rate of rise of Tc of 2.0 °C.h^{-1}, 67 ± 11 %HRmax). The highest peak Tc was for the MTFA task where one participant reached 39.2 °C. Ambient temperatures ranged from 12 to 17 °C and relative humidity ranged from 43 to 93 %. Across all 11 tasks, only 3% of the participants were classed as dehydrated.

In addition to continuing the successful hydration strategies used by personnel, further strategies to mitigate thermal strain due to high body temperatures could be used to improve performance during the job-related tasks undertaken by NARU. These strategies would be best prioritised for the MTFA, Clinical Decontamination, Subterranean Rescue and Over Ground Rescue tasks and are likely to be more important if the tasks were conducted in higher environmental temperatures than the present study.

28 ORAL 2: Occupation

Energy expenditure estimation during military load carriage over complex terrain

David Looney, William Santee, Anthony Karis, Laurie Blanchard, Maxwell Rome, Mark Buller, Alexander Welles, Alyssa Carter, Adam Potter

USARIEM, Natick, MA, USA

Introduction: Dismounted military operations often involve prolonged load carriage over complex terrain which can result in excessive metabolic costs that can directly impair Soldiers' performance. While estimating these demands is a critical interest for mission planning purposes, it is unclear whether existing estimation equations developed from controlled laboratory and field based studies accurately account for energy costs of traveling over complex terrain. Purpose: This study investigated the accuracy of seven equations derived from/for military populations when applied to data collected over complex terrain with two different levels of load carriage. Methods: Twelve volunteers (age 20 ± 3 yr; height 174 ± 8 cm; body mass 85.17 ± 12.63 kg) were monitored during load carriage (with loads equal to 30 % and 45 % of body mass) over a 10-km mixed terrain course during on two separate test days. The course was divided into 40 segments based on distance, grade, and/or surface factors. Timing gates and radio-frequency identification cards (SportIdent, Scarborough Orienteering, Huntington Beach, CA) were used to record completion times for each course segment. Breath-by-breath measures of energy expenditure were collected using portable oxygen exchange devices (COSMED Sri., Rome, Italy). The seven equations assessed were ACSM 2002, Giovani and Goldman 1971, Jobe et al. 2009, Minetti et al. 2002, Pandolf et al. 1977, Santee et al. 2003, and Weyand et al. 2013. Results: All equations had a significant negative estimation bias ($p < 0.05$). The Santee et al. equation produced the closest metabolic rate estimates with a mean absolute error of 118 ± 104 W. Discussion: Current predictive equations underestimate the metabolic cost of load carriage by military personnel over complex terrain. This investigation supports the use of the Santee et al. equation for predicting load carriage costs over alternative equations. However, this work also outlines the need for improvements to these methods, replacement with new methods, or the use of a multi-model approach to account for mixed terrain.

29 ORAL 2: Occupation

Evaluations of the daytime light environment adapted to the type of working task; Comparison between blue excitation and purple excitation white LEDs

Mayuko Fukuoka, Yurika Miyamoto, Maki Matsumoto, Emi Koyama

Kyoto Institute of Technology, Kyoto, Japan

The influence of the difference in the spectral distribution of LED lighting on the psychophysiological state during intellectual work has not yet been clarified. The purpose of this study is to investigate light environment requirements suitable for working task by conducting intellectual tasks under blue excitation LEDs and purple excitation LEDs. Participants in this experiment were healthy university students (10 males and 10 females), and measurement was conducted at approximately 25 °C laboratory with approval from the ethics committee. Measurement items are EEG, ECG, EOG, skin temperature, physiological vigilance level (AAT), subjective evaluation (VAS, JUMACL, STAI), impression evaluation on working task and light environment. After two day living control, practice and main measurement were carried out for one day each. The following nine kinds of intellectual tasks were carried out for a total of 60 minutes (A: point connection, B: origami, C: 100 square calculation, D: beads threading, E: counting the number of symbols, F: thinking how to use products, G: character rearrangement, H: numeral storage, I: coloring). The light environment during working tasks was set to 500 lx on the desk's horizontal level, and the two conditions of the blue excitation LEDs (B 500) and the purple excitation LEDs (P 500) were carried out on the same day in the randomized order. In the task performance results, the difference tendency between the two types of LEDs was seen only for the task of B: origami. Compared to the P500, the B500 condition showed a tendency to have more mistakes ($p = 0.066$). In addition, the P 500 condition showed a tendency to make origami beautifully as compared with the B 500 condition ($p = 0.086$). As for the evaluation of the impression on the light environment, as a result of the factor analysis, 10 sensuous word pairs were divided into two factors. The first factor constituted by the five word pairs expressing the visibility of things was interpreted as "visibility". The second factor constituted by the other five word pairs related to the subjective feelings at the time of evaluation was interpreted as "light affinity". Based on the results of the multiple regression and correlation analysis, the relationship between light environment impression factors, task scores and task impression, and psychophysiological conditions is shown in Fig.1. It is suggested that the type of adapted task depends on which environmental impression factor has stronger positive influences on the task under the LEDs of each excitation light. Furthermore, it is suggested that the physiological vigilance level and brain activation showed a negative correlation with the feeling of tension when the light environment impression factor had a positive influence on the task.

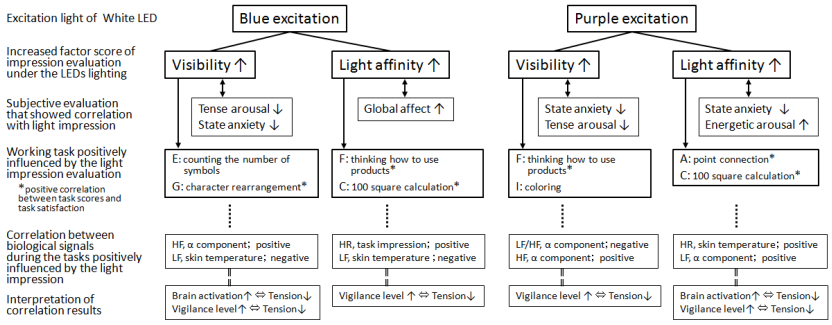

Figure 1: Relationship between light environment impression factors, tasks, and psychophysiological conditions

30 ORAL 2: Occupation

Musculoskeletal symptoms in the Norwegian fishing fleet

A register data and self-reported questionnaires study

Mariann Sandsund[1], Anita Øren Øren[1], Signe Sønvisen[2], Cecilie Thon Heidelberg[3,4], Ingunn Holmen[2], Trine Thorvaldsen[2], Lisbeth Aasmoe[3,4]

[1]SINTEF Technology and Society, Trondheim, Norway, [2]SINTEF Ocean, Trondheim, Norway, [3]University Hospital of North Norway, Tromsø, Norway, [4]The Arctic University of Norway, Tromsø, Norway

Many fishermen exposed to unfavorable environmental conditions in the fishing fleet suffer negative health effects. Few studies have investigated the effect of environmental work factors and musculoskeletal problems on fishermen. This study aimed to identify musculoskeletal symptoms in crewmembers in the Norwegian fishing fleet using data from several sources; register data, a telephone survey and a questionnaire. A sample of fishermen (n=25 971) was selected by Statistics Norway (SSB), based on occupation as fishermen for the period 2008-2013. An age- and gender-matched control population (n=77 913) was also selected. A sample of registered fishers on board Norwegian fishing vessels (n=832) was also surveyed and a questionnaire was distributed on board five deep-sea fishing vessels (n=102). Analysis of hospitalization and outpatient consultation data from the Norwegian Patient Registry (NPR) showed that compared to the control population, fishermen suffered significantly more acute incidents related to musculoskeletal diseases in general (5.4% vs. 4.8%, respectively), as well as arm (11.3% vs. 9.8%), foot (8.4% vs. 8%), and back injuries (0.9% vs. 0.7%). In the telephone survey, 61 and 43% reported often or very often monotonous work operations and heavy lifting, respectively. Thirty-three per cent had experienced pain in the neck/shoulders/arms often or very often in the course of the previous 12 months, and 93% believed this was fully or partly due to their work situation. The questionnaire issued to the crews of the five fishing vessels showed that 57 and 60% had experienced stiffness and/or pain in the neck/shoulders and lower back/small of the back respectively during the previous 12 months. Data from the register study, telephone survey and questionnaire survey all confirmed that musculoskeletal problems are common among fishers, although 77% of the crews of all the vessel groups and the fishers on the five deep-sea fishing vessels reported that their health was very good or good.

31 SYMPOSIUM: Early Career Researchers: Heat loss response

Early Career Researchers: Heat loss response

Naoto Fujii[1], Nicola Gerrett[2]

[1]Tsukuba University, Tsukuba, Japan, [2]Kobe University, Kobe, Japan

The Early Career Researcher symposium has been identified as an integral part of the ICEE program. The committee hope to bridge the gap between the students and well-established researchers by highlighting those individuals in the early stages of their research career. Postdoctoral research fellows, assistant or associate professors just starting out on their independent research career have been selected to showcase their research on topics associated with heat loss response.

Laboratory-based experiments provide us with a great opportunity to understand the fundamental mechanisms of heat loss responses. Field-based research in the heat is important to gauge the level of physiological strains experienced by individuals (e.g., field workers). The two opening presentations will focus on laboratory-based experiments aiming to understand the important mechanism of heat loss via cutaneous vasodilation and sweating. The techniques used to investigate such responses, important findings and future areas of research will be introduced and discussed. The final two presentations in this symposium will focus on field-based research with a particular focus on whole-body heat exchange after consecutive work shifts and interventions that reduce heat strain and kidney damage in sugarcane workers in the field.

32 SYMPOSIUM: Early Career Researchers: Heat loss response

The mechanisms underlying cutaneous vasodilation during exercise in the heat

Naoto Fujii, Takeshi Nishiyasu, Glen Kenny

[1]University of Tsukuba, Tsukuba, Japan, [2]University of Ottawa, Ottawa, Canada

The regulation of core temperature during exercise in the heat requires the transfer of heat from the body to the environment, which is mediated by cutaneous vasodilation and the resultant increase in blood flow through the cutaneous vasculature. The mechanisms underpinning the regulation of cutaneous perfusion during heat stress in humans *in vivo* have been extensively studied using laser-Doppler flowmetry coupled with intradermal microdialysis. However, these investigations have been limited to a passive heat stress wherein hyperthermia is induced via whole-body heating with a water perfusion suit. Importantly, some studies suggest that the mechanisms underpinning the regulation of cutaneous vasculature may differ between a passive- and exercise-induced heat stress potentially resulting from marked differences in tissue temperatures (i.e., skin, core, muscle), and therefore compartmental heat distribution, that occur with these different heating modalities. Thus, to advance our understanding of the mechanisms mediating the regulation of cutaneous vasodilation during exercise, responses should be examined using an exercise-induced heat stress model. Recent studies reveal that endothelial nitric oxide synthase contributes to cutaneous vasodilation during exercise in the heat, partially through mechanisms associated with heat shock protein 90. However, the contribution of nitric oxide synthase to cutaneous vasodilation is diminished with increasing exercise intensity, a response in part attributed to elevated oxidative stress. It has also been reported that ATP-sensitive, but not Ca^{2+}-activated and voltage-gated, K^{+} channels are involved in the regulation of cutaneous vasodilation during exercise in the heat. Finally, despite their importance to cutaneous vasodilation during whole-body passive heating, roles for factors such cyclooxygenase have not been observed in the cutaneous vasodilatory response to exercise heat stress. In this presentation, we will examine the mechanisms governing the regulation of cutaneous perfusion during an exercise-induced heat stress. Attendees will be given a comprehensive overview of current research on this growing area of focus as well as directions for future studies.

33 SYMPOSIUM: Early Career Researchers: Heat loss response

Sweat glands ion reabsorption

Nicola Gerrett[1], Tatsuro Amano[2], Narihiko Kondo[1]

[1]Kobe University, Kobe, Japan, [2]Niigata University, Niigata, Japan

The evaporation of sweat from the skin is an important mechanism for heat loss response in hot conditions. Whilst sweating, humans excrete a number of different electrolytes in varying quantities across different regions on the body. The quantity of these electrolytes, notably sodium chloride (NaCl), in sweat appears to be influenced by the sweat generation rate and the rate at which the ions are reabsorbed in the distal duct of the sweat glands. Upon stimulation, the sweat glands produce an isosmotic fluid in the proximal secretory coil that then travels through the distal duct towards the skin surface. To prevent excess ion loss, the distal duct reabsorbed these ions (notably Na+) but the rate of ion reabsorption is limited. We have recently developed a new technique to easily measure the maximum ion reabsorption rate of the sweat gland by measuring sweat rate (SR) and galvanic skin conductance (GSC). By plotting the relationship between sweat rate (ΔSR) and galvanic skin conductance (ΔGSC) we can identify the maximum ion reabsorption rate by observing the ΔSR threshold for an increasing ΔGSC (Amano et al. 2015). Using this technique we have been able to address some of the factors affecting the maximum ion reabsorption rate of the sweat glands. This presentation will touch upon some of these influential variables including: sex, training status, heat acclimation, skin temperature, regional differences across the body and differences between exercise and passive heating protocols. Gaps in our knowledge of this topic will conclude this presentation.

34 SYMPOSIUM: Early Career Researchers: Heat loss response

Heat strain over consecutive work shifts

Sean Notley, Robert Meade, Brian Friessen, Andrew D'Souza, Glen Kenny

University of Ottawa, Ottawa, Canada

Working in hot conditions is associated with considerable physiological strain, which is exacerbated by the physically demanding nature of many occupations (e.g., bush fire fighting, open pit mining) and the requirement for workers to don heavy and often impermeable protective clothing. Prolonged work in the heat can cause dangerous rises in body temperature that compromise cognitive function and productivity, and lead to heat-related illnesses. Whilst our understanding of occupational heat strain during single work bouts is extensive, less is known about the potential carry-over effects of heat strain on thermoregulatory function on the second of consecutive work days, even though many occupations necessitate back-to-back work days or shifts lasting ≥48 hrs (e.g., wild land fire fighting). In recent years, heat exposure has been shown to increase one's risk of heat-related illness on the following day, and exacerbate heat strain on the second of consecutive days of work in the heat. Consecutive days of heat strain may be particularly dangerous for the rising number of older workers, who possess marked impairments in heat loss responses of sweating and skin blood flow relative to their young counterparts, and may recover more slowly from prolonged work in the heat. Indeed, the carry-over effects associated with consecutive days of work in the heat may represent important considerations for current heat exposure guidelines directed at protecting workers from heat-related illness (e.g. American Conference of Governmental and Industrial Hygienists Threshold Limit Values). In this presentation, we will discuss recent field- and laboratory-based evaluations of heat strain in young and older workers over consecutive days of work in the heat. Specific attention will be directed to the effects of prolonged heat strain performed the day before on whole-body heat loss and exchange.

35 SYMPOSIUM: Early Career Researchers: Heat loss response

Intervention to reduce heat strain and kidney damage among sugarcane workers in El Salvador

Rebekah Lucas[1], I. Weiss[2], J. Glaser[2], C. Wesseling[3], T. Bodin[3], K Jackobsson[4], S. Pereza[5], J Apelgvist[6], U Ekstrom[6], C Hogsedt[3], DH Wegman[7]

[1]University of Birmingham, Birmingham, UK, [2]La Isla Foundation, Michigan, USA, [3]Karolinska Institutet, Stockholm, Sweden, [4]Gothenburg University, Gotherburg, Sweden, [5]Program on Work, Environment and Health in Central America, Central America, USA, [6]Lund University, Lund, Sweden, [7]University of Massachusetts, Massachusetts, USA

In Mesoamerica chronic kidney disease of unknown etiology (CKDu) is epidemic among sugarcane workers. The etiology is likely multi-causal; however, excessive heat stress and workload are believed to contribute to the onset and acceleration of CKDu. The Worker Health and Efficiency (WE) Program is the first evaluated intervention to address excessive heat stress and workload in sugarcane workers.

Objectives: 1) to assess level of heat stress, dehydration, physical workload and resultant heat strain in sugarcane workers in the field; 2) to assess feasibility of implementing a combined water, rest, shade (WRS) and efficiency intervention amongst sugarcane workers, and 3) evaluate impact of intervention on patterns of heat illness/dehydration, kidney function, physical workload and productivity.

Data were collected in three cohorts of sugarcane workers (totaling 320 individuals) during two sugarcane harvests (November 2014 – April 2015; November 2015 – March 2016). A WRS intervention adapted from US Occupational Safety and Health Administration (OSHA) coupled with an efficiency program was introduced two months into the 5-month harvest; allowing assessment of the intervention via self-controls. Daily wet bulb globe temperatures (WBGT; QUESTemp 34) were recorded across the harvest. Health data (anthropometric and questionnaires), blood and urine were collected at baseline and at three subsequent times over the course of the harvest. Estimated glomerular filtration rate was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine equation. Heart rate (HR, Polar; n=25), workload (tri-accelerometers; n=24) and gastro-intestinal temperature (T_{GI}, Equivital, vitalsense; n=14) were measured in a subset of workers.

WBGT exceeded 26°C for the majority (~80%) of the workday in both regions. During the 2014-2015 harvest, only the Inland cohort received the intervention (*n*=60 Inland and *n*=57 Coastland). These data indicated eGFR acutely decreased -10.5 mL/min/1.73m^2 [95% confidence interval (95% CI) -11.8– -9.1] in both cohorts across a workday. Across the harvest period eGFR chronically decreased -3.4 mL/min/1.73m^2 (95% CI -5.5– -1.3) and -5.3 mL/min/1.73m^2 (95% CI -7.9– -2.7) in the Inland and Coastland cohorts respectively. This corresponded to an increase in water consumption and decrease in heat illness/dehydration symptoms as reported by the Inland workers. Data from a subset of workers indicated that HR averaged 54%HR_{max} (95% CI: 56 to 53%HR_{max}) during the workday. T_{GI} averaged 37.5°C (95% CI: 37.7 to 37.4°C) across a workday and reached a maximum of 38.4°C (95% CI: 38.7 to 38.1°C). Two out of 14 workers T_{GI} exceeded 39.0°C.

Strenuous work in hot environments was associated with negative impacts on biomarkers of kidney function over the workday and over the harvest. A WRS and efficiency intervention program was successfully introduced for workers in sugarcane fields. These pilot data indicate a decrease in heat-related illness, improved hydration, and possibly stabilization in kidney function following the intervention.

36 ORAL 3: Perception 1

Physiological evaluations and development for comfort cabin

Atsushi Takamatsu, Norimichi Yoshizawa, Akinari Hirao

NISSAN MOTOR CO., LTD., Kanagawa, Japan

NISSAN MOTOR CO., LTD. has already announced “Health and Wellbeing” concept for realizing comfortable car cabin environment since 2010, and also developed many technologies based on 2 pillars, “Comfortable posture and thermal environment” and “Good air quality”. In this time, we would introduce especially about the former one, by explaining following 3 issues; i) Technological development improving physical comfort by focusing on blood circulation in whole body, ii) Investigation about muscular fatigue mechanism by focusing on local blood circulation, iii) Characteristics about physical fatigue in ultra-long time driving under Eyes-on Autonomous Driving condition, would be explained.

i) At first, we would introduce our motivation and detailed process for making physiological index of comfort by focusing on “Stroke volume per one heart beat”, representative of whole body blood circulation state and could affect both posture and thermal comfort. Then we would introduce 3 key technologies, whose performances were confirmed by this index and already adapted to current car, as followings; a) Neutral Posture Support, b) Spinal Support Seat, c) Quick Comfort Seat Heater.

ii) In contrast of whole body blood circulation, we would introduce our investigation about mechanism of “Stiff Shoulder” due to keeping driving position, as example of physical fatigue more affected by local blood circulation. Kinetics of oxygen in muscle, representative of local blood circulation state, would be one of key indexes for measuring muscular fatigue and its recovery extent.

iii) We would introduce our experimental results about physical fatigue in ultra-long time (Over 6 hours) driving, assuming Eyes-on Autonomous Driving situation, as results of applying our existing postural comfort technologies described above. Some distinctive features especially under ultra-long time riding condition would be pointed out and possibilities of our future works would be suggested.

37 ORAL 3: Perception 1

Ethnic differences in preferred air flow temperature in a vehicle environment

George Havenith[1], Yifen Qiu[1,2], Rebecca Bartlett[1], Simon Hodder[1]

[1]Loughborough University Design School, Loughborough, UK, [2]bSchool of Aeronautical Science and Engineering, Beijing 100191, China

Ethnic differences in thermoregulatory responses in exposure to heat and cold have been described but evidence for differences in comfort thermal sensation is limited. Comparisons of thermal perception responses to different climates between different ethnicities are complicated by the use of thermal sensation and comfort scales in different languages. Despite translations of scales being performed by people into their mother tongue, the interpretations of scale wording by different ethnic groups may be biased towards their personal experience, language and cultural subtleties.

Therefore, in the present study a different approach was chosen, i.e. rather than exposing individuals to fixed conditions and asking for a rating, the individuals were instructed to adjust the climate to their personal preference. It is hypothesised that this will lead to a rating of neutral, and of thermal comfort in all individuals.

Groups of Japanese, Chinese and British male individuals was recruited for the study, which was approved by the local research ethics committee. Participants wore identical clothing and were seated in a car seat in front of an airflow generating device which allowed individual temperature control of the airflow aimed at the participant. In the setup, participants were exposed to approximately 600 wm-2 of solar radiation. For the first 30 minutes, no airflow apart from the chamber airflow at 25°C was present. Then, the cooling system was activated and participants controlled the airflow temperature for the next 15/20 minutes.

In the first 30 minutes thermal ratings increased due to the radiation exposure to ‘warm’ and ‘slightly uncomfortable’ with a preference to ‘being cooler’. Once the adjustment was allowed, sensations quickly changed to ‘neutral’, ‘comfortable’ and ‘no change’. The selected temperature of the cooling airflow was on average around 5 to 7 degrees higher in the Asian groups compared to the British. This was combined with a higher skin temperature of about a degree Celsius.

It is concluded that relevant differences in preferred comfort temperature in this vehicle simulation exist, with British groups requiring a more powerful cooling system to attain comfort in the conditions tested.

38 ORAL 3: Perception 1

ABSTRACT WITHDRAWN

39 ORAL 3: Perception 1

An innovative HVAC control system: Comparison of the system outputs to comfort votes

Miloš Fojtlín, Jan Fišer, Jan Pokorný, Róbert Toma, Miroslav Jícha

Brno University of Technology, Brno, Czech Republic

Human thermal comfort in vehicular cabins has been broadly discussed in various contents. The most actual topics relate to efficient energy utilisation and enhancement of thermal comfort experience – especially in electric passenger vehicles. In fact, these two factors are contradictory at present; therefore, new concepts of HVAC management are being investigated. The presented study shows progress in the iHVAC project (Fišer et al., 2015; Fojtlín et al., 2017) that serves as a support system for a driver and passengers. The aim of the project is real-time evaluation of thermal conditions in the cabin using compact equivalent temperature sensors. To do so, methodology of the Comfort zone diagram and the MTV index (Mean Thermal Vote) are exploited. The concept has been tested previously against a newton type Manikin with good results. Now, the system performance was examined in two scenarios against a pool of eight volunteers. Firstly, the test vehicle was preconditioned to 0 °C and volunteers wore prescribed clothing (0.75 clo). In the second run, the chamber temperature was 10 °C and lighter clothing was worn (0.5 clo). The test protocol of both scenarios comprises preconditioning (60 min, t_{amb} 23 °C), seating in a precooled vehicle (45 min, t_{amb} 0 and 10 °C), and at the same time initiation of the HVAC system set to AUTO 24 °C. The volunteers were asked to rate the thermal comfort and sensation in the cabin every 3 min. These votes were compared with the system outputs and good match was found on the head, hands, and torso. The predictions were least accurate for legs, feet, and arms. Moreover, the methodology has its limitations, mainly to its applicability in stationary conditions, and further research is needed.

Fišer J. et al., 2015. Implementation of the equivalent temperature measurement system as a part of the vehicle Heating, ventilation and Air-conditioning unit. Extrem. Physiol. Med. 4, A159. doi:10.1186/2046-7648-4-S1-A159

Fojtlín, M. et al., 2017. An innovative HVAC control system: Implementation and testing in a vehicular cabin. J. Therm. Biol. doi:10.1016/j.jtherbio.2017.04.002

40 ORAL 3: Perception 1

Does the vertical position of the axis of whole-body rolling affect discomfort in seated persons?

Hisato Ohno, Hiroharu Endoh

Railway Technical Research Institute, Tokyo, Japan

Tilt trains have a unique mechanism to tilt their car-bodies in lateral directions. With this mechanism, tilt trains can run faster through curved sections without increasing lateral accelerations acting on passengers, tilting their car-bodies to the inner-side of the curve.

At the same time, since tilting car-bodies naturally produce rolling of the car-bodies, ride for rolling have become another research issue in tilt trains. In the past, relationships between characteristics of rolling and ride were studied. Based on those results, 5 deg/s of roll velocity and 15 deg/s^2 of roll acceleration are ride criteria for rolling in tilt trains in Japan. In this way, the relationships between the characteristics of roll motions and ride have been understood to some extent. But, on the other hand, the relationship between the height of the center of rolling above the vehicle floor and ride is still unknown. Since the relative position of the center of rolling and passengers affects the motion of passengers' body, it possibly affect passengers' ride. Thus, the height of the center of rolling above the vehicle floor could be a parameter in designing tilt trains from the aspect of ride. Therefore, we examined the effect of vertical position of the axis of whole-body rolling on the subjective discomfort in seated persons. In the 1st examination, 34 healthy seated subjects were individually exposed to rolling stimulus, using the Ride Comfort Simulator at RTRI. The vertical position of the axis of rolling was changed at 5 levels between 0 to 150 cm above the vehicle floor. The subjects rated their subjective discomfort with questionnaire. The results showed no clear relationship between the vertical position of the axis of rolling and ride. To test the validity of the 1st examination, the 2nd examination conducted theoretical analysis of dynamics of accelerations acting on seated persons. The result showed that lateral acceleration changes in accordance with the vertical position of the axis of rolling, to be sure, but when roll velocity remains 5 deg/sec or less, lateral accelerations were so small that they scarcely affect subjective discomfort. In this way, the results of the 1st and 2nd examinations were consistent to each other, and the influence of the vertical position of the axis of whole-body rolling on discomfort was small enough. Consequently, we concluded that the height of center of car-body rolling can be ignored substantially.

41 ORAL 4: Physiology and Exercise Physiology

The human ventilatory responses to different stresses

Mike Tipton[1], Abbi Harper[2], Julian Paton[3], Joseph Costello[1]

[1]Extreme Environments Laboratory, Department of Sport and Exercise Science, University of Portsmouth, Portsmouth, Hants, UK, [2]Southmead Hospital, Bristol, UK, [3]School of Physiology, Pharmacology and Neuroscience, Biomedical Sciences, University of Bristol, Bristol, UK

Many stressors cause an increase in ventilation in humans. This is predominantly reported as an increase in minute ventilation (VE). But, the same (VE) can be achieved by a wide variety of changes in the depth (tidal volume, V_T) and number of breaths (respiratory frequency, fR). This analysis of published papers investigated the impact of stressors on fR and V_T, including:

- Sudden or prolonged cold exposure (12 studies; 176 participants)
- Passive and Active hyperthermia (13 studies; 153 participants)
- Hypoxia (10 studies; 290 participants)
- Panic (8 studies; 470 participants)
- Pain (4 studies, 56 participants)

The aim was to determine if there is an overall differential control of fR and V_T that applies in a wide range of conditions. Results: for the stressors reviewed, as the stress becomes more intense $\dot{V}_E$ generally becomes increased more by fR than V_T, regardless of whether this was the case at lower intensities of stress. We have suggested that, given the range of respiratory responses that can be elicited from the ventral respiratory column when connected to the pons, it is a most likely site for directly mediating fR and/or V_T changes. We were tempted to conclude that the ventilatory response evoked by a stress depends on the nature of that stress: with metabolic/chemical stimuli normally resulting in an increase in both fR and V_T; and non-metabolic/non-chemical intense stimuli (thermal, nociceptive, psychological) primarily resulting in an increase in fR. However, current understanding of the pathways involved, the complex integration, the multiple mechanical and physiological determinants of the ventilatory response and the difficulty of experimentally evoking and isolating a standardised stressor, make this suggestion impossible to test definitively at this time. In the areas of Acute Mountain Sickness, disease-related hypoxic ventilatory responses and clinical psychology we have some tentative evidence to support the idea that the pattern of the fR and V_T response of an individual may provide information regarding their physiological and pathophysiological state. We conclude that a careful analysis of the breathing pattern of a patient might be informative diagnostically; there are likely to be associations between breathing pattern and potential causes of a disease and these could inform effective treatment strategy. Much more investigation is required in this area.

Separate effects of voluntary hyperventilation and resultant hypocapnia on metabolic and cardiovascular responses during and following supramaximal exercise

Kohei Dobashi[1], Naoto Fujii[2], Tomomi Fujimoto[1], Satoru Tanigawa[2], Masashi Ichinose[3], Takeshi Nishiyasu[2]

[1]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, [2]Institute of Health and Sports Sciences, Tsukuba, Ibaraki, Japan, [3]Human Integrative Physiology, School of Business Administration, Meiji University, Tokyo, Japan

Voluntary hyperventilation (VH) washes out CO_2 from the body, leading to reductions in arterial CO_2 pressure (hypocapnia). We recently showed that voluntary hypocapnic hyperventilation decreased aerobic metabolism and blunted the tachycardia response during supramaximal exercise (three bouts of 30-s cycling) (Dobashi et al. 2017) in comparison to spontaneous breathing condition. Furthermore, this study also demonstrated that heart rate (HR) following the supramaximal exercise was lower with voluntary hypocapnic hyperventilation (Dobashi et al. 2017). However, as VH causes both hypocapnia and increased activity of respiratory muscles, it remains unclear whether hypocapnia and/or VH per se lead to the aforementioned physiological responses during and following the supramaximal exercise. Therefore, the purpose of this study was to assess the separate effects of VH and resultant hypocapnia on metabolic and cardiovascular responses during and following supramaximal exercise.

Ten participants (9 males and 1 female) performed a 60-s supramaximal cycling exercise (120% peak oxygen uptake) in three different trials: 1) spontaneous breathing (control), 2) hypocapnia or 3) normocapnia trials. Hypocapnia was developed through VH for 20 min prior to the exercise. In the normocapnia trial, as with the hypocapnia trial, VH was performed but hypocapnia was prevented with CO_2 inhalation. Respiratory gases, arterial blood pressure, and HR were assessed throughout.

VH decreased end-tidal CO_2 pressure ($P_{ET}CO_2$, an index of arterial CO_2 pressure) in the hypocapnia trial prior to the exercise. By contrast, $P_{ET}CO_2$ remained unchanged during VH in the normocapnia trial. Oxygen uptake ($\dot{V}O_2$) during the exercise in both hypocapnia and normocapnia trials was lower than control trial. Moreover, $\dot{V}O_2$ during the exercise was lower in the hypocapnia vs. normocapnia trials. HR during and after the exercise was lower in the hypocapnia relative to the other two trials with no difference between the control and normocapnia trials. Systolic arterial blood pressure during the exercise was lower in the hypocapnia than the other two trials, whereas it did not differ between the control and normocapnia trials.

Our results suggest that both hypocapnia and VH lower aerobic metabolic rate during supramaximal exercise. Furthermore, hypocapnia alone affects HR and blood pressure responses during and/or following the exercise.

43 ORAL 4: Physiology and Exercise Physiology

Combined effects of cold pressor test and apnea on cardiovascular responses during dynamic two-legged knee extension exercise

Ryoko Matsutake[1], Tomomi Fujimoto[1,3], Kazuhito Watanabe[2,3], Masashi Ichinose[4], Naoto Fujii[2], Takeshi Nishiyasu[2]

[1]Graduate School of Comprehensive Human Science, University of Tsukuba, Tsukuba City/Ibaraki, Japan, [2]Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba City/Ibaraki, Japan, [3]Japan Society for the Promotion of Science, Tokyo, Japan, [4]Human Integrative Physiology Laboratory, School of Business Administration, Meiji University, Tokyo, Japan

Cold stress and breath hold can occur simultaneously during exercise in the water. It has been demonstrated that cold stress elicited by cold pressor test (CPT) can increase blood pressure and heart rate (HR), while it has no effect on active muscle blood flow during exercise (Wray et al. 2007). On the other hand, breath holding can cause increases in blood pressure with concomitant reductions in HR and active muscle blood flow (Nishiyasu et al. 2012). However, the combined effects of CPT and apnea on blood pressure, HR, and active muscle blood flow during exercise are unknown. It might be that these two effects on cardiovascular responses are simply additive or there may be an interaction between these two effects such that the combined effects of them are smaller or greater than a summation of each separate effects. In this study, we assessed the combined effects of CPT and apnea on blood pressure, HR, and active muscle blood flow during dynamic two-legged knee extension exercise.

Ten participants (9 male and 1 female) performed 3 trials: 1) CPT achieved by immersing the right hand into water regulated at 4°C, 2) maximal-duration breath holding (Apnea), and 3) a combination of CPT and Apnea. Each trial was performed while participants performed a dynamic two-legged knee extension exercise at a work load that elicits a HR of approximately 100 beats/min. Mean arterial pressure (MAP, finometer), HR, cardiac output (CO, ultrasound Doppler system), leg blood flow (LBF, ultrasound Doppler system), and leg vascular conductance (LVC, LBF/MAP) were measured. The 1-min period immediately before commencing CPT and/or apnea was defined as Baseline. Peak response of each variables during CPT and/or apnea were used for data analyses.

MAP increased in response to CPT, apnea, and a combination of both ($P<0.05$). Changes in MAP from baseline (ΔMAP) induced by a combination of CPT and apnea was smaller than that mathematically calculated by a summation of CPT-induced and apnea-induced ΔMAP ($P<0.05$). HR, CO, and LVC decreased in response to apnea regardless of the presence or absence of CPT ($P<0.05$). However, apnea-induced changes in these variables from baseline did not differ with and without CPT ($P>0.05$).

An inhibitory interaction exists between CPT and apnea in eliciting pressor response, whereas there is no interaction between the two stimuli for cardiac and active muscle brood flow responses during exercise.

44 ORAL 4: Physiology and Exercise Physiology

Expiratory flow limitation under moderate hypobaric hypoxia does not influence ventilation, oxygen uptake, and operating lung volumes during incremental running in endurance runners

Yinhang Cao[1], Yuhei Ichikawa[1], Yosuke Sasaki[2], Takeshi Ogawa[3], Tsutomu Hiroyama[4], Yasushi Enomoto[4], Naoto Fujii[4], Takeshi Nishiyasu[4]

[1]Comprehensive Human Science, University of Tsukuba, Tsukuba, Japan, [2]Niigata Sangro University, Niigata, Japan, [3]Osaka Kyoiku University, Osaka, Japan, [4]Faculty of Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan

Peak oxygen uptake (VO_{2peak}) decreases at altitude compared to sea level, and this response exhibits a large inter-individual variability (Fulco et al. 1998). Regarding this, we demonstrated that endurance athletes who show a greater decrement in VO_{2peak} in hypobaric hypoxia (2,500m) exhibit a smaller increase in peak ventilation (VE_{peak}) (Ogawa et al. 2007). However, mechanisms underpinning this smaller increase in VE_{peak} in these athletes remain to be elucidated. A report showed that some endurance athletes experienced expiratory flow limitation (EFL), which in turn limited their VEpeak at normobaric hypoxia (~1,000m) (Chapman et al. 1998). It seems therefore possible that in endurance athletes who experience EFL under moderate hypobaric hypoxic environment (2500m), their VE_{peak} may be restricted as compared to those without EFL, leading to a greater reduction in VO_{2peak}.

Study showed that at sea level, there are no differences in operating lung volumes between athletes with or without EFL (Iandelli et al. 2002). However, it remains unclear whether similar results are also observed under moderate hypobaric hypoxia. The purpose of this study therefore was to examine whether endurance athletes with EFL would exhibit lower VE_{peak} thereby exacerbating reductions in VO_{2peak} under moderate hypobaric hypoxic condition. We also evaluated whether operating lung volumes under moderate hypobaric hypoxia differs between athletes with and without EFL.

Seventeen healthy young endurance male runners performed an incremental running test under hypobaric hypoxia (HH, 2500m) or normobaric normoxia (NN). Oxygen uptake (VO_2), minute ventilation (VE) and arterial oxyhemoglobin saturation (SaO_2) were assessed. Changes in end-expiratory and end-inspiratory lung volume (EELV and EILV) were quantified using a maximal expiratory flow-volume curve (MEFV) and inspiratory capacity maneuvers during the last 30s of each stage. A minimum of 5% tidal flow volume loop reaching or exceeding the MEFV curve was considered EFL (Derchak et al. 2000). Participants were divided into two groups: individuals with (EFL group, n=6) and without EFL (Non-EFL group, n=11).

VE_{peak} and VO_{2peak} were not different between EFL and Non-EFL groups in either NN (VE_{peak}: EFL vs. Non-EFL, 144±17 vs. 133±10 $l \cdot min^{-1}$; VO_{2peak}: 66±3 vs. 61±4 $ml \cdot kg^{-1} \cdot min^{-1}$, $p > 0.05$) or HH (VE_{peak}: EFL vs. Non-EFL,150±16 vs. 136±12 $l \cdot min^{-1}$; VO_{2peak}: 54±4 vs. 51±5 $ml \cdot kg^{-1} \cdot min^{-1}$, $p > 0.05$). There were no differences in maximal running velocity, SaO_2, EELV and EILV between the groups in either condition. Along these lines, the changes in the aforementioned variables from NN to HH did not differ between the groups.

Our results suggest that EFL can occur in some endurance competitive runners under moderate hypobaric hypoxic condition (i.e., ~2,500m), however, EFL does not appear to influence their VE_{peak}, VO_{2peak}, and operating lung volumes.

45 ORAL 4: Physiology and Exercise Physiology

Q_{10} effect and thermal cardiac reactivity related to the interrelation between heart rate and oxygen consumption under heat stress

Peter Bröde[1], Bernhard Kampmann[2]

[1]Leibniz Research Centre for Working Environment and Human Factors (IfADo), Dortmund, Germany, [2]Department of Mechanical Engineering and Safety Engineering, University of Wuppertal, Wuppertal, Germany

The positive correlation between energy expenditure and heart rate (HR) is used for estimating metabolic rate (M) in observational heat stress studies. As the concomitant effects of rectal temperature (t_{re}) on metabolic rate (Q_{10}) and HR (thermal cardiac reactivity, TCR) might influence the HR-to-M correlation, we studied the interrelation of oxygen consumption (VO_2) with HR and t_{re} using an extensive database of climate chamber experiments. VO_2, HR and t_{re} averaged over the third hour of each exposure were obtained from 1511 trials organized in 50 series performed by 29 young males (20.8 ± 1.1 yrs, 182.6 ± 4.5 cm, 71.0 ± 7.3 kg, 1.9 ± 0.1 m^2, 49.2 ± 9.1 mL/min/kg VO_{2max}) under widely varying heat stress conditions (t_a 15-60 °C, p_a 0.3-5.7 kPa, v_a 0.3-2 m/s, $\Delta t_r = t_r - t_a$ 0-128 °C), and different clothing (Icl=0.1, 0.7, 1 clo) and activities (Figure 1). By linear regression we calculated slopes of the HR-to-VO_2 relation as well as for Q_{10} and TCR, as shown for a semi-nude male in Figure 1. Mixed model ANCOVA showed that HR-to-VO_2 slopes did not depend on clothing and activity, but significantly increased with Q_{10} and decreased with TCR. Thus, thermal effects might contribute to the HR-to-VO_2 relation, which largely depends on dynamic muscular load (cf. overall regression in Figure 1).

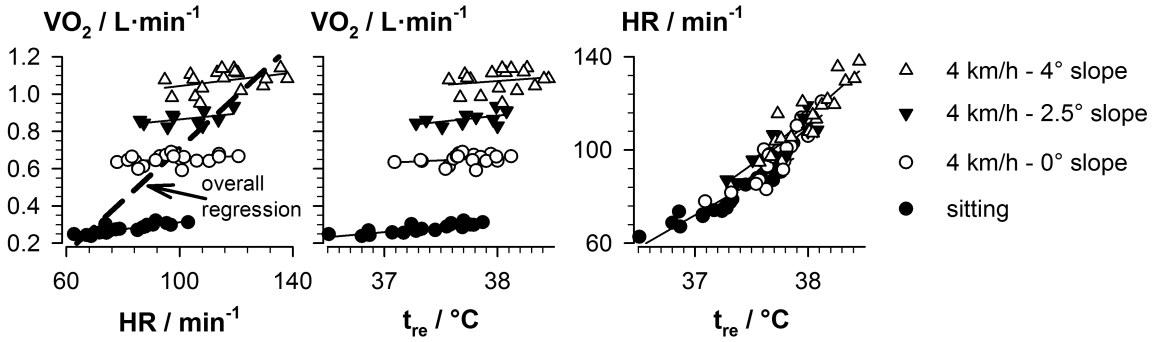

Figure 1: HR-to-VO_2 relation (left panel), Q_{10} effect (mid) and TCR (right) for a semi-nude male from 69 trials in 4 series with varying activities and levels of heat stress.

Oxygen availability effects on exercise performance and tissue oxygenation during mild hypothermia

Steven Ferguson[1], Neil Eves[2], Brian Roy[1], Gary Hodges[1], Stephen Cheung[1]

[1]Brock University, St. Catharines, Ontario, Canada, [2]University of British Columbia - Okanagan, Kelowna, British Columbia, Canada

Hypothermia impairs exercise by causing muscular vasoconstriction, reducing tissue blood flow and oxygenation. Contrarily, hyperoxia increases arterial oxygen saturation and tissue oxygen content, thus potentially restoring oxygen delivery and performance. We tested whether hyperoxia improves exercise performance in mildly-cooled individuals, along with the relationship between cold and hyperoxia on cerebral and muscle oxygenation as potential mechanisms for improvement. We hypothesized that: 1) performance in Neutral will be higher than with mild (-0.5°C) core cooling during both Cold and Cold+Hyper trials, with Cold+Hyper improved compared to Cold, 2) Cold+Hyper and Neutral will have enhanced cerebral and maintained muscle oxygenation compared to Cold.Ten healthy trained male cyclists completed self-paced 15 km time trials (TT) a week apart in three environmental conditions: Neutral (23°C, F_iO_2: 0.21), Cold (0°C, F_iO_2: 0.21), and Cold+Hyper (0°C, F_iO_2: 0.40). Cold conditions were done after participants were passively cooled by 0.5°C rectal temperature. Near infrared spectroscopy was used to measure changes in cerebral and muscle oxygenation. Specifically, we assessed tissue oxygenation index (TOI), a percentage change of oxygenated haemoglobin to total haemoglobin representing overall tissue oxygenation. Arterial oxygen saturation measured with pulse oximetry was maintained ($p < 0.01$) at baseline levels throughout the TT in Cold+Hyper, while Neutral and Cold were decreased ($p < 0.01$) over the entire TT. Power output during Cold+Hyper reached similar ($p \geq 0.258$) levels as Neutral by 7.5 km while also being higher ($p \leq 0.010$) than Cold from 10 km onwards. Power output during Neutral was higher than Cold at all time points except 12.5 km ($p \leq 0.014$). Cerebral TOI in Neutral was higher ($p \leq 0.011$) than Cold throughout the entire TT, while Cold+Hyper reached similar ($p \geq 0.567$) oxygenation levels as Neutral from 10 km onwards. Cerebral TOI in Cold and Cold+Hyper followed the same trend as power output, with Cold lower than Cold+Hyper from 10 km onwards ($p \leq 0.026$). Muscle TOI in Neutral was higher than Cold from 2.5 km to 7.5 km ($p \leq 0.042$), with no difference from 10 km onwards ($p \geq 0.109$). Cold+Hyper maintained muscle TOI compared to Neutral, and was higher ($p \leq 0.042$) than Cold throughout the entire TT. Despite mild core temperature decreases, hyperoxia of 0.40 F_iO_2 maintained cerebral and muscle oxygenation at thermoneutral levels for most or all of a prolonged cycling time trial, respectively. Cerebral oxygenation and power output in Cold+Hyper followed an identical trend, suggesting that the reversal of cerebral deoxygenation in the middle of exercise may have improved performance by altering central motor drive.

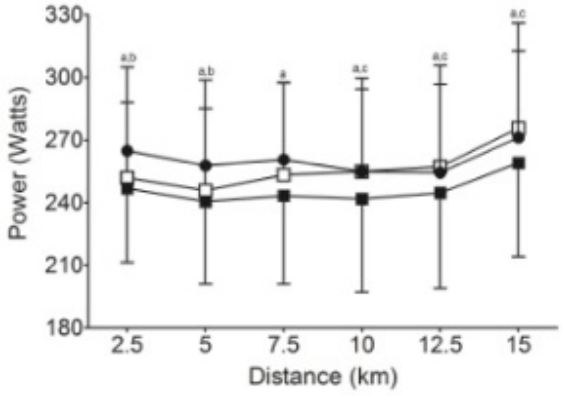

Figure 1: Power output during Neutral (Closed circles), Cold (Closed squares), Cold+Hyper (Open squares). [a]Neutral different from Cold. [b]Neutral different from Cold+Hyper. [c]Cold+Hyper different from Cold.

47 POSER SESSION 2

Experimental study on the practical effect of solar radiation on a clothed body by using a thermal manikin

Yuta Kato[1], Kazuo Nagano[1], Shinichi Watanabe[2]

[1]Kyoto Prefectural University, Kyoto, Japan, [2]Daido University, Nagoya, Japan

Human thermal comfort is decided by the air temperature, longwave radiation, humidity, air velocity, clothing insulation, and metabolic rate. Solar radiation should be also considered in outdoor spaces. The thermal indices as UTCI, OUT_SET*, and so on are based on a human heat balance model and can evaluate the universal effect of all these environmental parameters on human thermal comfort. This study examines the validity of the heat balance equation by using a thermal manikin in an outdoor space.

In order to diminish the wind velocity and to protect the manikin from the rain, the manikin was put in a plastic greenhouse that was placed on the roof at Kyoto Prefectural University. After the white or black clothes made of the same materials were put on the manikin, all 17 segments of local skin temperature were controlled at 33 °C. In the greenhouse, the air temperature, humidity, longwave radiation, shortwave radiation, air velocity, skin temperature, and sensible heat losses from the skin surface were measured at 10-second intervals. The heat balance equation was calculated by using these measured values.

The results showed that the absorbed solar radiation derived from the manikin experiment was considerably smaller than the estimation by the observation of solar radiation and the net solar absorptance and transmittance of the clothing. This suggests that part of the incident solar radiation at the clothing surface could be lost through the heat transfer process from the clothing to the skin. It also indicates that the above indices overestimate the solar effect since these indices are usually calculated by using the latter estimation of the absorbed solar radiation.

Consequently, this study proposes the ratio of the former to the latter as a new factor to correct the absorbed solar radiation. The factors are 0.66 for black clothing and 0.74 for white. In other words, 34% of solar radiation, which was supposed to be absorbed by the clothing and the skin of the manikin wearing the black clothing, could not have been practically absorbed. In case of the white clothing, 26% of them could not have been absorbed. It is expected that this factor will make evaluations of the outdoor environment by the thermal indices more accurate.

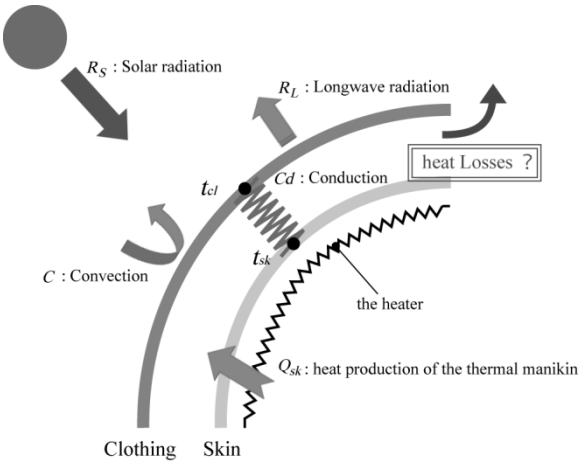

Figure 1: The sensible heat balance for a clothed person at an outdoor space

48 POSER SESSION 2

Effects of wind and air gap on the thermal resistance of chemical protective clothing fabrics

Liwen Wang, Jie Yang, Rui Li, Chunhui Xiang, Guowen Song

Iowa State University, Ames, Iowa, USA

Chemical protective clothing (CPC) is designed to prevent harm to human body and fatalities from exposure to chemical and biological substances. However, the bulky structure and poor permeability of fabric make heat stress a critical issue for CPC. To evaluate clothing thermal properties, thermal resistance (Rct) has been widely used. Previous studies have shown that wind and air gap may affect clothing thermal resistance in different ways depending on clothing construction and fabric. In this study, the effects of wind and air gap on the Rct of CPC fabrics were investigated. Three fabrics were evaluated: one control fabric for industry workwear (permeable, denoted as Nomex), one for level D CPC (semipermeable, denoted as D), and one for level C CPC (non-permeable, denoted as C). The Rct of fabrics were tested on a sweating hot plate with/without air gap according to ASTM F1868. Three spacers were applied to create 3mm, 6mm, and 9mm air gap under the fabric, and the wind speed in the testing chamber was set at 0.5, 1.0 and 2.0 m/s, respectively. The results for each fabric are presented in Figure 1 and analyzed with multiple linear regression. Significant effects (significance level 0.05) of both wind speed and air gap thickness were found on the Rct of Nomex, D, and C with wind affecting Rct negatively (standardized coefficients Beta: -0.274, -0.130, and -0.244), while air gap thickness affecting Rct positively (standardized coefficients Beta: 0.934, 0.977, and 0.959). No significant interaction between wind speed and air gap thickness was found. The results suggest a fit design for CPC and a consideration of worksite wind speed when providing Rct values.

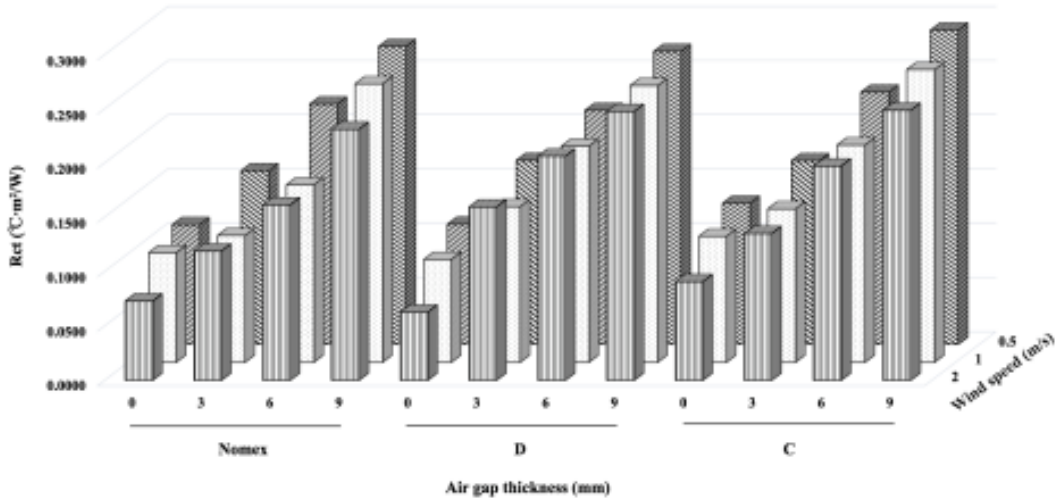

Figure 1: Rct of different fabrics with different air gap thickness and wind speed

49 POSER SESSION 2

Agreement between the measured and estimated effects of wind-speed on the heat exchange properties of military protective clothing

Andrew Hunt[1,2], Adam Potter[3], Alison Fogarty[2], Julio Gonzalez[3]

[1]Queensland University of Technology, Brisbane, QLD, Australia, [2]Defence Science and Technology Group, Melbourne, VIC, Australia, [3]United States Army Research Institute of Environmental Medicine, Natick, MA, USA

Biophysical modelling is used to evaluate the effects protective clothing systems have on body heat storage. The modelling input parameters include the heat exchange properties of the protective clothing systems (insulation and evaporative resistance) measured at 1 m/s wind-speed on a heated sweating manikin, however, standard test procedures stipulate 0.4 m/s. The aim of this study was to evaluate the agreement between clothing parameters measured on a heated manikin at three wind-speeds and those estimated from the standard wind-speed.Thermal insulation and evaporative resistance of military protective clothing systems from two laboratories (USARIEM n=65 (20 for equation development and 45 for verification); DST n=33) were measured on a heated sweating manikin in accordance with standard test procedures (ASTM F1291-10 & ASTM F2370-10), at wind-speeds 0.4, 1.12 and 2.2 m/s. The ensembles were characterised by their total thermal insulation (I_T), permeability index (i_m), and evaporative potential (i_m/clo). To estimate I_T *and* i_m/clo at 1 m/s from the standard 0.4 m/s wind-speed data, twenty USARIEM ensembles were analysed by a forward adding stepwise multiple linear regression to generate prediction equations for I_T ($I_{T\,[1m/s]} = I_{T\,[0.4m/s]} * (0.782) - i_m * (0.827) + 0.333$) and i_m/clo ($i_m/clo_{\,[1m/s]} = i_m/clo_{\,[0.4m/s]} * (1.48) + 0.40$). These equations showed an R^2=998 and R^2=0.998 respectively for I_T and i_m/clo respectively.Agreement between measured and estimated I_T and i_m/clo was evaluated by the mean difference ± the standard deviation, with 95% limits of agreement (LOA) and Root Mean Squared Error (RMSE) reported in parenthesis. For USARIEM ensembles, estimated I_T was 0.048±0.060 clo (LOA: -0.070 to 0.167, RMSE = 0.077) and i_m/clo was 0.001±0.016 (LOA: -0.030 to 0.032, RMSE = 0.016) from the measured values. Similarly, DST ensembles showed I_T was 0.033±0.046 clo (LOA: -0.058 to 0.124, RMSE = 0.056) and i_m/clo was 0.004±0.015 (LOA: -0.025 to 0.033, RMSE = 0.015) from the measured values. Collectively, estimated I_T was 0.041±0.055 clo (LOA: -0.066 to 0.149, RMSE = 0.068) and i_m/clo was 0.002±0.015 (LOA: -0.028 to 0.033, RMSE = 0.016) different from measured values. However, visual inspections of Bland-Altman plots reveal a trend for the differences to shift positively at higher I_T, and to shift negatively at higher i_m/clo (Figure 1).

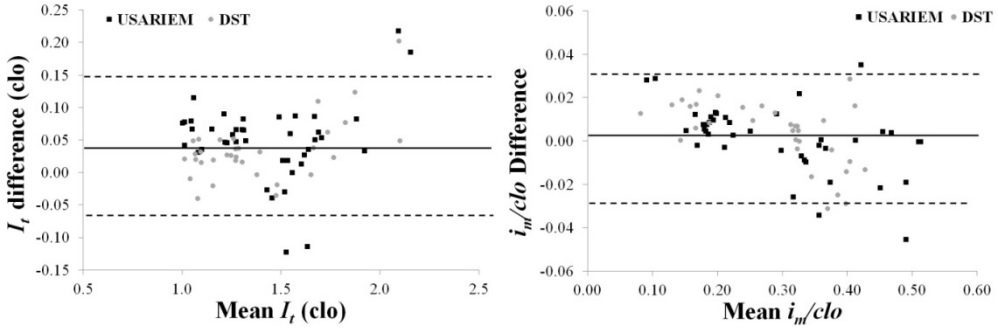

Figure 1: Bland-Altman plots with mean difference (solid line) and 95% limits of agreement (dashed lines) for I_T (left) and i_m/clo (right)

The agreement between measured and estimated I_T was within the ASTM 95% reproducibility limit of 0.158 clo. Furthermore, the agreement of i_m/clo estimates represents a difference in evaporative potential of an ensemble of only 3%. Therefore these prediction equations show an acceptable level of accuracy and will provide a valuable tool in the biophysical modelling of the thermal properties of military protective clothing systems.

50 POSER SESSION 2

The application of 3D scanning technology in the assessment of protective clothing and its validity verification

Shitan Wang[1,2], Yunyi Wang[1,2]

[1]College of Fashion and Design, Donghua University, Shanghai, China, [2]Key Laboratory of Clothing Design & Technology, Donghua University, Shanghai, China

A 3D body scanner is used to quickly and easily capture body dimensions and then to create whole-body digital image. Recently, 3D body scanning technology is developing along a visualization and quantification direction, which accelerates its application in the anthropometric database, ergonomic evaluation, computer modeling and simulation, garment-body interaction relationship, etc. The purpose of this study is to summarize the application status of body scanner in the evaluation of clothing fit, protection, thermal and movement comfort. The methods of error measurement are also concluded.

The results showed that by capturing images of both a three-dimensional nude body and a clothed body, when combined with reverse engineering software, the scanner can show the spatial relationship between the body and clothing in a three-dimensional and intuitive way. Besides, two-dimensional or three-dimensional garment-body parameters such as circumference slices, surface areas, and air volume, size, distribution between the body and the clothed scan can be further extracted to evaluate clothing quantitatively. Now, air gap entrapped in clothing is important characterization index of heat transfer and an air gap size above 8mm was suggested for the thermal protective clothing design.

However, as the scanning technology application range extends, it inevitably results in the measurement inaccuracies, especially in the recognition of dynamic postures. The potential sources of errors mainly include the measurement error in the 3D scanner, the computational algorithm error of the data processing software and the consistency of active postures. The Technical Error of Measurement (TEM) and Reliability coefficient(R) are most widely accepted for estimation of measurement accuracy. The acceptable error ranges are TEM $\leqslant$15mm and R values $\geqslant$0.95.

Lastly, local garment-body parameters should be extracted by 3D body scanner in the future to depict more complex spatial relationship between body and clothing. In addition, developing standard test posture and constructing adjustable manikin to reduce the deviation of multiple measurements should be considered in ISO standards.

51 POSER SESSION 2

Determining temperature ratings for children's sleeping bags

Steven Eckels, Meredith Schlabach, Elizabeth McCullough

Kansas State University, Manhattan, Kansas, USA

Manufacturers label their sleeping bags with a temperature rating to help consumers select a bag that will provide them with an acceptable level of thermal protection under the expected conditions of use. These temperature ratings are typically determined by first measuring the insulation provided by the sleeping bag when used with the appropriate auxiliary products (e.g., pad, clothing) and then using a whole-body heat loss model to predict the environmental temperature (i.e., temperature rating) for comfort. Due to physical and physiological differences between children and adults, existing adult temperature rating models cannot be applied to children's bags. Therefore, a model for determining the temperature ratings of children's sleeping bags is proposed. The child model takes into account the unique physiology and morphology of children, with each age represented by the 50th percentile male. The results of the model indicate that an older child has a higher temperature rating than a younger child for the same level of insulation (see Figure 1). As the age of the child increases, the temperature rating prediction approaches that for adults. Validation data for adults is included for comparison.

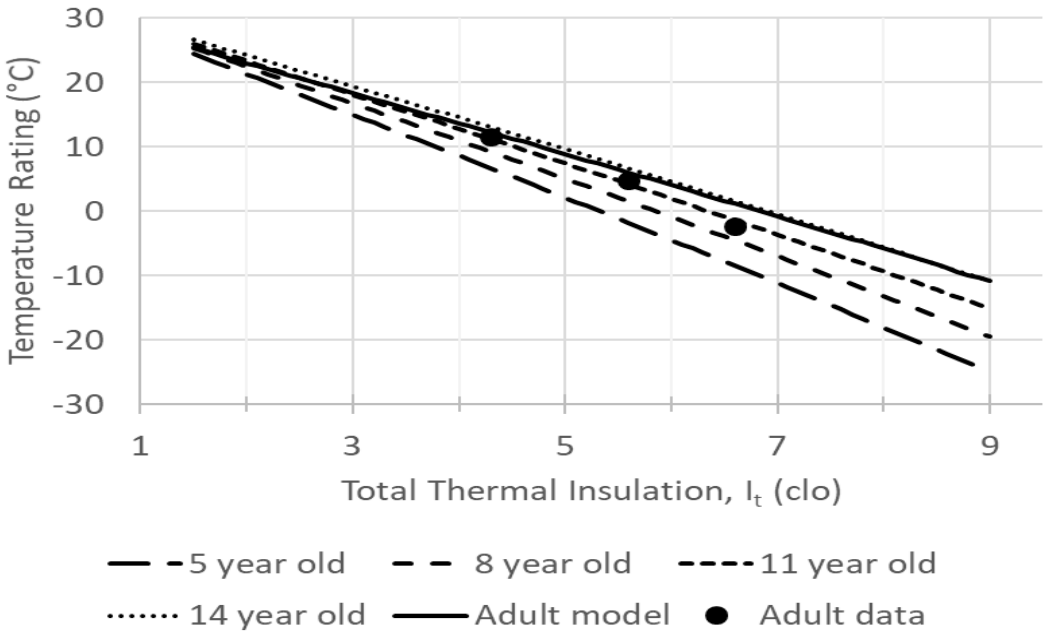

Figure 1: Results of the KSU whole body heat loss model for select ages (years).

52 POSER SESSION 2

Exertional heat illness and acute injury related to WBGT during deep water horizon clean-up

Ximena Garzón, Alfred Mbah, Yougui Wu, Michael Hiles, Hanna Moore, Skai Schwart, Thomas Bernard

University of South Florida, Tampa, FL, USA

Heat-related disorders are associated with ambient thermal conditions and there is some evidence that accidents may be also. In the aftermath of the BP Deepwater Horizon oil platform explosion in the Gulf of Mexico, there were substantial exposures to heat stress during the cleanup efforts. This study was designed to examine if increases in heat exposure result in (1) a higher risk of exertional heat illness (EHI) and (2) increased risk of acute injuries (AI). It is also hypothesized that there is a cumulative effect from the previous day's heat stress level on the risk of EHI and acute injuries.

There were 3,326 records of occupationally-related EHI and AIrecorded by BP, and reported to a first aid station during cleanup efforts from May 2010 through March 2011. Day was the unit of observation, daily count of EHI and AI divided by the total number of workers on a given day was the dependent variable in the analysis. The independent variables were maximum estimated wet bulb globe temperature (WBGTmax) and severity (first aid and medical treatment). To assess the cumulative effect of the previous day, its WBGTmax and an interaction term with the previous day WBGTmax were included in the model. Poisson regression models were used to explore the associations.

There were 1707 EHIs and 1619 AIs. The odds to present with an EHI and AI in workers exposed to WBGTmax greater than 20 ˚C-WBGT, increased with WBGTmax (Rate Ratio (RR) = 1.40; and RR = 1.06 / °C-WBGTmax, respectively). Prior day's ambient thermal conditions appeared to be associated with higher risk to present an EHI. The interaction term between the day of the injury's WBGTmax and the previous day's WBGTmax was statistically significant behaving as an effect modifier on the association between the variables under study. There is evidence of a possible synergistic effect between the previous day's WBGTmax and the day of the injury's WBGTmax that becomes more evident with increasing temperatures above 28 °C-WBGT with RRs between 1.0 and 10.

Ambient thermal conditions are a risk for those workers who perform their job in outdoor conditions, the association between rising temperature and the odds to present an acute event increases significantly. There is evidence of the cumulative effect from the prior's day's temperature. Further work is needed to elucidate such association.

53 POSER SESSION 2

Performance analysis of membrane fabric used for thermal protective clothing in steam and radiant hazards

Yun Su[1,2], Rui Li[2], Guowen Song[2], Jun Li[1]

[1]Donghua university, Shanghai, China, [2]Iowa state university, Iowa, USA

Membrane fabric due to waterproof and breathable properties has been widely used for thermal protective clothing. However, few studies were performed for investigating thermal protective performance of the membrane fabric under steam and thermal radiation. A developed steam simulator and a TPP tester were used to simulate steam and radiant hazards, respectively. Four kinds of membrane fabric with two configurations (membrane and substrate sides) were exposed to two thermal environments. The skin temperature and thermal energy were measured to determine the influence of configuration and properties of the membrane fabric on the thermal protective performance. The thermal energy absorbed by the skin in two conditions is shown in Table 1. A significant difference was observed between two configurations for steam hazard ($P<0.05$), while no significant difference was observed for radiant heat hazard ($P>0.05$). This indicates that the dual characters of membrane fabric existed only in the steam hazard, because of the occurrence of mass transfer. For radiant heat exposure, heat conduction is the dominant mode of heat transfer, and radiant heat transfer can penetrate into a certain depth of fabric. Convective heat transfer is usually ignored, owing to the pore size of the textile material. Therefore, the configuration of a membrane fabric does not significantly affect the conductive and radiant heat transfer. The largest difference between steam and radiant heat hazards is 3.12 times, indicating that steam heat transfer is the dominant factor in producing burn injury. In addition, different types of membrane fabrics had different protective performance in two heat hazards. The thermal protective performance provided by porous membranes (A4) presented the highest protective level in radiant heat hazard, while absorptive membranes (A1) afforded the highest thermal protective performance against steam hazard. In summary, for steam hazard, the most important factor in protection is resistance to the penetration and storage of moisture in protective clothing. For radiant heat hazard, the main factor in protection is to decrease conduction and radiation heat transfer in protective clothing.

Table 1: Thermal energy absorbed by skin for two configurations in steam and radiant heat hazards

Configuration	Membrane fabric	Thermal energy in steam hazard (kJ/m^2)	Thermal energy in radiant hazard (kJ/m^2)
Membrane side	A1	252.35 (1.44)	143.73 (2.36)
	A2	359.41 (0.68)	173.60 (4.25)
	A3	351.24 (1.24)	144.91 (5.23)
	A4	293.76 (2.84)	129.83 (6.45)
Substrate side	A1	453.25 (1.43)	145.50 (2.55)
	A2	444.12 (0.78)	173.10 (2.93)
	A3	431.16 (1.38)	150.74 (3.20)
	A4	350.62 (2.56)	137.60 (0.40)

54 POSER SESSION 2

Body-mapping nano-porous polyethylene (PE) clothing could prompt radiative body heat dissipation in moderate warm indoor environments

Faming Wang[1], Pengjun Xu[2], Ying Ke[3], Bin Yang[4], Li-Yen Lin[5]

[1]The Hong Kong Polytechnic University, Kowloon, Hong Kong, [2]Minjiang University, Fuzhou, China, [3]Jiangnan University, Wuxi, China, [4]Umeå University, Umeå, Sweden, [5]Taiwan Textile Research institute, Taipei, Taiwan

Extreme weather events like heatwaves and cold spells are increasing due to global warming and human-caused climate change. In hot climates and heatwave incidents, there is a huge amount of energy consumption due to indoor temperature regulation. It has been criticized that the use of air conditioning systems causes too much energy consumption due to the conditioning of large building spaces. Scientists started to seek for effective and energy-saving methods to provide people thermal comfort environments with minimal energy consumptions. One of the effective and most-often methods is the use of personal conditioning clothing such as air ventilation clothing, moisture evaporation clothing and water/air cooling clothing. Nevertheless, such person conditioning clothing still requires cooling sources and energy use. In indoor environments, the infrared radiative heat released by our human body accounts for over 50% of the total body heat. Traditional clothing made from either natural or synthetic fibres is not designed for infrared radiation management because they do prevent the infrared radiative heat from being dissipated to the indoor environment. Therefore, it would be ideal to develop novel passive personal cooling clothing without energy input for indoor occupants. In this study, we have explored the possibility of designing passive personal cooling clothing without energy input. A novel body-mapping nanoporous polyethylene uniform was developed to examine its effectiveness in dissipating infrared radiative heat loss in indoor environments. Eight female subjects voluntarily participated in this study. Each subject completed two 65-minute trials presented in a randomized order. The environmental temperature inside the climate chamber is controlled and increased in 12 equal steps from 24.0 °C to 30.0 °C (i.e., the increment rate is 0.5 °C every five minutes). Heart rate, skin temperatures at 10 local body sites and perceptual sensations such as thermal sensation, thermal preference, thermal acceptability, comfort sensation, skin humidity sensation are surveyed throughout the whole trials. Two clothing ensembles with the same design were chosen: Nanoporous PE clothing and traditional clothing (business trousers and long-sleeve shirt). It was found that the mean skin temperature started to rise at 26.0 °C when wearing cotton clothing while the mean skin temperature increased at around 27.0 °C in nano PE clothing. The post-trial mean skin temperature was increased by 1.29 and 0.92 °C in cotton clothing and nano-porous PE clothing, respectively. It was thus to conclude that the nano-porous PE clothing could prompt radiative body heat dissipation in moderate warm indoor environments and thereby contribute to saving energy.

55 POSER SESSION 2

A novel high elastic fabric with comfortable properties developed for burn survivors in Taiwan

Heng-Yi Chen, Gwo-tsuen Jou

Taiwan Textile Research Institute, New Taipei City, Taiwan

On June 27, 2015, at the Formosa Fun Coast water park outside Taipei, a tragedy happened when colored powder was ignited under the heat of a spotlight, causing a series of deadly blasts. Nearly 500 young guys were severely suffered in the accidence. Fortunately, most victims survived but went through a long journey of physical rehabilitation.It is well known that the pressure garments are normally used in the treatment of hypertrophic scarring following serious burns. Most pressure garments are made from high performance elastic fabrics and often wear up to 2 years. To enhance pressure therapy, the fabric must be able to offer an appropriate pressure and also provide comfortable properties for the patient.In this study, we compare two kinds of garments which were made by different kind of fabric. The first one is usually used for compression garment, which is one of the strongest power-net fabrics available in market. The other one is newly designed and we call it “Super-net” which is similar, but a little different from the traditional power-net structure. Although both fabrics kept strong elastic forces when stretched, they showed quite different stress–strain curves. It was found the properties of the two garments were influenced by the fabrics significantly.Since the pressure of 25 mmHg was suggested by OT (occupational therapist), the ideal reduction factors needed to make pressure garment (ex. sleeve) were able to calculate by Laplace’s law based on the measurement from human body. (In our study, the elastic forces versus extensions are obtained by ASTM D4964.) The results showed in table 1, reveals that the pressures predicted by Laplace’s law well in most of cases for the newly designed fabric. However, the traditional power-net fabric showed lower pressure and can’t meet the pressure we need because of its soft stretch curve. We found the pressure did not go up much more even if the reduction factors were increased, till it was unable to wear.Moreover, a human test was conducted in this study. Two groups of burn patients were applied to two different kinds of pressure garment randomly. The results showed the burn patients which applied to the new “super-net” fabric have better recovery. Therefore, by using the new pressure garment, the pressure therapy were improved compared to the one made of the traditional power-net fabrics.We would like to thank Sunshine Social Welfare Foundation, Taiwan for their assistance and cooperation, and the financial support from the Industrial Development Bureau, Ministry of Economic Affairs of Taiwan.)

Table 1: Sleeve compression pressure comparison between the “power-net” fabric and the “super-net” fabric.(the pressure 25 mmHg was expected)

Items	**Positions**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sleeve made by power-net fabric used in Taiwan before.	**Reduc. F (**%)	14	18	20	22	20	18	18	19	21	20
	Min. P (mmHg)	17	16	17	13	14	16	17	16	16	17
	Max. P (mmHg)	22	20	19	20	22	20	17	18	17	21
	Mean (mmHg)	19	18	18	16.5	18	18	17	17	16.5	19
	Bias (%)	**-24**	**-28**	**-28**	**-34**	**-28**	**-28**	**-32**	**-32**	**-34**	**-24**
Sleeve made by new super-net fabric in this study.	**Reduc. F**	12%	16%	17%	19%	18%	16%	15%	16%	18%	17%
	Min. P (mmHg)	23	22	24	24	24	21	11	22	22	21
	Max. P(mmHg)	28	32	27	28	30	32	29	22	25	21
	Mean (mmHg)	25.5	27	25.5	26	27	26.5	20	22	23.5	21
	Bias (%)	**2**	**8**	**2**	**4**	**8**	**6**	**-20**	**-12**	**-6**	**-16**

56 POSER SESSION 2

Regional differences in skin hydration on the hand by medical glove type

Sang-Hyun Roh, Cheol-Seung Hyun, Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

Fine dexterity is required for medical doctors or experimenters who wear latex gloves but the moisture accumulated inside the latex glove during manual work often interrupts the dexterity of the hands. To reduce the moisture inside the latex gloves, inner gloves (knitted with superfine fibers of polyester) are often worn. The purpose of this study was to investigate the effects of wearing latex medical gloves with its inner glove on hand skin hydration. Sixteen male students participated in two glove conditions: wearing latex globe (LG) and latex glove with inner glove (LGIG) along with a bare hand condition (BH). Subjects performed a regulated typing task for 120 min in a sitting position. Skin hydration was measured on the dorsum of the hand, palm, thenar, and finger (digitus medius) using a corneometer (CM 825, Courage+Khazaka electronic GmbH, Germany). The results showed that 1) no significant differences in skin hydration were found between LG and LGIG, but skin hydration for the glove conditions were significantly greater than values for BH (all $P<0.001$). 2) Skin hydration on the thenar increased as time passed, while values on the other three regions were maintained for 120 min (Fig. 1). 3) Skin hydration had greater values on the thenar than the palm (BH) and palm/finger (LG, LHIG) (Fig. 1). 4) The dorsum of the hand showed greater skin hydration than the palm while wearing latex gloves, but the regional difference reduced in LGIG. These results can be applied to improve glove design to reduce humidity around the dorsum and thenar while completing manual tasks.

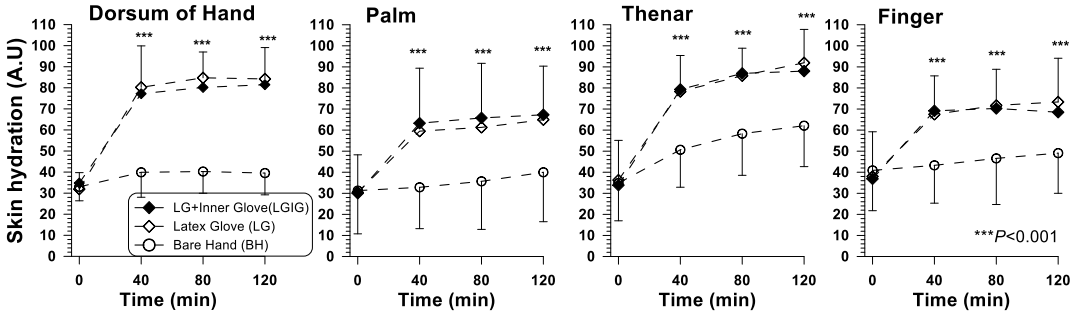

Figure 1**:** Hand regional skin hydration on the four regions: the dorsum of hand, palm, thenar, and finger (***P<0.001 among the three experimental conditions).

ACKNOWLEDGMENTS: This research was supported by the Fire Fighting Safety & 119 Rescue Technology Research and Development Program funded by the Ministry of Public Safety and Security (MPSS- Fire Fighting Safety-2015-82)

57 POSER SESSION 2

Effects of bathing on psychophysiological responses in the elderly and the young males

Linran Ruan[1], Nobuko Hashiguchi[2], Masanobu Hayashi[1], Hiroko Koga[3], Takashi Nonaka[3], Takafumi Maeda[4]

[1]Graduate School of Design, Kyushu University, Fukuoka, Japan, [2]Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan, [3]Noritz Corporation, Akashi, Japan, [4]Faculty of Design, Kyushu University, Fukuoka, Japan

To many Japanese, taking a hot bath is an essential part of their daily life. However, there have been hot bath-related illness and deaths among the elderly populations, especially during winter. The purpose of this study was to clarify the variation in physiological and psychological responses of the elderly and the young males during and after taking a hot bath.

Ten healthy old men (70.2±4.1 years old) and ten healthy young men (22.6±0.84 years old) participated in this experiment. They stayed in a sitting posture with sweat pants and bathrobe in the pre-room (air temperature:20°C, relative humidity:50%) for 60 min. And then they took off the clothes and moved to the bathroom, subsequently stayed in the bathtub for 8 minutes. The water temperature was set at 40°C and 42°C on separate days for each participant. We measured blood pressure, heart rate, skin and rectal temperature, thermal sensation, and thermal comfort periodically before, during and after bathing.

Systolic blood pressure(SBP) of the elderly significantly increased just after getting into hot water and significantly decreased during bathing. However, SBP of the young did not change. In addition, SBP of the elderly decreased further in the standing position soon after getting out of the bathtub but immediately increased by changing into sitting posture.

Besides, heart rates (HR) of the elderly were not changed by bathing, but that of the young were significantly increased during bathing at 42°C. HR were increased by standing and decreased by sitting in both age groups, and the change in HR of the young was wider than the elderly.

The results suggested that the weakened cardiovascular functions such as heart pump ability, blood vessel flexibility, and baroreflex sensitivity of the elderly might induce the large change in blood pressure and small change in heart rate, resulting in higher risk of accidents for the elderly to take a hot bath during winter.

Study on psychological effects by reproduction of ambient music and sound effects

Atsushi Watanabe, Tetsu Aoki

National Institute of Technology, Gifu College, Gifu, Japan

We are considering psychological physiological influences by reproducing environmental music in previous studies. By combining environmental music and sound effects, it is expected that the influences will be further increased. In this study, we aim to verify psychological effects such as thermal sensation by reproduction simultaneously sound effects and ambient music in architectural space. At first, in order to select the sound effects to be reproduced with the ambient music, the impression evaluation experiment of the sound effects was carried out. Sound effects were selected the natural sounds. The subjects in the impression evaluation experiment were 18 males and females in total around the age of 20. We presented sound effects in headphones to them who sat down on the chair in the room with the air conditioner. The experiment was conducted according to the timetable in Figure1. Secondly, the impression evaluation experiment of sound synthesized environmental music created for selected sound effects was carried out. The music consisted of F major code with reference to 440 Hz which did not have a clear melody line. The experiment sounds was 16 sounds which synthesized 2 kinds of music using the timbre of “warm”, “square” from the General MIDI tones and 8 sound effects. Other experiments reported that "warm" is felt warm "square" is felt cold. The subjects in the impression evaluation experiment were 12 males and females in total around the age of 20. PMV value was adjusted to be about 0. As the result of the experiment, the seasonal sound effects reminiscent of summer had the impression that it was hot. Seasonal sounds are sound effects that can only be heard in a particular season. Moreover the seasonless sound effect related to water gave the impression that it is cold. The seasonless sound effects may have a possibility that the physical characteristics of the sound itself such as sound pressure change and frequency range affect thermal sensation. As the result of analyzing the physical characteristics, the frequency distribution of sound effects on water was similar. However, it was different from seasonal sound effects in frequency distribution and temporal change in sound pressure level. We thought that elements affected by thermal sensation are not physical characteristics but seasonal images (empirical concept). Sound effects whose sound pressure level is fluctuating over time had a more comfortable impression than stationary sound effects. Therefore, we considered that temporal sound change was also a major influencing factor for comfort. We thought that the empirical concept of the subject for sound effects influenced warm sensation by both experiments. It is also suggested that harmony between environmental music and sound effects may affect comfort.

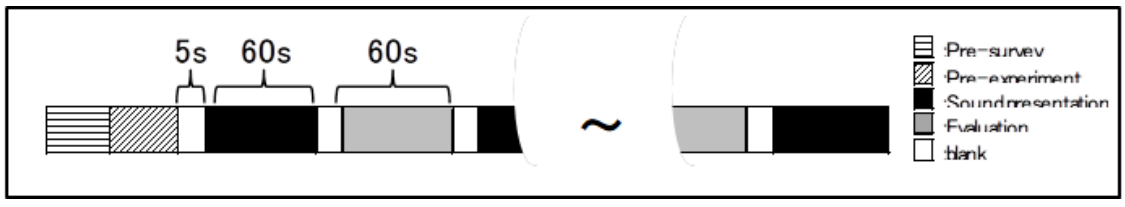

Figure 1: Experimental timetable

59 POSER SESSION 2

Self-identified thermal comfort zone and perceived climate changes: a questionnaire study in temperate, tropical and cold climates

Yung-Bin Kim[1,2], Sang-Hyun Roh[1], Rokho Kim[2], Juhee Sohn[3], Joeun Lee[4], Titis Wijayanto[5], Ahmad Munir Che Muhamed[6], Kalev Kuklane[7], Siyeon Kim[1,7], Joo-Young Lee[1]

[1]Seoul National University, Seoul, Republic of Korea, [2]World Health Organization, Fiji, Suva, Fiji, [3]University of Toyama, Toyama, Toyama prefecture, Japan, [4]Mongol International University, Ulaanbaatar, Mongolia, [5]Gadjah Mada University, Yogyakarta, Special Region of Yogyakarta, Indonesia, [6]Universiti Sains Malaysia, Penang, State of Penang, Malaysia, [7]Lund University, Lund, Scania, Sweden

The present study was conducted to explore self-identified thermal comfort zone and the perceived climate changes of indigenes who live in temperate, tropical and cold climates. A questionnaire study was carried out in the following seven countries: Mongol (Bsk by Köppen's climate classification), Sweden (Cfb), Korea (Dwa), Japan (Cfa), Fiji (Af), Indonesia (Af), and Malaysia (Af). A total of 125 Mogolians, 83 Swedish, 240 Koreans, 231 Japanese, 391 Fijian, 101 Malaysians, and 137 Indonesians participated in this questionnaire from Oct 2016 ~ Jan 2017. The questionnaire consisted of 52 questions on self-identified thermal tolerance, behavioral thermoregulation, thermal neutral zone, thermal comfort, and perceived climate changes. The questionnaire was cross-translated between languages based on an original English version. The results showed that the self-identified thermal comfort zone in the summer or wet season was higher for tropical indigenes (24~27oC for Malaysians and Indonesians) than for indigenes in cold climates (18~21oC for Mongolians and Swedish) (Fig. 1_Left). For the winter or dry season, similar results were found (Fig. 1_Right). Interestingly, 21.8% of Mongolians preferred indoor temperature lower than 15oC whereas 25.0% of Malaysians preferred indoor temperature higher than 27oC in the winter (or dry) season (Fig. 1_Right). In particular, Koreans and Fijian perceived hotter summers and colder winters due to climate changes during the last five years when compared to other people.

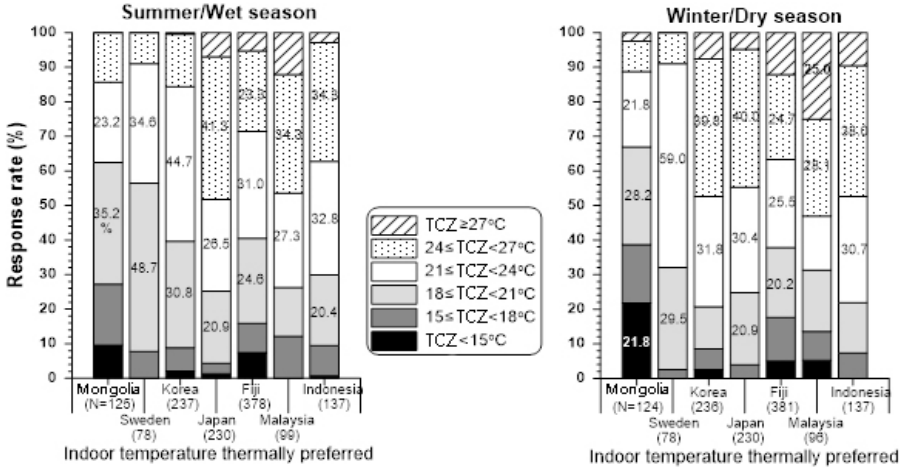

Figure 1: Thermal comfort zones of young indigenes who live in tropical, temperate and cold climates (TCZ: Self-identified thermal comfort zone).

Effects of variations in air velocity on endurance exercise capacity and thermoregulation in a hot environment

Hidenori Otani[1], Mitsuharu Kaya[2], Akira Tamaki[2], Phillip Watson[3], Ronald Maughan[4]

[1]Himeji Dokkyo University, Himeji, Japan, [2]Hyogo University of Health Sciences, Kobe, Japan, [3]Vrije Universiteit Brussel, Brussels, Belgium, [4]University of St Andrews, St Andrews, UK

It remains unclear to what extent gradual variations in air velocity influence endurance exercise performance in a hot environment. Therefore, the aim of the present study was to examine the effects of variations in air velocity on endurance exercise capacity and thermoregulatory responses to exercise in a hot environment. Eight healthy, heat-acclimatized males participated in this investigation. Volunteers completed stationary cycle exercise trials at 70% maximum oxygen uptake until exhaustion in an environmental chamber maintained at 30°C ambient temperature and 50% relative humidity. Four air velocity conditions, 30, 20, 10 and 0 km/h, were tested, and the headwind was directed at the frontal aspect of the subject by two industrial fans, with blade diameters of 1 m and 0.5 m, set in series and positioned 3 m from the subject's chest. Rectal temperature, skin temperature (chest, upper arm, thigh and calf), heart rate, skin blood flow, blood pressure, perceived thermal sensation and rating of perceived exertion were recorded. Mean skin and body temperatures, cutaneous vascular conductance, the rate of heat storage, and dry and evaporative heat losses were calculated. Mean±SD exercise time to exhaustion was 90±17, 73±16, 58±13 and 41±10 min in the 30, 20, 10 and 0 km/h trials respectively, and was different between all trials ($P < 0.05$). There was a progressive elevation in mean skin temperature, heat storage and perceived thermal sensation as airflow decreases ($P < 0.05$). Rectal temperature, mean body temperature, heart rate, skin blood flow, cutaneous vascular conductance and rating of perceived exertion were higher and evaporative heat loss was lower without airflow than at any given airflow ($P < 0.05$). Dry heat loss was not different between trials ($P > 0.05$). The present study demonstrates that endurance exercise capacity in a hot environment falls progressively as air velocity decreases. This response is mainly associated with a higher skin temperature, heat storage and perceived thermal stress with decreasing air velocity. Moreover, even a modest airflow, at least more than 10 km/h or 2.8 m/s, might contribute to reducing thermoregulatory and cardiovascular strain and perceived exertion in individuals exercising in a hot environment.

61 POSER SESSION 2

Thermal sensitivity to a warm and a cold stimulus: An age comparison

Nicole Coull, Alex Lloyd, Simon Hodder, George Havenith

Loughborough University, Leicestershire, UK

Thermal sensitivity is one of the main sensory modalities of the skin and is suggested to alter with age as the ability to detect temperature change declines. Consequently, during extreme weather conditions, older individuals may be more at risk of cold- and heat-induced illness than their younger counterparts. Previous studies have assessed age-related differences in thermal sensitivity at a limited number of body regions. However, little is known about how sensitivity varies over the entire body as it ages. This study investigated regional and age-related differences in warm and cold sensitivity in young and older individuals, using a body-mapping approach. 13 young (18-30 yrs) and 13 older (60-90 yrs) healthy males, matched for body characteristics, volunteered for the study. After a familiarisation session, participants rested in a thermo-neutral environment (25°C/40% RH) on two occasions, whilst a pressure controlled thermal probe set at 40°C (WARM trial) and 20°C (COLD trial) was applied to 33 body regions in a balanced order. Participants used a perceptual scale to rate thermal sensation pre and post (10 s) probe application. Whole body thermal sensation, thermal comfort and skin and core temperature were also recorded throughout the trials. Sensitivity to WARM and COLD stimuli varied significantly between body regions within each age group ($p < 0.05$). However, there were only significant age-related differences at the foot. The older group were significantly less sensitive at the top and sole of the foot in response to a WARM stimulus and at the top of the foot only to a COLD stimulus ($p < 0.05$). The most sensitive region to COLD was the lateral torso and the least sensitive was the top of the foot in both groups. However, this varied between groups in response to WARM. Furthermore, it was observed that the inter-individual variation in sensitivity to WARM and COLD was much larger in the young compared to older group. Regional variation in sensitivity to WARM and COLD exists across age groups. Older individuals were less sensitive at the foot compared to young. This suggests that sensitivity at the extremities may be the first to deteriorate, which coincides with previous findings. It was also observed that inter-individual variation in sensitivity decreases with age.

62 POSER SESSION 2

Effect of short-term endurance interval training on venous compliance in humans

Anna Oue, Michiko Saito, Yasuhiro Iimura

Toyo University, Ora-gun, Japan

The veins have a high distensibility and contain 60-70% of whole blood at resting condition, so that the venous system plays an important role in hemodynamic control. Some cross-sectional studies have reported that the chronic long-term exercise training improves the venous compliance. However, it is not understood well the effect of longitudinal short-term exercise training on venous compliance. Thus, the purpose of this study was to investigate whether 8-wk interval endurance training increased the venous compliance in young subjects. Twenty subjects participated in this study (training group (TRA): n = 9, control group (CON): n = 11). Training program consisted of cycling exercise at repetition of 40 % Heart rate (HR) reserve and 80%HRreserve every 2 min for 40-min 3 times a week for 8 weeks. Venous volume in forearm and calf was measured in the supine position by inflating a venous collecting cuff placed around upper arm and thigh to 60 mmHg for 8 min and then decreasing cuff pressure to 0 mmHg at a rate of 1 mmHg/s. Venous compliance was determined using the first derive of the cuff pressure-venous volume relation during cuff pressure reduction (compliance = $\beta 1 + 2\beta 2 \times$ cuff pressure). In addition, venous capacitance was defined as the increase in venous volume during cuff inflation of 60 mmHg for 8 min. And, maximal venous outflow was defined as the change in venous volume during cuff deflation from 60 mmHg to 0 mmHg. In TRA, calf venous capacitance increased significantly ($P < 0.05$) and calf venous compliance ($P = 0.086$) and maximal calf venous outflow ($P = 0.086$) tended to increase after training. But, all parameters in forearm did not differ between before and after training. In CON, all venous parameters in both calf and forearm were similar between pre and post of 8wk. These results suggest that the short-term interval endurance training might tend to cause the specific increase in venous compliance of exercising limb.

63 POSER SESSION 2

Functional and physical adaptations to resistance training with external muscle heating

Antony Stadnyk, Nancy Rehrer, Phil Handcock, Kim Meredith-Jones, James Cotter

University of Otago, Dunedin, New Zealand

Heat is a major stressor during exercise, though its value in driving adaptation is not well understood. Heat shock protein induction is upregulated during exercise and heat stress, which has multiple effects including (re)generation of muscle primarily through facilitation of muscle protein synthesis[1]. Muscle heating could protect against disuse atrophy[2] or even produce hypertrophy in humans[3], however only one study has investigated the effects of muscle heating adjunct to a resistance training programme; it showed superior gains in strength and muscle area[4]. Thus, heat may provide a novel means to increase muscle mass and quality, potentially improving metabolic control, functional performance, and quality of life. The aim of this study was to investigate whether supplemental heating of active muscle during resistance training differentially affected physical and functional adaptations compared to traditional training without muscle heating.

In a contralateral-limb control design, 10 resistance-untrained participants (21 ± 3 y; 5 female) completed 12-weeks (30 sessions) of progressive resistance training of the knee extensors, comprising 32 repetitions (4 sets of 8 per leg) of unilateral knee extensions at 70% of leg-specific 1RM. One randomly allocated thigh was heated during and for 20 min after each training session, using a customised heat pad eliciting muscle temperatures of 38–39.5 °C (unheated limb: 36–37 °C). Thigh lean mass was measured using dual x-ray absorptiometry (Lunar Prodigy, GE Medical Systems, V16) at baseline and 12 weeks, and concentric knee extensor 3-RM and maximal isokinetic ($90°.s^{-1}$) torque was measured at baseline and every 4 weeks.

Quadriceps' lean mass increased across 12 weeks of training by 15 ± 7% (761 ± 280 g; $p = 0.00$) and 15 ± 6% (752 ± 304 g; $p = 0.00$) in the heated and control limbs, respectively; the difference being trivial (0 ± 6%; $p = 0.94$). Peak torque increased ($p = 0.02$) by 30 ± 25% ($p = 0.00$) and 34 ± 33% ($p = 0.01$), respectively, with no significant difference ($p = 0.93$) between limbs. Rate of torque development increased by 42 ± 47% in the heated limb ($p = 0.04$) and 37 ± 34% ($p = 0.02$) in the control limb (difference: 5 ± 44%; $p = 0.73$). 3-RM strength increased by 75 ± 16% in the heated ($p = 0.00$) and by 71 ± 14% in the control limb (difference: 4 ± 5%; $p = 0.80$).

Heating of active muscle mass during and after resistance training shows no clear positive (or negative) effect on training-induced hypertrophy or improvements in strength compared to those from resistance training without heat. Thus, exercise *per se* provides by far the major stimulus for strength and hypertrophy, although pre-conditioning effects of heating on training-induced responses cannot be discounted.

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64 POSER SESSION 2

Shoe microclimate: an objective and subjective evaluation

Anna West[1], David Schönfisch[2], Antoni Picard[2], James Tarrier[3], Simon Hodder[1], George Havenith[1]

[1]Loughborough University, Loughborough, UK, [2]University of Applied Sciences Kaiserslautern, Zweibrücken, Germany, [3]adidas Future, Herzogenaurach, Germany

The demand for functional and comfortable footwear is increasing. Factors which govern our perceptions of comfort are complex and multi-factorial based on interactions which affect foot function during activity. These interactions can be linked to the mechanical or thermal properties of shoes. Thermal properties of shoes are attributed to the development of shoe microclimate (temperature and humidity). Research has emphasised that parameters of footwear microclimate have a decisive influence on the user's sensations and perceptions of thermal comfort. The aim of this study was to investigate shoe microclimate development during running and how this influences perceptions of whole body and local foot thermal comfort.

Ten healthy females (22±3 years; 165.8±6.2 cm; 61.4±8.9 kg) undertook this study. Two types of running shoe of the same model but different material construction (A – open; B – closed) were tested. Standardised socks were worn for both shoe conditions. Participants completed two trials in 23°C, 35% relative humidity consisting of three phases: rest (10min seated), treadmill running (40min, 7.5km.hr^{-1}), recovery (30min seated). Footwear microclimate and subjective perception were recorded throughout the trials. Foot skin temperature, in-shoe air temperature and in-shoe relative humidity were measured at 7 sites on the right foot. Perceptual scales were used to rate thermal sensation, wetness perception, stickiness and thermal comfort for the whole body and local foot.

Whole body mean skin temperature, core temperature, thermal sensation and thermal comfort were not influenced by shoe condition (p>0.05). At the end of the run (50mins) there was a significant difference (p<0.05) between shoe A and shoe B in foot skin temperature (36.6°C and 37.1°C, respectively), in-shoe temperature (35.2°C and 36.1°C, respectively) and in-shoe relative humidity (75.7% and 84%, respectively). Foot skin temperature was higher than in-shoe temperature throughout the run for shoe A and shoe B (0.7-1.0°C and 0.8-1.4°C, respectively). Significant differences in thermal sensation, wetness perception, stickiness and thermal comfort were present throughout the run (p<0.05), however these differences were not significant at 50mins (p>0.05).

Shoe microclimate causes local foot discomfort but does not affect whole body comfort. Shoe construction influences foot skin temperature, in-shoe temperature and in-shoe relative humidity, as greater values were observed for shoe B. As the development of foot skin temperature and in-shoe air temperature were similar throughout the run, the use of one of these measures may be suitable for the assessment of shoe microclimate. Furthermore, changes in shoe microclimate were perceivable in both shoes.

65 POSER SESSION 2

Effects of cold young coconut water ingestion for precooling on physiological responses during exercise in hot and humid environment

Valentina Kunthi Bratadewi, Titis Wijayanto, Moony Sinawang, Harendrasena Surya Prakasa, Ghani Furqon Abdul Rahman

Universitas Gadjah Mada, Yogyakarta, Indonesia

Ingestion of ice slurry solutions as precooling has been reported to be more effective at cooling than liquid solutions in lowering body core temperature during exercise. Young coconut water has been considered as a natural alternative to plain water and manufactured sport drinks for fluid replacement during exercise. The physiological effects of using young coconut water as material for ice slurry solutions that ingested before exercise is however unknown. This study investigated the effects of cold young coconut water ingestion in the form of cold fluid and ice slurry for internal precooling strategy on physiological and subjective responses during exercise in hot and humid environment. This study used young coconut water due to the aforementioned benefits and its availability in tropical countries. Nine healthy males (age: 22.1±0.9 years old; height: 169.8±3.1 cm; weight: 70.8±4.2 kg) participated in this study. They performed treadmill exercise; ran for 30 mins at 65% HR_{max} followed by sat for 30 mins recovery in a chamber set at 36.6±0.8ºC and 72±6% of relative humidity. Three randomized treadmill exercise trials were performed with: no fluid ingestion (CON), 7.5 mL kg^{-1} body mass of commercial young coconut water ingestion for precooling in cold liquid form (CF) and ice slurry form (ICE) on separated days. Cold liquid or ice slurry was ingested 30 mins prior to performing exercise. The results showed that both ingesting either ICE or CF significantly lowered pre-exercise tympanic temperature. Tympanic temperature was also lower at the end of exercise in both precooling conditions compared to CON condition ($P<0.05$). There was no significant difference in tympanic temperature between that ICE and CF conditions. In comparison between ICE and CF condition, ICE condition showed more significant effect in lowering heart rate and improving heat sink at pre-exercise phase compared to CF condition ($P<0.05$). In addition, ICE condition also had significant effect in improving thermal comfort and perceived exertion during exercise in comparison with CF condition. From these results, it can be concluded that young coconut water in ice slurry form can be used for precooling technique which is more effective in reducing physiological strain during exercise in hot-humid environment compared to ingesting cold young coconut water in liquid form.

66 POSER SESSION 2

Thermoregulatory properties of hair: is human hair morphology adaptive?

Tina Lasisi[1], Nina Jablonski[1], Mark Shriver[1], Larry Kenny[2], George Havenith[1]

[1]Department of Anthropology, Pennsylvania State University, Pennsylvania, USA, [2]Noll Laboratory, Department of Kinesiology, Pennsylvania State University, Pennsylvania, USA, [3]Environmental Ergonomics Research Centre, Loughborough University, Loughborough, UK

The scalp hair of modern people is variable: hair fibres can be fine or thick, straight or tightly coiled. The evolutionary reasons for this variation are unknown. Because the scalp is one of the few regions of the human body that has not evolved to be effectively hairless, it is important to understand whether natural selection has shaped human hair variation to the extent that it has shaped the fur (hair) of other mammalian species. It has been suggested that tightly coiled hair, as is found in many African populations today, has evolved to facilitate evaporative cooling and protect a thermogenic and thermosensitive brain from solar radiation. Likewise, the thick hair fibres found in many East Asian populations have been hypothesized to be an adaptation to cold climates. However, to date, there has been no attempt to empirically test the functional significance of human hair variation. We propose to use principles from environmental ergonomics to evaluate the hypothesis that variation in human hair morphology evolved as a thermoregulatory adaptation. Information on optimization of materials for various thermal environments drawn from environmental ergonomics can be used to inform appropriate experiments and simulations to test this hypothesis. Here we present information on the expected differences in insulating properties of different hair types, and data on the environmental conditions under which human hair types are thought to have evolved, as well as what is currently known of the evolutionary genetics of human hair variation. Our aim is to understand the insulating properties of hair and the extent to which insulation afforded by scalp hair affected human physiology and hence selective pressures on human hair morphology.

67 ORAL 5: Material and Design 1

Effect of material thermal properties on thermal performance of multi-layer personal protective ensembles

Xiaojiang Xu, Timothy P. Rioux

Biophysics and Biomedical Modeling Division U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA

The material used for personal protective equipment (PPE) has been considered one of the major barriers to reducing thermal burden imposed by PPE, but it is not clear to what extent material thermal properties affect ensemble thermal properties and heat strain. This paper studies relationships between the thermal properties of eight materials and thermal properties of fourteen PPE ensembles. The eight materials samples consist of seven prototype chemical protective materials and one traditional material (baseline). Each of the fourteen ensembles includes typical chemical protective clothing which is made from one material and other protective equipment, e.g., mask, gloves and overboots. The fabric samples were tested on a Sweating Guarded Hot Plate (SGHP) at 20 or 35 °C and 50 or 40 % RH to measure intrinsic thermal (R_{cl}) and evaporative resistances (R_{ecl}), respectively. The ensembles were tested on a thermal manikin at 20 or 35 °C and 50 or 40 %RH to measure ensemble R_{cl} and R_{ecl}, respectively. The air velocity was set to 1 and 0.4 m/s for SGHP and thermal manikin testing, respectively. All testing was conducted according to the standard procedures ASTM F1868-14, F1291-15 and F2370-15 (ASTM international). Material R_{cl} and R_{ecl} ranged from 0.01 to 0.05 $m^2 \cdot °C \cdot W^{-1}$ and from 3.84 to 12.82 $m^2 \cdot Pa \cdot W^{-1}$, respectively. Ensemble R_{cl} and R_{ecl} ranged from 0.16 to 0.29 $m^2 \cdot °C \cdot W^{-1}$ and 27.05 to 65.15 $m^2 \cdot Pa \cdot W^{-1}$, separately. Material properties contribute only ~10.6 % of the thermal resistance and ~14.5 % of the evaporative resistance of the ensemble. Heat strain in a multi-layer PPE is a result of the combined effects of every layer or component in the ensemble. Material properties contribute only a relatively small percentage to the overall ensemble resistance. If thermal properties were the same as the baseline fabric (R_{cl} and R_{ecl} 0.02 $m^2 \cdot °C \cdot W^{-1}$, 3.84 $m^2 \cdot Pa \cdot W^{-1}$), the ensemble R_{cl} and R_{ecl} would reduce by only 2.7% and 6.7%, respectively. This suggests that improvement in material thermal properties will result in either a slight change or no difference in thermal properties of ensembles. Therefore, it is important to continue to improve the thermal properties of individual protective materials, but it may be more beneficial to focus efforts on identifying ways to modify and manipulate complete ensembles to reduce the thermal burden in PPE.

Acknowledgment: The views expressed in this abstract are those of the authors and do not reflect the official policy of the Department of Army, Department of Defense, or the U.S. Government.

68 ORAL 5: Material and Design 1

Investigation of low risk category industrial workwear materials for use in hot environments

Christopher Watson, Olga Troynikov, Nazia Nawaz

RMIT University, Melbourne, Victoria, Australia

Personal protective clothing (PPC) is designed to protect workers from workplace hazards, and it is also known that compliance to safety and protection standards can place increased thermophysiological strains on wearers, which can result in fatigue, reduced manual performance or injury (1, 2). This is amplified when working in hot and humid environmental conditions.

There are many industrial workplaces where low risk category PPC is used, such as mining, and construction operations, however, research in this category is much less extensive than in high risk categories, such as firefighting or military. Commonly, this PPC is purchased “off the shelf” for supply to workforces. As a result, this workwear provides inadequate support to thermal management and function for the wearer as it is not specifically designed for the physical activities undertaken or with working conditions in mind.

This present study investigated textile materials used in low risk category PPC to provide an understanding of the thermal management support of existing materials used in the PPC for industrial workers exposed to hot working environments, and determine how their attributes may contribute to thermophysiological strain. Twenty-one materials were identified on the basis that they were compliant with protection standards of one of two hazard risk categories (HRC) that is HRC 1 and HRC 2 based on compliance with standard NFPA70E (3) which is widely used for industrial workplace situations. The materials were selected to provide a broad cross section and effective representation of products. This included materials of a variety of fibre types and blends, ranging from 100% natural fibre compositions to blends with majority content synthetic fibre, along with different mass and material constructions. The thermal attributes of the experimental materials were determined using standard methods relevant to thermal comfort of wearers in hot environmental conditions, such as thermal and water vapour resistance; and liquid moisture transport.

The study found that these attributes vary significantly between PPC materials. The variation in vapour resistance between materials was found to be statistically significant in a number of cases, with differences of more than 40% between some materials. Differences in thermal resistance were also significant, where variances greater than 60% were seen between materials. Further, liquid moisture transport attributes also displayed significant differences.

The results of the study show that there is substantial opportunity for improvement of PPC in low level hazard risk categories by including criteria for thermal management performance of materials in the product design and selection process.

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69 ORAL 5: Material and Design 1

Evaluation of CO_2 permeability for water vapour permeable waterproof clothes

Yayoi Satsumoto[1], Takuya Aoyagi[1], Tomoko Koshiba[2], Terue Tamura[2], Ayano Denpoya[3]

[1]Yokohama National University, Yokohama, Kanagawa, Japan, [2]Bunka Gakuen University, Yoyogi, Tokyo, Japan, [3]Kanagawa University, Yokohama, Kanagawa, Japan

To develop the suitable material of an outdoor parka to promote heat and water vapour transfer from the human body in the outdoor activities, we use tracer gas method to measure ventilation rate. CO_2 gas was used as tracer gas by ventilation rate measurement. We assumed permeability of moisture and one of CO_2 was proportional. However, it is not verified that CO_2 gas can penetrate clothes like water vapour through the vapour permeable waterproof clothes. So this study aims to clarify whether there is correlation in permeability of water vapour and CO_2 gas. To make clear the relation between the water vapour permeability and CO_2 permeability of the material, three levels of water vapour permeable materials of outdoor parkas were compared one another, high permeable HP, middle permeable MP, and impermeable IM. Permeability of water vapour and CO_2 gas of 3 materials were measured. CO_2 permeability of materials were HP>>MP>IM as shown in Figure1. HP tends to penetrate 4 times more than MP. Water vapour permeability was HP > MP and the former was 1.3 times. The difference in the permeability of CO_2 was the tendency bigger than the difference in the permeability of the water vapour.

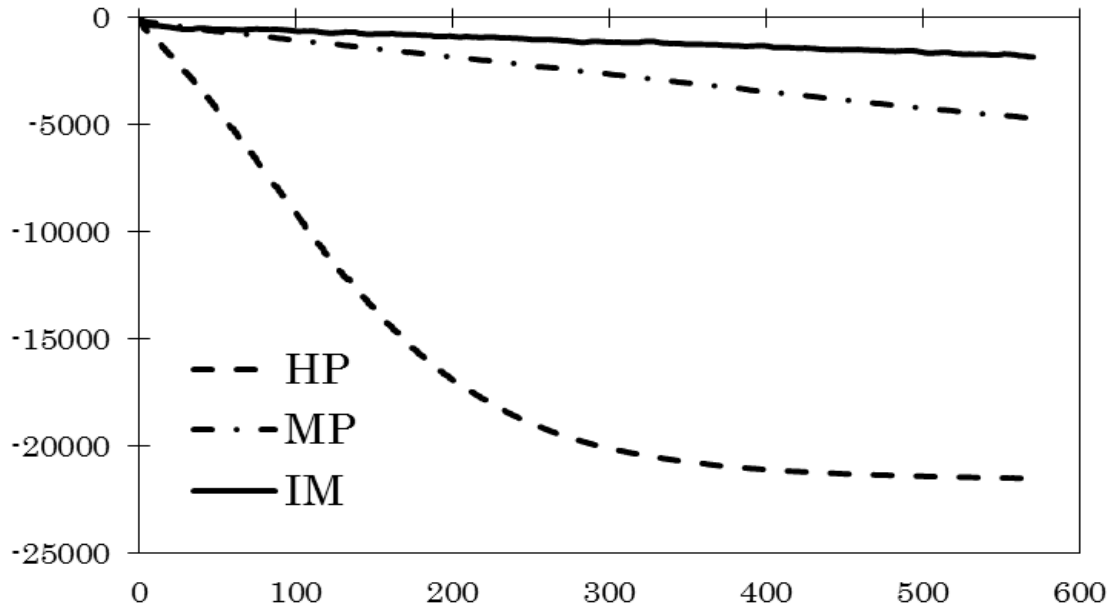


Figure 1: Change in CO_2 concentration in the container covered by each material

70 ORAL 5: Material and Design 1

Analysis of local clothing area factors of typical office clothing items and their correlation to the ease allowance at various body landmarks

Stephanie Veselá[1], Arjan JH Frijns[1], Agnes Psikuta[2]

[1]Eindhoven University of Technology, Eindhoven, The Netherlands, [2]Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland

With the development of energy efficient localized heating and cooling systems, the demand for an accurate prediction of local skin temperatures and local thermal sensation increased. To meet this goal, accurate local clothing properties including the local dry and evaporative resistance as well as local area factors must be known. However, in the published literature only few complete data sets of these properties for office clothing ensembles are available. To close this gap, we investigated the clothing properties of a large variety of garments and ensembles typically worn in an office environment. Here, we focus on the local area factors.

Local area factors are defined as the ratio of the dressed to the nude surface area of a specific body part. We obtained the surface areas using 3D scans of a nude and dressed manikin. A total of 10 upper body and 4 lower body garments were scanned three times with redressing the manikin in between to account for differences in draping. 8 body parts (lower and upper arm, chest, back, hip front and back, thighs and lower legs) were defined for which the local area factors were calculated. To be able to generalize these results to other manikins or humans, the circumferences of the manikin and clothing items were measured at 7 body landmarks (chest, waist, hip, biceps, lower arm, thigh, lower leg). The difference of the circumference of the manikin and the clothing item at a specific body landmark is defined as the ease allowance. This ease allowance was measured and calculated for all items at the relevant positions.

Considering our analysed garments, the variance of the local area factors can be identified. For example, the area factors at the chest vary from 1.02 to 1.31, whereas at the lower arm they vary from 1.16 to 1.69. Furthermore, for most body parts and clothing items, the ease allowance and the area factors correlate strongly (R^2-values of 0.7 to 0.9). In summary, these correlations can be used to estimate the local clothing area factor of specific garments on thermal manikins or human subjects.

71 ORAL 6: Material and Design 2

The development of smart heating gloves and performance evaluation

Yehu Lu[1,2], Fanfei Xu[1], Nini Ma[1]

[1]College of Textile and Clothing Engineering, Soochow University, Suzhou, China, [2]National Enginnering Laboratory for Modern Silk, Soochow University, Suzhou, China

Prolonged exposure in cold environments would provoke cold-related illnesses, leading to numbness, frostbite, hypothermia, and eventually death. Gloves serve as one of the most important tools to protect the human hands against cold stress. Previous studies have shown that glove thickness will significantly affect the performance of workers in cold conditions, i.e., too thin gloves can not provide enough hand protection and may cause hand frostbite, thick gloves, although providing better thermal insulation, however, would hinder the workers to work in some way. In view of the above situation, this study has designed a more lightweight, and sustainable smart electrical heating gloves. The heating element uses heating material which is conductive, of good thermal conductivity, and suitable for hand activities. An appropriate temperature controller is installed in the glove, and temperature control interval is set to 26°C-30°C. In order to evaluate its ergonomic performance, we carry out the human trial tests. The experimental conditions are as follows: 2.5 °C, RH 60%, two wind speeds (0 and 0.5m/s). Six subjects were involved in four test scenarios: control condition (gloves are not heated) and heating condition (gloves are heated) with wind (0.5 m/s) and no wind. The duration of the experiment was set at 60 minutes; the local finger temperatures and thermal sensation were recorded. The results show that the heating gloves keep the temperature at the back of the hand and fingers in the comfort zone (i.e., 25°C to 30°C) at the set heating conditions. Compared with the unheated condition, finger thermal sensation and comfort sensation have been greatly improved, whereas the thermal sensation and comfort sensation for the whole body increase slightly. It indicates that the electric heating gloves can improve the local heat and comfort.

72 ORAL 6: Material and Design 2

Heated gloves for rewarming and sustaining hand temperatures at cold work

Kirsi Jussila, Sirkka Rissanen, Hannu Rintamäki

Finnish Institute of Occupational Health, Oulu, Finland

In the cold, work capacity and productivity decrease and the risk of errors and accidents increases. Peripheral body parts, such as hands, are the first to cool when exposed to cold resulting in reduced manual and psychomotor performance. The overall aims of the study were to individually protect the hands at cold work and equalize the workers with different cooling rates of hands. The detailed aims were to find cooling pattern of the hands and fingers and create interactive heating systems using existing technology.

Heated glove prototypes were produced and effectiveness of the heating elements and their optimum placement on the hand was studied. The required additional heating power with gloves (thermal insulation was 0.191-0.224 m²K/W) to maintain hand skin temperature in thermoneutral at temperatures of +10, 0, and -10°C and in wind speeds of 0.3 and 4 m/s was measured by thermal hand model. Finger dexterity with gloves was tested by Minnesota Pegboard and dexterity test according to standard EN 420+A1 (2009). Hand and finger skin temperatures were measured in separate test while ten test subjects were standing still for an hour at ambient temperature of -10°C. The subjects wore gloves and sufficient winter clothing to prevent whole body cooling.

Three different cooling patterns of fingers were observed at -10°C without additional heating: 1) a rapid cooling group, 2) a slow cooling group and 3) a cold tolerant group. The results showed that the required additional heating to work gloves was about 9W per hand in calm wind and about 12W per hand in moderate wind (4 m/s) at ambient temperature of -10°C to prevent hand cooling. Finger dexterity with gloves was dependent on material structure, its flexibility, and patterning of the glove and finger tips.

This study was part of the project “SmartPro” that is financed by the Saf€ra program and the Finnish Work Environment Fund.

73 ORAL 6: Material and Design 2

Hand movement, skin deformation behaviour and glove-skin interfacial pressure: impact on therapeutic glove design

Siti Hana Nasir[1,2], Olga Troynikov[2]

[1]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Malaysia, [2]School of Fashion and Textiles, RMIT University, Melbourne, Australia

Therapeutic gloves are an intervention widely recommended and prescribed for management and treatment of hand arthritis. Patients are recommended to wear gloves during the day and/or night to relieve arthritic symptoms and improve hand function. Since the gloves need to be worn for a prolonged period, it is crucial for them to be comfortable to wear. The fit of a glove directly influences the hand function of the wearer and resultant ergonomic comfort. Inappropriate glove fit, especially negative fit, will result in restriction of hand movement and high glove-skin interfacial pressure, which may, apart from discomfort, lead to abrasion and bruising of underlying tissue. Present research explores skin deformation behaviour and the glove-skin interfacial pressure at the dorsal side of the hand in a relaxed hand posture and two dynamic hand postures. Thirteen female participants between the ages of 40-65 years, with hand size medium (M) participated in the study. For the skin deformation, the hand of each participant was scanned in three selected postures and the skin relaxed-strain ratios at 20 hand locations were measured. Next, four pressure sensors with rectangular sensing area of 49 mm^2 were used to measure glove-skin interfacial pressures in four selected locations. Participants were instructed to wore a therapeutic glove and performed the same three hand postures. The sensor converts the energy from the pressure stimulus into electrical signal output which was displayed on novel proprietary developed device. The metacarpal region showed the greatest change in skin relaxed-strain ratios; ranging between 13-71% for grip posture, and between 8-103% for power grip posture. When the hand transitions from a relaxed posture to a grip or power grip posture, the curvature of the bones in the metacarpal region becomes more prominent, increasing skin deformation. For the glove–skin interfacial pressures, a mean pressure of 0.93 kPa was recorded in relaxed posture. The interfacial pressure further increased when the hand was clenched in a power grip posture (mean pressure 52.38 kPa), again, due to the large curvatures and pointy geometry of the hand at certain locations. Due to the skin strain, the strain placed onto the fabric changes, which directly affects the fabric tension and hence, the converted glove pressure. This research concluded that the geometry and the curvature of the hand significantly impact the skin deformation behaviour and the resultant glove-skin interfacial pressure. This research further contributed to enhancing the knowledge of the skin deformation behaviour during hand movement and the interfacial pressure generated by the glove which are important for the design and engineering of therapeutic gloves. Data collected from the research could be mapped to represent the critical areas of the hand which provide valuable information in the design of therapeutic gloves.

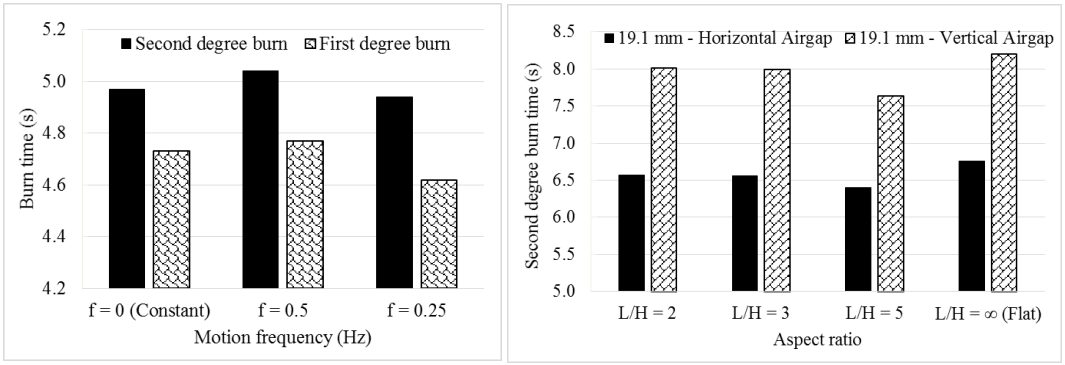
74 ORAL 6: Material and Design 2

A numerical study to analyse the effect of dynamic and heterogeneous microclimates in protective clothing on skin burn injury

UdayRaj[1,2], Faming Wang[1], Prabal Talukdar[2], Apurba Das[3], Ramasamy Alagirusamy[3]

[1]Institute of Textiles and Clothing (ITC), The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, [2]Department of Mechanical Engineering, IIT Delhi, New Delhi, India, [3]Department of Textile Technology, IIT Delhi, New Delhi, India

Microclimate plays an important role in protective clothing as it reduces heat transfer and chances of skin burn injury. In the present study, an advance FVM (finite volume method) based numerical model for heat transfer through microclimate considering coupled CFD (computational fluid dynamics)-radiation was developed and validated. This model was coupled with the Pennes bio-heat transfer model to determine severity of skin burn injuries. Two frequencies (*f*=0.25 and 0.5 Hz) of dynamically varying microclimates were considered to analyse effect of two different speeds of body movement on skin burn injuries. Effect of horizontal and vertical heterogeneous microclimates of different aspect ratios was also analysed on skin burn. The results are presented in Figure 1. Results show that the vertical orientation offers better thermal protection as compared to the horizontal microclimate orientation. Skin is more susceptible to burn injuries in case of the heterogeneous microclimates and the fold aspect ratio (L/H) affects the thermal protective performance significantly.



(a) (b)

Figure 1: (a) Skin burn times for 6.4 mm dynamically varying homogeneous horizontal clothing microclimates for different motion frequencies and (b) Second degree burn time for 19.1 mm heterogeneous microclimate of different aspect ratios, L/H (L is width and H is height of fold).

75 ORAL 6: Material and Design 2

Evaluating the effect of transient sleeping environments on athletic sleep quality using thermal manikins

Chris Watson, Olga Troynikov, Nazia Nawaz

RMIT University, Melbourne, VIC, Australia

Sleep is considered critical to human physiological and cognitive function. Much of the previous research has reported that exercise performance is negatively affected following sleep loss. For an athlete sleep is arguably one of the best forms of recovery available to achieve the peak performance in an event. Sleep is a strategy that contributes to significant recovery from multiple fatiguing events, including both cognitive and physiological tasks, and is an influential factor in avoiding overtraining. Sleep deprivation leads to poor performance.

There are many factors which may disturb sleep prior to an athletic event such as jetlag or anxiety including health and emotional states, bedding assembly used, clothing worn during sleep and by ambient environments. Thermal manikins are commonly used for evaluation of thermal and vapour resistance of clothing ensembles, however not common for evaluation of bedding ensembles.

The present study aimed to investigate and determine the effect of selected bedding ensembles on the next to skin (i.e. between the skin and the sleepwear) microclimates using the sweating thermal manikin, Newton, following a dynamic protocol consisting heating and sweating phases to simulate the sleeping metabolic and sweating activity conditions through the sleep phases of an athlete. The advantage of this approach is that it is possible to isolate specific variables, while keeping all the other variables constant, which is not possible to do in human trials.

The results of this study concluded that next to skin microclimates produced by the different experimental bedding ensembles was significantly different. The results showed that I next to skin microclimates was higher for one of the experimental bedding ensembles than the other experimental ensemble with all other variables being constant.

This experiment demonstrated that using a thermal manikin, it is possible to objectively investigate the effect of different bedding ensembles on the microclimate temperature and humidity, when manikins programmed to dynamically simulate basic physiology of a sleeping human.

76 ORAL 6: Material and Design 2

Determination of the insulation of baby sleeping bags – material test versus manikin test

Edith Classen

Hohenstein Intitute, Boennigheim, Germany

The EU Commission adopted a decision on safety requirements for products in the sleep environment of children. New safety standards for children's sleeping items - including baby sleeping bags – are under development. Depending on the product, the quality is determined with physical, chemical or clothing physiological test devices. One important property of the baby sleeping bags is the thermal insulation. Baby sleeping bags should keep the baby warm in cold condition and prevent an overheating during sleep and should protect the baby. Thermal insulation of textile materials can be determine with different test devices according the ISO 11092. In the UK, the Shirley togmeter according BS 4745 is often used. These two methods are under discussion for the determination of the thermal insulation of baby sleeping bags in the new standard. However, the thermal insulation of the material is not comparable with the thermal insulation of the product. Therefore, the judgement of the insulation of sleeping bags for adults used the thermal insulation determined with thermal manikins. The shape of the sleeping bags and the influences of the shape to the insulation can only determine with three-dimensional manikins. Up to now, the standard is not valid for children sleeping bags. At the institute the thermal manikin Charlene was developed in 2008. Charlene is a thermal child manikin three years old. Charlene was used for an investigation of the thermal insulation of various child sleeping bags, which were selected from the German market. The sleeping bags differ in the design, the shape, the filling material (e.g. PES fleece, CO, downs), the weight, the thickness and the outer shell material (e.g. cotton and blends with synthetic fibres). The values of the thermal insulation R_c measured with Charlene differ between 0,319 – 0.499 m²K/W (measurement condition: Ta = 15°C, r.h. = 50%, s= 0,3m/s, skin temperature of Charlene: 31°C)). The material specific thermal insulation R_{ct} of the baby sleeping bags was measured with the sweating guarded hotplate (ISO 11092). In this case, the insulation values R_{ct} vary between 0.045 m²K/W and 0.926 m²K/W. The sleeping bag with the highest R_{ct}-value (0.926 m²K/W) (material parameter) does not show the highest-value R_c-value. The results show that manikin measurements are necessary to judge the baby sleeping bag. Only the material specific values are not sufficient and lead to untrue statements. However, Charlene do not represent a baby and so the next step must be to develop a thermal baby manikin. This is important because there are significant differences between the body proportions of babies and children. It is an important challenge to develop a method to judge baby sleeping bags for the European standardization process.

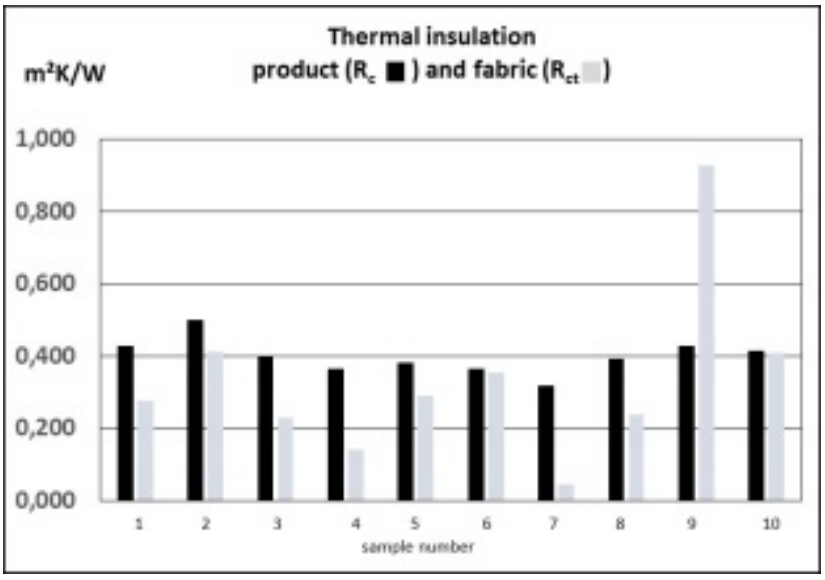


Figure 1: R_{ct} and R_c values of different sleeping bags

77 SYMPOSIUM: Aging in a hotter world

Aging in a hotter world. Introduction to the problem

Larry Kenney

Noll Laboratory, Department of Kinesiology, Pennsylvania State University

The earth's temperatures are rising, and although humans are tropical animals, the expected increase in the number and severity of heat waves will impact health and well-being. Although humans are capable of withstanding high temperatures for short periods of time, the cardiovascular strain induced by prolonged heat exposure increases morbidity and mortality, particularly among the elderly. Even in the absence of overt disease, the elderly are the most vulnerable population during prolonged environmental stress. As the global population of older men and women grows, an increasingly larger proportion of the population will be at risk. Aging is accompanied by mechanistic changes in the way we tolerate and mitigate heat stress. This symposium will discuss physiological and pathophysiological changes that accompany the human aging process and how those changes impact our ability to healthfully respond to high ambient temperatures.

78 SYMPOSIUM: Aging in a hotter world

The aged human cutaneous vasculature: altered mechanisms of vasodilation, emerging knowledge, and remaining questions

Lacy Alexander

The Pennsylvania State University, Pennsylvania, USA

Primary human aging in the absence of overt pathology is associated with attenuated reflex cutaneous vasodilation. While, cardiac output during hyperthermia is attenuated in the aged the mechanisms mediating reflex vasodilation are negatively impacted. Aged humans have a reduction in cholinergic co-transmitter(s) mediated vasodilation and alterations in second messenger pathways. Specifically, this presentation will address alterations in endothelial nitric oxide, and prostaniod pathways. Additionally, emerging endothelium-derived hyperpolarizing factor(s) including the gasotransmitter hydrogen sulfide will be discussed. The attendee will gain a greater understanding of how primary aging affects peripheral vascular function in the context of thermoregulation in the heat.

79 SYMPOSIUM: Aging in a hotter world

Aging and integrated cardiovascular responses to heat stress

Craig Crandall[1], Daniel Gagnon[2]

[1]University Southwestern Medical Centre, Dallas, USA, [2]University of Montreal, Quebec, Canada

The elderly represent the population at greatest risk for injury or death during heat waves. Healthy aging alters cardiovascular responses to heat stress, which is particularly evident by an ~50% attenuation in the elevation of cardiac output in this population to such exposure. Impaired cardiovascular responses may contribute to reduced heat dissipation in the elderly. That said, the mechanisms and consequences, particularly as it pertains to heat dissipation, of such cardiovascular responses to heat stress in the elderly are not entirely understood. This presentation will address our current understanding (and mechanisms) of altered cardiovascular responses to heat stress in elderly humans, as well as explore how any such deficits may lead to impaired heat dissipation. The attendee will gain a greater understanding of the consequences of aging on cardiovascular responses to heat stress that may contribute to increased morbidity and mortality during conditions of elevated environmental temperature in this population.

80 SYMPOSIUM: Aging in a hotter world

Aging, sweating, and sweat gland function

Yoshimitsu Inoue[1], Narihiko Kondo[2]

[1]Osaka International University, Osaka, Japan, [2]Kobe University, Kobe, Japan

In Japan under the influence of record intense heat in the summer of 2010, 1745 people died of heat-related illness and approximately 80% of the death toll occurred among people over 65 years of age. This suggests that the elderly are more susceptible to hyperthermia and heat illness, and perform worse in the heat than young adults. Considering global warming, the increasing population of elderly, and the susceptibility of the elderly to heat illness, the incidence of heat illness in the elderly during daily life in warm weather is expected to increase more in future. The main effector response for dissipating heat when exposed to environmental heat is sweating. In order to provide a rational basis for preventive strategies to reduce the incidence of heat illness among the elderly, it is important to understand age-related impairment of sweating function. In addition, strategies to alleviate heat strain, such as exercise training and heat acclimation/acclimatization on the sweating function of the elderly must be understood. This presentation is based on our studies of the heat-, exerciseacetylcholine-induced sweating responses and will address (1) the decline of the sweating function with aging, (2) the primary mechanisms underlying the aging-related alterations in the sweating function, and (3) the potential to modify these alterations by exercise training.

81 SYMPOSIUM: Aging in a hotter world

Environmental factors impacting responses of older individuals to heat

Glen Kenny

University of Ottawa, Ottawa, Canada

Everyday activities require that the thermoregulatory system constantly activate heat dissipating mechanisms to offset perturbations in body core temperature created by changes in metabolic heat production due to physical activity and/or exposure to a warmer environment. However, the ability to physiologically maintain body core temperature during heat stress becomes compromised with healthy aging. This decrease in thermoregulatory ability can be attributed to a combination of factors including changes in sweating and skin blood flow as well as cardiovascular function which occur independently of the individual's level of acclimation. This can be exacerbated by reductions in physical fitness and increases in body adiposity that may accompany aging. When combined, these age-related changes in thermoregulatory and cardiovascular function can decrease the body's ability to maintain body core temperature at safe levels during extended periods of heat exposure and/or physical activity especially under conditions of high ambient humidity. This presentation will discuss recent research in the area of aging and thermoregulatory control with an emphasis on the examination of recent calorimetric evidence directed at evaluating the consequences of aging on whole-body heat dissipation. Finally, we will briefly examine the efficacy of interventions (e.g., use of fans) in modulating the level of thermal strain in older adults during exposure to extreme heat and humidity. Attendees will acquire valuable insight on current and novel research examining the consequences of healthy aging on thermal adjustments to heat stress. This will stimulate discussion on future avenues of research within this field of study.

82 ORAL 7: Temperature regulation 2

Acute anxiety predicts components of the cold shock response on cold water immersion before and after repeated immersion: implications for control of ventilation

Martin Barwood[1], Jo Corbett[2], Heather Massey[2], Terry McMorris[3,4], Mike Tipton[2], Christopher Wagstaff[2]

[1]Leeds Trinity University, Leeds, West Yorkshire, UK, [2]Portsmouth University, Portsmouth, Hampshire, UK, [3]Northumbria University, Newcastle Upon Tyne, Tyne and Wear, UK, [4]Chichester University, Chichester, West Sussex, UK

Accidental cold-water immersion (CWI) triggers the life-threatening cold shock response (CSR) which is a precursor to sudden death on immersion. We have recently identified that acute anxiety accentuates the CSR in unhabituated participants; partially reverses the cardiac component of the response when acute anxiety is elevated after habituation has taken place (i.e. repeated, short, CWIs) and prevents habituation when present during habituation immersions; evidently, acute anxiety is integral to the CSR. From our database of CWIs we examined the predictive relationship between self-report anxiety ratings prior to immersion and the CSR during the first minute of CWI, when the CSR peaks, and therefore, is the most life-threatening period of acute immersion. We examined this relationship in unhabituated participants and those who underwent repeated CWI. Two analyses were undertaken. Study 1 included forty-eight unhabituated participants (34 male, 14 female; mean [SD] age 20.3 [1.7] years, height 1.75 [0.1] m, mass 76.2 [16.7] kg) who completed an initial, seven-minute immersion in to cold water (15 °C). Study 2 considered twenty-four of those participants (16 male, 8 female; age 20.4 [2.1] years, height 1.75 [0.1] m, mass 77.9 [17.2] kg) who completed a further four standardized CWIs followed by two counter-balanced immersions where anxiety was increased by deception prior to immersion (ANX) and the other acted as a control (CON). Anxiety (20 cm visual analogue scale) and cardiorespiratory responses (cardiac frequency [f_c], respiratory frequency [f_R], tidal volume [V_T], minute ventilation [$\dot{V}_E$]) were measured. Stepwise multiple regression analyses were undertaken for components of the CSR predicted by the acute anxiety rating. Anxiety rating predicted the f_c component of the CSR ($p=0.02, r=0.436, r^2=0.190$) in unhabituated participants (i.e. study 1). In study 2 in the CON immersion anxiety rating predicted the f_R component of the CSR ($p=0.03, r=0.566, r^2=0.320$) but predicted the f_c ($p=0.03, r=0.443, r^2=0.197$) component in the ANX immersion. Acute anxiety prior to immersion predicts different components of the CSR before and after repeated CWI. We suggest raised anxiety levels reduce the voluntary capability to control ventilation during CWI.

83 ORAL 7: Temperature regulation 2

Low intensity exercise delays shivering response to core cooling

Tomomi Fujimoto[1,2], Yasuo Sengoku[3], Kohei Dobashi[1], Naoto Fujii[3], Takeshi Nishiyasu[3]

[1]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, [2]Research Fellow of Japan Society for the Promotion of Science, Chiyoda-ku, Tokyo, Japan, [3]Faculty of Health and Sport Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan

Hypothermia is a common phenomenon even in elite swimmers during open water swimming (Castro et al. 2009). Hypothermia is known to elicit shivering that can coexist with exercise. Thermoregulatory responses such as heat loss responses of sweating and cutaneous vasodilation are modulated by not only thermal factors (changes in core and skin temperatures) but also exercise (Kondo et al. 2010). However, whether exercise also modulates shivering response, a thermoregulatory response to hypothermia, remains unknown. The purpose of this study therefore was to investigate the effect of exercise on shivering response during core cooling achieved by cool water immersion.

Eight healthy young men performed two trials (rest and exercise trials). In both trials, subjects were initially immersed to warm water [water temperature (T_w) = 42°C] to increase resting esophageal temperature (T_{es}). Then subjects were immersed to and remained in cool water [T_w = 25°C] in the rest trial, whereas they performed a low-intensity cycle exercise (0 W, 30 rpm) in the water in the exercise trial. T_{es}, mean skin temperature [$\dot{T}_{sk}$: calculated from four skin temperatures (Ramanathan 1964)], oxygen uptake, heart rate, and thermal sensation (TS) were measured throughout. Shivering threshold and sensitivity were determined from oxygen uptake plotted against T_{es}. Slope and intercept of regression lines derived by TS and T_{es} relationships were also evaluated.

T_{es} and cooling rate were not different between the trials, although $\dot{T}_{sk}$ during cool water immersion was lower in the exercise than rest trial. The T_{es} threshold at which shivering initiated was lower in the exercise relative to rest trial (36.2 ± 0.4°C vs. 36.5 ± 0.4°C, $P < 0.05$), while its sensitivity did not differ between the trials (-411.8 ± 268.1 ml·min^{-1}·°C^{-1} vs. -441.3 ± 177.4 ml·min^{-1}·°C^{-1}, $P > 0.05$). The slope and intercept evaluated from the relationships of TS with T_{es} were not different between the trials ($P > 0.05$).

Our results suggest that the core temperature threshold for the onset of shivering is delayed during low-intensity cycling exercise compared to that at rest with unchanged shivering sensitivity.

84 ORAL 7: Temperature regulation 2

Behavioural and autonomic thermoregulation during exercise in differing thermal profiles of heat matched for vapour pressure

Tze-Huan Lei[1], James David Cotter[2], Zachary Schlader[3], Ahmad Munir Che Muhamed[4], Stephen Robert Stannard[1], Toby Mündel[1]

[1]Massey University, Palmerston North, New Zealand, [2]University of Otago, Dunedin, New Zealand, [3]The State University of New York, Buffalo, USA, [4]Universiti Sains Malaysia, Penang, Malaysia

There has been a renaissance of investigation into behavioural thermoregulation using self-selected work-rate during exercise in the heat as a model, which can be used to complement the abundance of investigations on the autonomic responses. Thermally stressful environments vary according to multiple parameters, such as ambient temperature and humidity, which are often quantified into singular heat stress indices (e.g., WBGT). However, behavioural thermoregulation needs further elucidation within studies in which at least one parameter remains stable, to determine the impact of other parameters. Therefore, the purpose of this study was to investigate the contribution of ambient temperature with matched absolute humidity on behavioural and autonomic thermoregulation during exercise. Ten moderate to highly trained cyclists (age: 30 ± 12 years; height:176 ± 5 cm; mass: 73 ± 7 kg; $\dot{V}O_2$max: 62 ± 8 mL.kg^{-1}.min^{-1}; body surface area: 1.9 ± 0.1 m^2; body fat: 14 ± 5%; peak power output: 402 ± 44 watts) were recruited, where they underwent one 30-min self-paced exercise bout in moderate heat (34.9 ± 0.2°C, 49.9 ± 1.1% relative humidity; 2.79 ± 0.07 kPa, absolute humidity) and one in mild heat (29.2 ± 0.2 °C, 69.6 ± 0.7% relative humidity, 2.84 ± 0.02 kPa). Trials were separated by at least 7 days and were counter-balanced. Autonomic effector (cutaneous blood flow, local sweat rate) and body temperature (rectal and mean skin temperature) responses were recorded continuously throughout, whilst power output was recorded every 6 min during exercise to serve as an index of behavioural regulation. Data were analysed using two-way repeated measures ANOVA. Despite mean skin temperature being 2°C higher in moderate than mild heat (36.2 ± 0.1 vs. 34.2 ± 0.2 °C, P < 0.01), all other variables, such as rectal temperature (38.0 ± 0.1 vs. 37.8 ± 0.1°C, P = 0.20), local sweat rate (0.98 ± 0.10 vs. 0.83 ± 0.09 mg.cm^2.min^{-1}, P = 0.14), cutaneous blood flow (285 ± 33 vs 260 ± 26 PU, P = 0.49), mean power output (217 ± 12 vs. 216 ± 13 W, P = 0.87), and total work completed (390 ± 67 vs. 388 ± 75 kJ, P = 0.87) did not show a significant difference between environments. We conclude that in warm-hot but compensable environments matched for evaporative capacity, ambient temperature played a limited role in the autonomic and behavioural responses observed.

85 ORAL 7: Temperature regulation 2

The body core is far more thermosensitive than the skin in driving behavioural thermoregulation during swimming

Carl Bradford[1], David Gerrard[1], Samuel Lucas[1,2], Chris Button[1], James Cotter[1]

[1]University of Otago, Dunedin, New Zealand, [2]University of Birmingham, Birmingham, UK

Introduction: Humans' autonomic thermoregulation is remarkably powerful and complex, but behavioural thermoregulation is more powerful and complex and thus more important. Autonomic thermoregulation uses thermoafferent input from deep body thermoreceptors (i.e., ~core temperature, T_c) to much greater extent than from superficial thermoreceptors (i.e., ~skin temperature, T_{sk}), by a factor of 5:1 to 20:1 depending on the research study and effector examined. The relative afferent contributions, or thermosensitivities, of T_c:T_{sk} in driving behavioural thermoregulation are even less well resolved; estimates range full scale from 1:0 to 0:1. The purpose of this study was therefore to help ascertain the relative T_c:T_{sk} thermosensitivities for behavioural thermoregulation, by utilising an endurance swimming model whereby T_{sk} was clamped at each of four levels (~21 to 33 ^oC) while T_c ranged by up to ±2.3 ^oC (mostly 0.5 to 1.1 ^oC) and thermal perceptions were recorded.

Methods: Twenty swimmers or triathletes undertook 2-9 swims of 20, 60 or 120 min, in a swimming flume (StreamliNZ, Dunedin, NZ) with water temperature (T_w) controlled at 20, 27, 30 or 32 ^oC. Air temperature was controlled correspondingly. Swims were normally ~7 d apart and in semi-randomised order. Participants' characteristics were: 29 (SD 8, range 19-49) y of age, 177 (9, 159-188) cm tall, 77 (9, 61-92) kg body mass, 1.9 (0.2, 1.7-2.2) m^2 surface area, and 16% (8, 8-37) body fat. The five females were tested in the follicular phase of their menstrual cycle. T_c was measured rectally. T_{sk} was clamped within 1.2 ^oC of T_w, as verified using insulated skin thermistors taped to the forehead, scapula, arm and thigh for all T_w in three swimmers. Perceived body temperature and thermal discomfort were recorded every 10-30 min using 13- and 9-point scales [extended from Gagge et al. (1967) Environ Res, 1:1-20]. Linear relations between T_c and T_{sk} and perceptions were examined using multiple linear regression.

Results: Of 117 swims, four were terminated early due to cold intolerance or low T_c (<35.5 ^oC). T_c averaged 37.1 ^oC (0.4) at rest and ranged from 35.0 to 39.45 ^oC during swimming, whereas thermal sensation ranged from cold to very hot, and discomfort ranged from comfortable to extremely uncomfortable. Thermal sensation and discomfort were linearly related to T_c (i.e., within each T_w), whereas T_{sk} had an additive effect (i.e., between T_w). The T_c:T_{sk} contributions were 4.6:1.0 for perceived body temperature and 60:1 for thermal discomfort. Specifically, Thermal sensation = $-59 + 1.48T_c + 0.32T_{sk}$, and Thermal discomfort = $-65 + 1.78T_c + 0.03T_{sk}$.

Conclusion: When T_{sk} is clamped such that it provides only a static thermosensitivity, the T_c provides far greater (perhaps 60x) contribution to thermal discomfort, which drives behaviour. Even perceived body temperature is dominated (~5:1) by T_c relative to T_{sk}.

86 ORAL 8: Heat Exposure 1

Evaluation of commercial cooling systems to minimise thermal strain while wearing chemical-biological protective clothing

Matthew Maley, Geoffrey Minett, Aaron Bach, Stephanie Zietek, Ian Stewart

Queensland University of Technology, Brisbane, QLD, Australia

Protection from chemical and biological agents requires an individual to wear a chemical, biological [CB] suit that impedes evaporative heat loss (McLellan et al., 2013). These CB suits add mass to an individual creating a potentially lethal cocktail of increased metabolic heat production during work and reduced heat loss, impairing tolerance times. Previous research has shown that liquid or air cooling is effective at reducing the thermal burden during work in a CB suit (McLellan et al., 1999). However, there is limited data comparing commercially available cooling garments during prolonged continuous work in CB suits. Therefore, the aim of this study was to investigate the effect of commercially available cooling garments on thermal strain and tolerance times dressed in a CB suit.Eight recreationally trained healthy males volunteered; as the study is ongoing an example of one participant's data is presented. In a randomised order, separated by 72 hours, participants attended the laboratory on five occasions. Trials consisted of resting for 30 min in 24 °C, then subsequently walking on a treadmill (4.5 $km.h^{-1}$, 1 % grade) for a maximum of 120 min in 35 °C, 50 % rh, dressed in a CB suit (Lion Apparel, ERS, NFPA 1994 Class 3) with respirator and concurrent cooling. A no cooling trial served as the control (CON), whilst the cooling trials consisted of: *1)* ice vest (IV); *2)* ice vest + slushy (-2°C, consumed during 30 min rest [IVSL]); *3)* phase change vest (melting at 14 °C, [PCV]); *4)* portable water-perfused suit (2 L capacity, inlet water temperature: 11 °C [WPS]). Rectal temperature (T_{rec}) and skin temperature (ISO 9886, 2004 [T_{sk}]) were recorded throughout. The participant managed to complete 120 min of walking in all trials, except in the WPS which was terminated due to T_{rec} reaching 39 °C. The weight of the filled water bottle and suit (~3 kg) as well as the increased skin coverage would have increased metabolic rate and reduced heat loss during walking, contributing to the accentuated thermal strain. All cooling trials, except WPS, finished with a T_{rec} between 0.3 °C and 0.2 °C lower than CON. These initial results suggest commercially available cooling may be capable of alleviating thermal strain during work in CB suits.

		Personal Cooling System				
Variable	**Time**	**CON**	**IV**	**IVSL**	**PCV**	**WPS**
Tolerance Time (min)	-	120	120	120	120	115
T_{rec} (°C)	Pre	37.2	37.0	36.5	37.0	36.9
	Post	38.6	38.3	38.3	38.2	39.0
T_{sk} (°C)	Pre	31.7	30.1	30.3	30.3	31.7
	Post	36.8	37.0	36.7	36.7	37.7
HR (bpm)	Pre	91	88	73	80	97
	Post	152	142	144	145	160
Body mass loss (kg)	-	1.8	1.9	2.1	1.3	1.0

87 ORAL 8: Heat Exposure 1

Validation of core body temperature estimation from heart rate in sugarcane harvesters

Rebekah A. I. Lucas[1], Mark J. Buller[2], Ilana Weiss[3], Sandra Peraza[4], David H. Wegman[5]

[1]School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, UK, [2]US Army Research Institute of Environmental Medicine, MA, USA, [3]La Isla Foundation, IL, USA, [4]Program on Work, Environment and Health in Central America (SALTRA), San Salvador, El Salvador, [5]Department of Work Environment, University of Massachusetts Lowell, Massachusetts, USA

Sugarcane cutters work in difficult, hot and strenuous work conditions. These work conditions are believed to be key causal factors in chronic kidney disease of unknown origin (CKDu) epidemic occurring in Mesoamerica. The aim of this study was to validate the Buller et al. (2013) body core temperature estimation algorithm in sugarcane cutters during a workday. Data were collected over three consecutive workdays in a total of 14 costal sugarcane cutters (4-5 workers per day) during the 2015-2016 harvests in El Salvador. Outdoor Wet Bulb Globe Temperatures (WBGT) were calculated (WBGT (outdoor) = 0.7WB + 0.2G + 0.1DB) via the QuesTemp °34. Heart rate, chest temperature, gastro-intestinal temperature (T_{GI}, Equivital, vitalsense), plus water consumption was recorded. An algorithm using sequential HR data was used to estimate body core temperature (T_{core}) in these workers. Agreement between daily maximum as well as daily average T_{GI} measures and T_{core} estimates were assessed using a Bland-Altman plot. Workers started cutting between 5:30 and 6:30am and worked on average for 4:43 hours (range 4:00 - 5:10 hours). In the field, WBGT reached 33°C (95% confidence interval [CI]: 35°C to 32°C), with 79% (95% CI: 82 to 76%) of the day spent working at a WBGT above 26°C (OSHA recommended WBGT threshold limit for continuous strenuous work). Heart rates averaged 111 bpm (95% CI: 117 to 105 bpm) and chest skin temperature averaged 36.2°C (95% CI: 36.6 to 35.9°C) during work. T_{GI} averaged 37.6°C (95% CI: 37.7 to 37.5 °C) and reached a maximum of 38.1°C (95% CI: 38.3 to 37.9°C) during work. Figure 1 shows the difference of agreement between average T_{GI} and T_{core} estimated. The mean difference was -0.20°C (95% CI: -0.64 to 0.23°C) for each worker during their workday. The mean difference of agreement for maximum T_{GI} and T_{core} estimated attained was -0.12°C (95% CI: -0.89 to 0.67°C) for each worker during their workday. **Conclusion:** On average there is generally good agreement between T_{GI} and T_{core} estimates using sequential HR measures across a workday. Given the relative ease and low cost of measuring heart rate in the field, the Buller et al., (2013) algorithm shows promise for broad and long-term monitoring and assessment of heat strain in sugarcane workers.

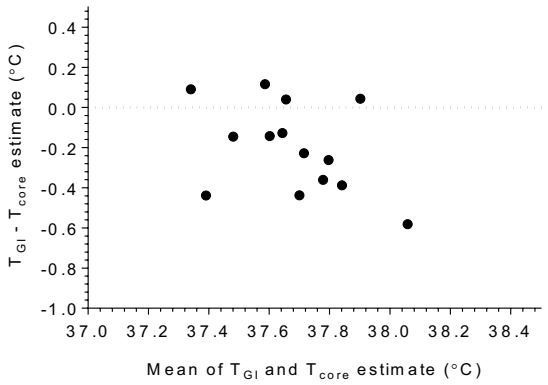


Figure 1: Bland-Altman plot comparing average gastro-intestinal temperature (T_{GI}) and estimated average body core temperature from heart rate (T_{core} estimate) for 14 sugarcane workers during their workday.

Disclaimer: The views expressed are those of the authors and do not reflect the official policy of their respective governments.

88 ORAL 8: Heat Exposure 1

Physiological and perceptual responses in the elderly to simulated daily living activities in UK summer climatic conditions

Kirsty Waldock, Peter Watt, Mark Hayes, Neil Maxwell

University of Brighton, Eastbourne, UK

The global climate is changing, 2016 was the third consecutive hottest year on record (MET Office, 2016) and as the mean global temperature rises so does the frequency, severity and duration of heatwaves (Hajat et al., 2014). This presents a significant health risk to the population, with the elderly being the most vulnerable to heat-related illnesses and death due to a reduced capacity to dissipate excess heat (Kenney et al., 2014). Consequently, up to 90% of excess deaths during heatwaves occur in people over 65 years (Conti et al., 2005). The aim of this investigation was to assess the physiological and perceptual responses of elderly people during exercise in UK summer climatic conditions. Twenty- eight participants (18 males and 10 females: age; 71 ± 4 years, body mass; 76.9 ± 15.1 kg, body fat percentage; 22.7 ± 3.9%) were randomly assigned into three experimental groups; 15°C, 25°C or 35°C, 50% relative humidity. Participants completed a preliminary trial and three experimental trials within their assigned environment. The data from the preliminary incremental recumbent cycling test was used to calculate individual exercise intensities equating to 2, 4 and 6 metabolic equivalents (METs) for the subsequent trials. In the experimental trials participants completed 30 minutes of seated rest and 30 minutes of cycling exercise. Throughout the experiment heart rate, core temperature (T_c) and skin temperature (T_{skin}) were recorded every 5 minutes; and rating of perceived exertion, thermal sensation (TS) and thermal comfort (TC) every 10 minutes. End T_{skin} increased significantly ($P < 0.05$) with environmental temperature when exercise intensity did not change. Furthermore, ΔT_c increased significantly ($P < 0.05$) from rest to end exercise when exercise intensity remained the same and environmental temperature was increased from 15-35°C and from 25-35°C, highlighting a significant increase in thermal strain. However, there was no significant increase ($P>0.05$) in end TC and TS when completing exercise at 6 METs in 25°C compared to 35°C. Findings suggest that when completing exercise that equates to activities of daily living, elderly people could have a decreased perceptual awareness of the environment due to significant increases in T_{skin} and ΔT_c, but no changes in end TC (see figure 1) and minimal changes in end TS between exercising at 6 METs in 25°C compared to 35°C. The potential consequence of a decreased perceptual awareness of the environment is that the elderly will be less likely to implement lifesaving behavioural thermoregulation interventions such as; seeking shade, decreasing metabolic rate and removing excess layers, as thermal comfort is the drive for thermoregulatory behaviour (Flouris, 2011).

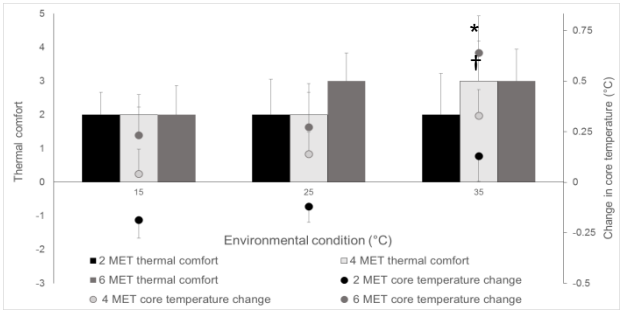


Figure 1: End exercise TC (bar chart) and ΔTc (closed circles) across environmental temperatures and exercise intensities. * † denote a significant increase ($P<0.05$) in ΔTc when exercise intensity is the same and environmental temperature is increased from 15-35°C and 25-35°C, respectively.

89 ORAL 9: Heat Exposure and Adaptation

A new occupational heat tolerance test

Emily Watkins, Mark Hayes, Peter Watt, Alan Richardson

University of Brighton, Eastbourne, East Sussex, UK

Heat tolerance tests are used in the military and with athletes to identify individuals who are susceptible to heat illnesses and to monitor adaptations. The standard test developed by Moran et al (2007) (MHTT: 2hr walk at 5km.hr^{-1} 1% gradient, 40°C 40% RH, in shorts and t-shirt) offers poor ecological validity to situations where protective clothing is worn. The test also uses a fixed absolute intensity, and therefore does not allow for robust comparisons between heterogeneous groups. This study aimed to assess the validity and reliability of a new occupational heat tolerance test (OHTT: 40min at 6W.kg^{-1} metabolic heat production, 50°C 10% RH, in firefighter protective clothing).

Seventeen participants (age: 21 ± 3yrs, mass: 81.66 ± 5.93kg, height: 180.2 ± 6.6cm) completed the MHTT and OHTT to assess validity, and 11 participants (age: 21 ± 2yrs, mass: 80.48 ± 5.62kg, height: 178.5 ± 6.3cm) completed two OHTT trials for reliability assessment. Physiological measures (rectal temperature [T_{re}], heart rate [HR], skin temperature [T_{skin}]) were recorded every 5 min and perceptual measures (thermal sensation [TS], rating of perceived exertion [RPE]) were recorded every 10min. A heat illness symptoms index [HISI] was also taken at rest and post exercise. A battery of validity and reliability tests were conducted, including Bland & Altman plots, typical error of the measurement (TEM), TEM as a coefficient of variation (CV%), and intra-class correlation coefficients (ICC), significance set at $p<0.05$.

Peak T_{re} displayed strong agreement (ICC=0.86, $p<0.001$), low TEM (CV%) (0.19°C (0.49%)), and small mean bias and limits of agreement (0.09 (-0.43, 0.62°C)) between MHTT (38.67 ± 0.42°C) and OHTT (38.58 ± 0.36°C). HR exhibited a mean bias of 22b.min^{-1} for OHTT than MHTT. OHTT and MHTT both identified 9 individuals as heat intolerant according to Moran's T_{re} criteria (>38.5°C). Strong agreement and low TEM (CV%) were displayed between the two OHTT trials for peak T_{re} (38.53 ± 0.37°C vs. 38.54 ± 0.35°C, ICC=0.98, $p<0.001$), peak HR (182 ± 20 b.min^{-1} vs. 182 ± 21 b.min^{-1}, ICC=0.99, $p<0.001$), peak T_{skin} (ICC=0.75, p=0.025), TS (ICC=0.87, p=0.002), RPE (ICC=0.97, $p<0.01$) and HISI (24 ± 15 vs. 26 ± 16, ICC=0.95, $p<0.001$).

These data indicate the OHTT is a valid and reliable test, it can consistently identify individuals' level of heat tolerance. The OHTT also supports the theory that individuals sit along a continuum of heat tolerance, with tolerance reducing the further peak T_{re} moves above 38.0°C. Consequently, the OHTT should be used to assess the heat tolerance of individuals wearing protective clothing in high temperatures, such as within the UK Fire Service where tolerance tests are currently not implemented. This will enable identification and monitoring of those at greatest risk of heat illnesses.

References

Moran, D.S., Erlich, T. and Epstein, Y., 2007. The heat tolerance test: an efficient screening tool for evaluating susceptibility to heat. *Journal of sport rehabilitation*, *16*(3), pp.215-221.

90 ORAL 9: Heat Exposure and Adaptation

The efficacy of twice daily long-term heat acclimation on heat acclimation state, immune function and exercise tolerance

Ash Willmott[1], Carl James[3], Oliver Gibson[2], Mark Hayes[1], Jeanne Dekerle[1], Neil Maxwell[1]

[1]University of Brigthon, Eastbourne, UK, [2]University of Brunel, London, UK, [3]Institut Sukan Negara, Kuala Lumpur, Malaysia

Aims: Heat acclimation (HA) is an important preparation intervention preceding exercise-heat stress to confer optimal heat adaptations. The acquisition of the heat-adaptive phenotype is optimized during once daily HA (ODHA), however a new twice daily HA (TDHA) concept (Willmott et al., 2016) may address the ecologically and applicable limitations associated within traditional protocols. This study refined current TDHA and investigated the efficacy of a non-consecutive long-term, intermittent TDHA protocol, compared to traditional ODHA, and temperate exercise (TE). Methods: Following the completion of a cycling LT-$\dot{V}O_{2peak}$ test, forty males were matched for biophysical characteristics and aerobic capacity, and assigned to; ODHA (mass: 77.2 ± 10.0 kg, BSA: 1.95 ± 0.16 m^2, body fat: 14.9 ± 2.7 % and $\dot{V}O_{2peak}$: 3.76 ± 0.46 $L.min^{-1}$), TDHA (75.3 ± 9.5 kg, 1.94 ± 0.13 m^2, 14.3 ± 3.7 % and 3.74 ± 0.50 $L.min^{-1}$), once daily TE (ODTE, 77.3 ± 8.6 kg, 1.92 ± 0.10 m2, 15.0 ± 1.7 %, 3.73 ± 0.43 $L.min^{-1}$) or twice daily TE (TDTE, 75.2 ± 7.8 kg, 1.93 ± 0.14 m^2, 14.6 ± 2.9 %, 3.69 ± 0.34 $L.min^{-1}$). Participants completed a heat acclimation state test (HAST) and a time to task failure (TTTF) in temperate ($TTTF_{TEMP}$: 22°C and 40% RH) and hot conditions ($TTTF_{HOT}$: 38°C and 20% RH), before and after 10 exercise sessions (60-mins of controlled hyperthermia) of HA (45°C, 20% RH) or TE (22°C, 40% RH). Resting, exercise and recovery physiological and perceptual measures were recorded. Immunological measures were recorded pre-post session 1, 5 and 10. The HAST consisted of three, 30-min periods of fixed metabolic heat production intensities (3, 4.5 and 6 W kg^{-1}) (Willmott et al., 2015), while TTTF were set at 80% PPO. Results: ODHA and TDHA significantly evoked a range of heat adaptations (Table 1. $P < 0.001$) and improved heat acclimation state (sweat setpoint: -0.22 ± 0.18°C, -0.22 ± 0.14°C, $P < 0.001$), without compromising immune function. Exercise tolerance was also significantly improved following ODHA and TDHA during $TTTF_{HOT}$ (+25 ± 4 %, +24 ± 10 %, $P < 0.001$), but not $TTTF_{TEMP}$ (+14 ± 4 %, +14 ± 8 %, $P > 0.05$), or LT-$\dot{V}O_{2peak}$. No changes in heat adaptations, nor exercise tolerance were found between HA groups. Conclusion: A refined long-term, intermittent TDHA strategy and traditional ODHA protocol conferred effective acquisitions of the heat adaptive phenotype and improved exercise tolerance in heat stress, without compromising immune status. TDHA may afford athletes and occupational personnel recovery days during HA, or provides the opportunity to continue their training quality, possibly as part of a concurrent training programme.

Table 1: Changes (∆) in rest and exercise measures during session 1, 5 and 10

	Session 1-5				**Session 5-10**				**Session 1-10**			
∆ variable	**ODHA**	**TDHA**	**ODTE**	**TDTE**	**ODHA**	**TDHA**	**ODTE**	**TDTE**	**ODHA**	**TDHA**	**ODTE**	**TDTE**
∆Rest T_{re} (°C)	-0.18± 0.27	-0.22± 0.17	0.03± 0.21	-0.04 ± 0.17	-0.11 ± 0.17	-0.06 ± 0.16	-0.04 ± 0.27	-0.06 ± 0.19	-0.28 ± 0.22	-0.28 ± 0.19	-0.10 ± 0.16	-0.11 ± 0.18
ΔT_{repeak} (C)	-0.04 ± 0.23	-0.06 ± 0.18	-0.25 ± 0.12	0.06 ± 0.27	-0.01 ± 0.29	-0.02 ± 0.15	0.12 ± 0.30	-0.05 ± 0.07	-0.06 ± 0.24	-0.08 ± 0.19	-0.12 ± 0.25	0.01 ± 0.31
∆Time > 38.0°C	-2.2 ± 13.0	-2.7 ± 7.0	-3.3 ± 11.7	3.8 ± 12.4	-2.2 ± 10.4	-3.6 ± 8.5	2.9 ± 12.0	-5.8 ± 6.6	-4.4 ± 10.2	-6.4 ± 7.1	-0.3 ± 6.2	-2.0 ± 12.5
∆Time > 38.5°C	-2.5 ± 10.9	-5.7 ± 6.2	0.0 ± 6.2	0.5 ± 1.6	-1.4 ± 8.8	0.9 ± 5.4	-3.0 ± 9.8	-0.3 ± 0.8	-3.9 ± 15.6	-4.3 ± 6.3	-3.0 ± 8.8	0.3 ± 0.8

∆Rest HR (beats.min^{-1})	-5 ± 1	-5 ± 5	-1 ± 1	1 ± 3	-4 ± 5	-5 ± 4	0 ± 1	-3 ± 5	-10 ± 3	-10 ± 4	-2 ± 1	-2 ± 6
∆HR_{peak} (beats.min^{-1})	-1 ± 10	0 ± 12	-7 ± 12	-11 ± 10	-3 ± 9	-7 ± 15	4 ± 17	-3 ± 15	-4 ± 9	-8 ± 10	-3 ± 18	-14 ± 10
∆NUFL (mL)	230 ± 207	178 ± 142	83 ± 86	48 ± 68	303 ± 168	220 ± 87	-2 ± 105	47 ± 98	533 ± 261	398 ± 97	81 ± 97	90 ± 118
∆NaCl (mmol.L^{-1})	-13 ± 13	-7 ± 6	-12 ± 12	-6 ± 12	-14 ± 10†‡	-8 ± 6	-12 ± 11	-3 ± 12	-27 ± 19*+†‡	-14 ± 5*	-24 ± 20	-11 ± 13
∆PV (%)	6.3 ± 4.0	5.4 ± 4.0	0.5 ± 2.8	1.5 ± 3.4	4.6 ± 4.3	4.8 ± 4.8	2.1 ± 1.6	-0.7 ± 2.4	10.1 ± 5.6	8.5 ± 3.1	1.5 ± 3.5	0.7 ± 4.1

*represents a significant (P < 0.05) within-group difference between session 1. †represents a significant (P < 0.05) between-group difference with ODTE. ‡represents a significant (P < 0.05) between-group difference with TDTE. +represents a significant (P < 0.05) between-group difference between session 5

Effects of 28-day cold and heat cross exposure on thermoregulatory and behavioral responses in mice

Joo-Young Lee, Yelin Ko, Joonhee Park

Seoul National University, Seoul, Republic of Korea

The purpose of the present study was to investigate the effects of cold and heat cross exposure for 28 days on thermoregulatory responses in mice. A cold and heat cross exposure (CH exposure) were proceeded by cold exposure at an air temperature (T_a) of 5°C for 24 hours first, followed by heat exposure at T_a 37°C for 24 hours. The 2-day CH exposure were consecutively repeated 14 times (2 days*14 times = 24 days) in a climate chamber for mice. A total of 10 male ICR mice (6 weeks in age) were used for the CH exposure (Exposed group) and another group of 10 male ICR mice was used as a control (T_a 25°C for 28 days). Mice were housed in the climate chamber on a 12/12 h light/dark cycle with the light cycle. All mice had ad libitum access to rodent chow and water. We measured rectal temperature (T_{re}), infrared skin temperature (T_{sk}), basic properties and corticosteroid in blood, body mass, and behavior of mice for the 28-days. After the 28-day exposure, an autopsy with the 20 mice was conducted to analyze brown adipose tissue (BAT) on the back and spine. The results showed that 1) T_{re} of the mice on the days exposed to 37°C decreased while T_{re} of the mice on the days the exposed to 5°C abruptly decreased for the the initial exposure and increased again (Table 1). 2) For control, mice gained weight from 31.7 ± 1.0 g to 34.8 ± 1.9 g on the 28th day, whereas the exposed group lost weight from 31.7 ± 1.0 g to 27.5 ± 1.2 g on the 28th day (P<0.001). 3) No differences in food intake between groups were found. 4) We found significant differences in total leucocyte count, total erythrocyte count, mean cell hemoglobin, and platelet between the two groups. 5) BAT was greater for the exposed group than the control group (control: 133.2 ± 15.3 mg, and the exposed: 152.2 ± 17.5 mg; *P*=0.018). 6) Plasma corticosterone was greater for the exposed group than the control group (control: 882.4 ± 101.0 ng/ml, and the exposed to 5°C: 993.6 ± 117.4 ng/ml; the exposed to 37°C: 1026.3 ± 75.6 ng/ml; *P*<0.05). These results suggest that cold and heat cross exposure might be able to induce thermal tolerance.

Table 1: Rectal temperature according to days exposed for control and the exposed group

Unit: °C	Control (25°C) N=10	Exposed (37°C) N=10	p-value		Control (25°C) N=10	Exposed (5°C) N=10	p-value
Day0	37.3 ± 0.9	37.8 ± 0.3	0.115	Day0	37.3 ± 0.9	37.8 ± 0.3	0.115
Day5	37.8 ± 0.7	37.2 ± 1.5	0.634	Day6	37.8 ± 0.9	29.2 ± 1.3	<0.001
Day9	38.3 ± 0.5	37.5 ± 0.4	0.001	Day8	38.2 ± 0.8	33.2 ± 0.7	<0.001
Day13	38.5 ± 0.4	37.3 ± 0.4	<0.001	Day12	37.7 ± 0.8	33.9 ± 0.8	<0.001
Day17	38.1 ± 0.6	37.8 ± 0.2	0.199	Day16	37.3 ± 1.0	33.5 ± 1.3	<0.001
Day19	38.3 ± 0.5	37.4 ± 0.6	0.003	Day20	38.2 ± 0.4	34.2 ± 1.3	<0.001
Day23	38.3 ± 0.6	37.1 ± 0.6	<0.001	Day24	37.9 ± 0.5	34.9 ± 0.9	<0.001
Change	0.99 ± 1.28	-0.68 ± 0.65	0.002	Change	0.58 ± 1.17	-2.94 ±0.88	<0.001

93 ORAL 10: Exercise Performance

The effects of cycling in the heat on gastrointestinal inflammation and neuromuscular performance

John Osborne, Ian Stewart, Geoffrey Minett

Queensland University of Technology, Brisbane, Queensland, Australia

Exercise in the heat is associated with thermoregulatory strain and marked deterioration in aerobic performance. Elevated core temperatures have been associated with a downregulation of central nervous system drive to the musculature, termed central fatigue. Prolonged exercise in the heat also damages the gastrointestinal tract, leading to translocation of endotoxins (LPS) and production of inflammatory cytokines. It has been proposed that this inflammatory response to exercise in the heat could potentially result in the development of central fatigue and subsequent attenuation of exercise performance. This study investigated the effect of a prolonged bout of exercise in the heat on neuromuscular function and the development of endotoxemia and inflammation.

Eleven male cyclists (mean±SD; 28.9±6.1 years, 178.7±7.6 cm, 73.9±9.5 kg and 58.7±6.1 $mL \cdot kg^{-1} \cdot min^{-1}$) completed two 60 min cycling sessions, comprised of alternating 3 min intervals at 50% and 70% P_{max} for 30 min, followed by 30 min at constant 50% P_{max}. While the exercise protocol was matched between trials, environmental conditions were controlled at 35° C and 50% RH (HOT) and 20° C and 50% RH (CON). Measures of physiological (heart rate, rectal temperature, skin temperature) and perceptual strain (perceived exertion, thermal sensation and comfort) were recorded during exercise. Neuromuscular function (torque, voluntary activation, evoked twitch properties) and recruitment (EMG) of the knee extensors were assessed pre-, post- and 1-h postexercise. Venous blood samples were also collected at these time points to determine circulating levels of inflammation, gastrointestinal permeability and damage. Repeated measures ANOVA (condition by time) was undertaken.

Heart rate and core temperature were significantly higher at completion of the HOT trial (172±11 $beats \cdot min^{-1}$ and 39.5±0.14 °C) in comparison to the CON (143±18 $beats \cdot min^{-1}$ and 38.4±0.22 °C; P= 0.004–0.015). Immediately following exercise, voluntary activation and maximal torque were significantly reduced compared to pre-exercise levels for both conditions. However, post-exercise voluntary activation in the HOT trial (83.19 ± 10.06 %) was significantly lower than that of the CON (87.90±7.63 %; P= 0.0004–0.0005), although this difference disappeared by 1-h post-exercise. The HOT cycle task resulted in significantly reduced relative EMG output compared to CON (HOT 74.4±12.4 % vs. CON 90.7±9.0; P= 0.004). Exercise in the HOT saw elevated gastrointestinal damage compared to the CON trial (P= 0.008), although this was not observed in any other markers of inflammation or permeability. Following exercise, median LPS values rose 65.3% (HOT) and 3.3% (CON) over pre-exercise levels, although this was not statistically significant.

Sub-optimal neuromuscular activation and recruitment apparent during exercise in the heat appears to coincide with increased expression of gastrointestinal damage markers. Whether this occurrence represents a cause and effect is unclear, though these finding may highlight the gut as a potential target for ergogenic intervention for exercise performance in hot conditions.

94 ORAL 10: Exercise Performance

Hypoxic acclimatization does not improve exercise performance and thermoregulatory responses in the heat: no evidence of cross-tolerance/adaptation

Alexandros Sotiridis[1], Tadej Debevec[1], Adam McDonnell[1], Ursa Ciuha[1], Ola Eiken[2], Igor B. Mekjavic[1]

[1]Department of Automation, Biocybernetics and Robotics , Jozef Stefan Institute, Ljubljana, Slovenia, [2]Department of Environmental Physiology, School of Technology and Health, KTH, Royal Institute of Technology, Stockholm, Sweden

The phenomenon, whereby adaptation to one environmental stressor may affect the responses when exposed to another environmental stressor, has been termed cross-adaptation (Hessemer et al 1986), and/or cross-tolerance (Horowitz 2007). The present study examined the cross-adaptation of aerobic performance and exercise temperature regulation under three environmental conditions (normoxia, NOR; hypoxia, HYP; and heat, HE), before and after acclimatization to normobaric hypoxia.Twelve recreationally active, healthy males performed three tests of maximal aerobic power (VO_{2max} in the following environmental conditions: heat (35 ℃, 50% RH) (HE), hypoxia (13.5% FiO_2) (HYP) and normoxia (NOR) in a randomized manner before and after a 10-day continuous normobaric hypoxic exposure (~14% FiO_2, PiO_2 = 917±6 mbar). VO_{2max} was defined as the highest VO2 averaged over 60s. All maximal tests were preceded by a steady-state exercise (30min at 40% peak power output) to assess the sweating response. Haematocrit and haemoglobin values were assessed from venous blood samples obtained immediately before and after the acclimatization period. During the hypoxic acclimatization the participants performed one daily exercise session on a cycle ergometer (60min @ 50% hypoxia specific peak power output).Hypoxic acclimatization induced marked increase in both haemoglobin and haematocrit values of the participants. VO_{2max} increased ($P<0.05$) by 10.7 and 7.9% from pre- to post-acclimatization in NOR and HE, respectively, whereas no differences were found in HYP (pre: 39.86±3.77 vs post: 39.44±5.11 mL/kg/min). However, the observed increase in VO_{2max} did not translate into increased peak power output in neither NOR or HE (Fig.1). Similarly, maximal heart rate and ventilation remain unchanged after acclimatization. No significant differences were found in the thresholds and gain of the sweating response independent of the acclimatization or the environmental conditions. The forearm-fingertip skin temperature gradient (ΔTf-f, vasodilation index) and T_{sk} in NOR were greater pre-to-post intervention (-3 and -0.9℃ pre-to-post difference, respectively). We conclude that that 10-days of normobaric hypoxic confinement (24 hrs/day) with daily exercise training, improve aerobic capacity, but do not augment exercise performance in normoxia and heat. Hypoxic confinement also does not seem to affect thermoregulatory responses in any of the three environmental conditions (NOR, HYP, HE). Acclimatization to hypoxia, as reflected by the changes in the hematology, did not affect normoxic and hypoxic exercise performance, and no benefit of hypoxic acclimatization was noted for the performance in the heat. These data do not support a meaningful cross-adaptation effect of hypoxic acclimatization on the exercise responses in a hot environment.

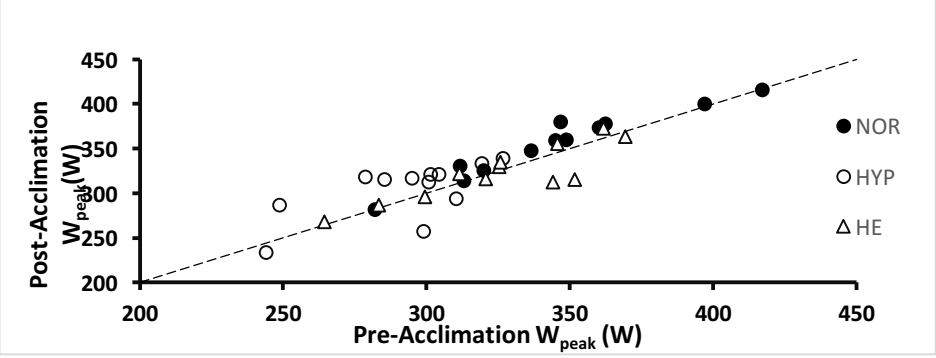


Figure 1: Pre- and post-intervention individual data for Peak Power Output (W_{peak}) in NOR (closed circles), HYP (open circles) and HE (triangles). The dashed line represents the line of equality.

95 ORAL 10: Exercise Performance

Thermal and cardiorespiratory responses and exercise performance in the heat during high intensity intermitted exercise that mimics rugby game

Michiaki Okuyama[1], Tomomi Fujimoto[1], Bun Tsuji[2], Takuo Furukawa[3], Naoto Fujii[3], Takeshi Nishiyasu[3]

[1]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, [2]Department of Health Sciences, Faculty of Human Culture and Science, Prefectural University of Hiroshima, Hiroshima, Japan, [3]Faculty of Health Sport Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan

Rugby World Cup 2019 will be held in Japan in summer season wherein ambient temperature can reach ~37 ºC. Hence during this competition, rugby players are required to perform their best performance during heat stress. Rugby game consists of high-intensity intermittent exercise bouts separated by resting periods. Drust et al. (2005) reported that during high-intensity intermittent cycling exercise (HICE) core temperature was higher and reduction in power output from the first to last exercise bouts was greater in hot (40ºC) vs. thermoneutral (20ºC) environments. However, the HICE protocol employed in the previous work differs from actual rugby game in terms of a ratio of exercise to recovery, the number of exercise repetitions, and the duration of exercise. Thus it remains to be determined whether the similar responses obtained in the above previous study would be also observed during HICE that mimics Rugby game. Also, hyperthermia is known to cause hyperventilation (Tsuji et al. 2015). Whether ventilatory response is augmented with hyperthermia during HICE simulating rugby game requires investigation. The purpose of this study therefore was to investigate the effect of hot environment on thermal and cardiorespiratory responses, and exercise performance during HICE that simulates rugby game.

Nine healthy young men performed an initial maximal-effort exercise (10sec, weight × 0.075kp) followed by 4 bouts of constant-workload exercise (each 10sec, weight × 0.075kp, 70rpm) each separated by 30-s recovery periods; a series of exercise was repeated 8 times each interspaced with 30-s recovery periods under hot (HOT: 37ºC) or cool (COOL: 15ºC) condition. Mean power output during each maximal-effort exercise (MP), % reduction in MP [(highest-lowest MP)/highest MP × 100], esophageal temperature (T_{es}), and expired gases were measured.

T_{es} at the end of HICE in HOT was greater than COOL (38.6 ± 0.3 vs. 37.9 ± 0.3ºC). MP at the first set was higher whereas that measured at 6-7th sets was lower in HOT compared to COOL. In line with this, % reduction in MP in HOT was greater than that in COOL. Minute ventilation during exercise was not different between the conditions, but it was higher in HOT in comparison to COOL during each recovery periods.

We show that during HICE simulating rugby game, 1) short-duration (~10 s) maximal-effort exercise performance is greater in the beginning, but is lower during the late stage in hot vs. cool conditions, and that 2) ventilation during recovery but not exercise bouts is augmented in hot relative to cool environments.

96 ORAL 10: Exercise Performance

The effects of heat exposure on the final sprint during a 20-km cycling time trial

Koen Levels, Ryan Lewin, Jos de Koning

VU University, Amsterdam, The Netherlands

The effect of heat on cycling time trial performance has been extensively studied. However, the effect on the final sprint, exemplary for the exercise-with-reserve concept, has not yet been investigated. Therefore, the aim of this study was to analyse the effect of heat exposure on the timing and magnitude of the final sprint during self-paced cycling time trials. To investigate this, 19 well-trained male cyclists completed a maximal incremental exercise, two 20-km familiarisation time trials and two 20-km experimental trials. Each test was separated by at least 72 hours. The 20-km time trials were performed either in thermoneutral (CON: 18.0 ± 0.8°C, 61 ± 5% relative humidity) or hot (HEAT: 33.0 ± 0.2°C , 48 ± 3% relative humidity) conditions and the order was counterbalanced among participants. A fan was placed in front of the cyclists which created an airflow of ~4 $m \cdot s^{-1}$. During the time trials, power output, heart rate, rectal and skin temperature, RPE, thermal sensation, and thermal discomfort were measured. The cyclists only received feedback on the remaining distance. The start of the final sprint was defined as the moment from when the power output until the finish remained more than two times the standard deviation higher than the mean power output during km 10-15 of the time trial.

Mean power output during the entire time trial was lower for HEAT (261 ± 44 W) than for CON (287 ± 49 W; $P<0.001$). No final sprint was performed in five trials (4 HEAT, 1 CON). When exercising in hot conditions, the final sprint began significantly later into the time trial (HEAT: 18.3 ± 1.3 km; CON: 17.4 ± 1.4 km; $P<0.001$). The sprint did not differ in magnitude, as the absolute increase in power output (HEAT: 169 ± 153 W; CON: 135 ± 91 W; $P=0.51$) and the relative increase in power output (HEAT: 72 ± 70%; CON: 51 ± 31%; $P=0.43$) were similar between conditions. Work completed during the final sprint was significantly lower in hot conditions (HEAT: 5.1 ± 5.2 kJ; CON: 7.8 ± 6.0 kJ; $P<0.05$). Heart rate, rectal temperature, and rating of perceived exertion during the time trial were similar in both conditions, whereas skin temperature, thermal sensation and thermal discomfort were higher in HEAT than in CON.

In conclusion, heat exposure delays the start of the final sprint in time trial cycling but the intensity of the sprint remains similar. This finding is relevant for cyclists and coaches designing an optimal pacing strategy for a time trial in hot conditions. The later sprint onset despite similar RPE values in the heat is in contrast to the notion that exercise intensity is anticipatorily regulated by the sensations experienced and the remaining exercise duration.

97 ORAL 10: Exercise Performance

Cold-water immersion recovery improves repeated sprint performance following a short training block in the heat

Geoffrey Minett[1], Rachel Gale[2,3], Georgia Wingfield[4], Frank Marino[4], Melissa Skein[4]

[1]Queensland University of Technology, Brisbane, Queensland, Australia, [2]Australian Institute of Sport, Canberra, Australian Capital Territory, Australia, [3]University of Canberra, Canberra, Australian Capital Territory, Australia, [4]Charles Sturt University, Bathurst, New South Wales, Australia

Cold-water immersion (CWI) recovery following exertional hyperthermia can ease thermally-regulated reductions in neuromuscular recruitment and activation, and assist to maintain repeated performance capabilities. While hastened recovery of work capacity between successive training sessions may increase the training load completed, the consequence of negating thermal strain immediately post-exercise and reducing exposure time must also be considered. This study examined the effects of CWI recovery on cycling performance, physiological and perceptual adaptation during five consecutive days of training in the heat.

Twenty recreationally-trained males (24 ± 5 y; 175 ± 5 cm; 76 ± 3 kg; 44 ± 4 $ml \cdot kg^{-1} \cdot min^{-1}$) cycled on a stationary ergometer at 40 % peak power at VO_{2max} (P_{max}) for 90 min in a temperature (32.0 ˚C) controlled room over five consecutive days. Participants were randomly assigned to complete a 20 min recovery within 5 min post-exercise while submerged to the sternal notch in 14 ˚C water (CWI; n= 10), or a passive control seated for the matched time in the heated room (CONT; n= 10). A 20 km cycling time trial (TT) and 5 x 6 s maximal repeated sprints were completed in the heat (33 °C, 60 % relative humidity) pre- and post-intervention. Physiological (heart rate, core temperature, and skin temperature) and perceptual measures (rating of perceived exertion, thermal sensation, and mood states) were recorded during all sessions. A repeated measures ANOVA was used to determine significant effects for time and day within conditions. A one-way ANOVA was used to determine significant differences between groups (CWI vs. CONT). Cohen's *d* effect sizes were also used to determine magnitude and trends in the data.

Neither the training period nor recovery intervention had a significant effect on 20 km TT performance (P=0.67-0.78, *d*=0.20-0.30). However, higher mean peak power outputs were observed during the post-intervention repeated sprints (CONT 400 ± 36 W vs. CWI 460 ± 76 W; P= 0.04, *d*= 1.42), despite no difference pre-intervention (P= 0.45, *d*= 0.49). Although changes in values remained similar between conditions for all other physiological and perceptual measures (P= 0.45, *d*= 0.49), large effects demonstrate higher perceptions of an active mood (CONT 2.8 ± 1.1 AU vs. CWI 3.7 ± 1.3 AU; *d*= 1.03) and lesser exhaustion (CONT 1.9 ± 0.7 AU vs. CWI 1.3 ± 0.7 AU; *d*= 1.20) before the CWI post-intervention session.

The current data suggest concerns regarding the blunting of advantageous thermal adaptations and performance gains associated with exercise in the heat by using CWI recovery may be unfounded. Indeed, the absence of any physiological differences between conditions could highlight a potential benefit of CWI in maintaining an athlete's mood during exercise training in the heat.

98 ORAL 10: Exercise Performance

Effects of training in cool vs. warm environment on subsequent aerobic performance in a warm and humid condition

Wee Hon Ang[1], Li Fang Kuah[1], Pavandip Singh Wasan[1], Tong Lee[1], Poh Ling Tan[1], Aiko Seko[1], Ivan Cherh Chiet Low[2], Jason Kai Wei Lee[1,2]

[1]DSO National Laboratories, Singapore, Singapore, [2]National University of Singapore, Singapore, Singapore

Training done in a warm and humid condition may impose limitation on the training intensity and/or duration due to greater thermoregulatory strain. This may in turn compromise training adaptations. This preliminary study aimed to investigate whether aerobic performance could be enhanced by training in a cool as compared to warm condition. Eleven participants were split into two groups, training in a cool (TIC) condition at 18°C with 60% relative humidity (RH) and training in a warm (TIW) condition at 30°C with 80% RH. Participants underwent 8 weeks of treadmill high-intensity interval training (HIIT) programme that comprised two training sessions per week. Each training session consists of a 5-min warm up at 60% VO_2 peak, followed by repeated bouts of 1-min HIIT at 120% VO_2 peak interspersed with 1-min of standing recovery. Peak oxygen consumption (VO_2 peak) was conducted under laboratory condition (22.2°C, 72% RH) while 2.4 km time trials were done in an outdoor warm and humid condition (25.5°C, 91% RH). Both were administered before (PRE: Week 0), at mid-point (MID: Week 4) and post-training (POST: Week 8). Heart rate (HR), core temperature (T_c), skin temperature (T_{sk}) and sweat sodium concentration [Na^+] were measured. Hedge's g was calculated to compare differences between and within groups. Participants in TIC completed more number of HIIT repetitions in the first 4 weeks of training than the TIW (TIC: 12±3, TIW: 9±2, g=0.88). Mean HR (g=0.19) and T_c (g=0.22) were similar during HIIT between groups. Mean T_{sk} was lower in TIC than TIW (TIC: 30.4±0.7°C, TIW: 34.2±0.4°C, g=-6.55). Mean improvement in 2.4 km time trial was 22 s more in TIC compared to TIW at MID (TIC: 71±30 s, TIW: 49±22 s, g= 0.79), but no observable difference at POST (TIC: 94±35 s, TIW: 89±32 s, g=0.15). Mean sweat [Na^+] was decreased in TIW at MID (-18±28 mmol/L, g=-0.68) and POST (-20±23 mmol/L, g=-0.73), but not for TIC (MID: g=0; POST: g=0.26). VO_2 peak was unchanged at MID for TIC (PRE: 46±8 ml/kg/min, MID: 47±6 ml/kg/min, g=-0.05) and TIW (PRE: 46±5 ml/kg/min, MID: 47±5 ml/kg/min, g=-0.11), but increased marginally at POST (48±5 ml/kg/min, g=0.31) as compared to PRE for TIC. Baseline HR was decreased for both groups at MID (TIC: -7±10, g=1.07; TIW: -2±10, g=0.19) and POST (TIC: -6±10 bpm, g=0.75; TIW: -3±11 bpm, g=0.40) with greater effect observed in TIC. Given a short training period (4-week), training in a cool environment can potentially accelerate training adaptations by allowing one to train longer. With a longer training period (8-week), the differences between groups narrowed, likely due to an added heat acclimation effect for the group training in warm condition.

Heat stress evaluation of miners in hot underground coal mines using an improved predicted heat strain model and an improved thermophysiological model

Jiansong Wu[1], Ming Fu[2], Xing Tong[1], Yueping Qin[1]

[1]China University of Mining and Technology, Beijing, Beijing, China, [2]Hefei Institute for Public Safety Research, Tsinghua University, Hefei, China

With the increasing mining depths and the improving mining mechanization, heat stress to miners have been becoming more frequent and serious in hot underground coal mines in China, especially at hot working faces and heading faces. In this paper, the Predicted Heat Stain (PHS) model is improved by adding the measured thermal insulation and evaporative resistance of working ensemble for hot coal mines and by introducing a metabolic rate formula for estimating underground mining activity. Firstly, the improved PHS model was employed to evaluate the physiological responses of miners under uniform thermal conditions that are to simulate the miners working at some certain spots in underground coal mines. Secondly, a multi-segment thermophysiological model with improvements in heat and moisture transfer through clothing was used to predict the thermal responses of miners at the working face where the air temperature is non-uniform (generally cool-hot changing along the working face once the coal mine is equipped with mine cooling system). It is found that the cool-hot changing thermal environment significantly affects miners' physiological responses and thermal sensations. This work could provide technical supports for thermal safety assessment and work organization in hot coal mines.

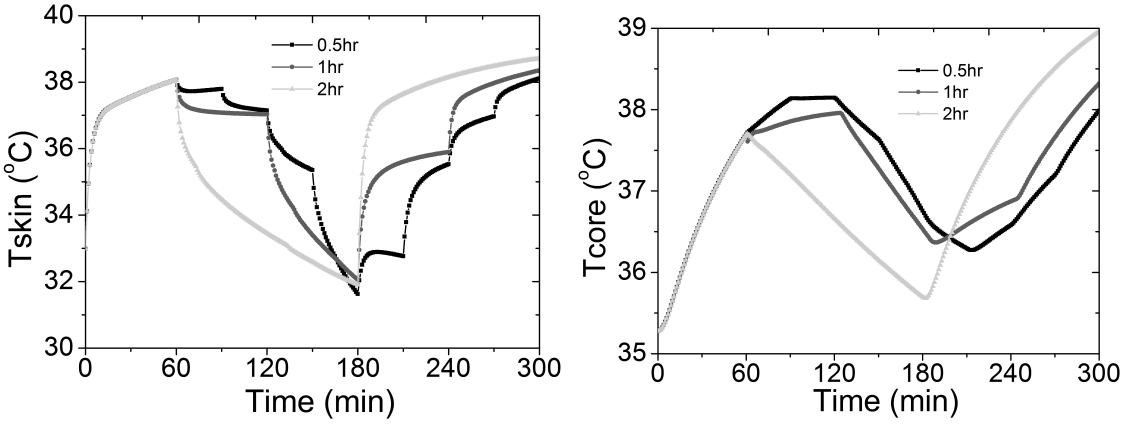


Figure 1: The predicted skin and core temperatures of miners at the non-uniform working face (step-change temperature set up by 0.5h/1h/2h in the simulation)

100 POSER SESSION 3

Development and validation of bench-level and manikin test methods to predict heat related comfort properties of mattresses

Forrest Cannon, Emiel DenHartog

NC State Univerity, Raleigh, USA

New mattresses are developed to increase the thermal comfort possible increasing sleep quality. However, no current standardized test method exists to assess thermal comfort of mattresses. In this research project we aimed to establish new testing methodologies for evaluating thermal properties of mattresses related to comfort by use of an inverted guarded hotplate and a segmented thermal manikin.

The properties of three different mattresses with known differences were determined. The inverted hot plate (IHP) is based on the same technology as the ASTM F1868 and ISO11092 standards, but is placed inverted on top of the product. Then, similarly, data on apparent insulation and apparent evaporative transfer is obtained. Additionally, the sweating thermal manikin was used to obtain information on local and whole body heat loss and apparent insulation values. To validate these methods and assess if obtained differences could be perceived, a human evaluation study was conducted where 12 test subjects laid on the same three mattresses for 60 minutes, providing both objective and subjective information.

The results showed correlations between the IHP data, manikin data and human comfort data within the first 30 minutes of the evaluations. Initial responses times and heat flux responses differed significantly and consistently between the three mattresses among the three methods. After 30 minutes the responses stabilized and ‘long term’ insulation factors could be obtained via a curve fit parameter estimation procedure. Stabilization of the measurements lasted more than 6 hours. The same differences, but less pronounced, were found with the manikin. Both devices could be used while ‘sweating’ as well, however this produced less reliable data suitable for testing. The human subject evaluations showed that the initial (<30 minutes) differences were also perceived as significant differences in thermal sensation and skin temperatures. The longer term differences could not be confirmed as the experiment time may have been too short and individual differences suppressed the small differences.

The IHP was shown to provide a reliable test method to assess significant differences in thermal properties of mattresses which were also perceived by human subjects.

101 POSER SESSION 3

Fast computation of temperature and water loss in human models for simultaneous exposure to ambient heat and solar radiation

Akimasa Hirata[1], Sachiko Kodera[1], Kazuma Hasegawa[1], Kazuya Kojima[1], Daisuke Sasaki[2], Takeshi Yamashita[2], Ryusuke Egawa[1]

[1]Nagoya Institute of Technology, Nagoya, Japan, [2]Tohoku University, Sendi, Japan

In the last decades, the number of heat waves with fatalities has been increasing in Europe, North America, and Asia. 50% of the patients in Japan are the elderly and suffering the illness in their home. In most cases, they do not notice their risk, because of the decline in their thermal sensitivity. Other typical victims are athletes and workers. Several indexes, e.g., heat index, wet-bulb globe temperature (WBGT), universal thermal climate index, etc, can be used to estimate risk of the heat illness. These indexes may become a metric of the risk under scenarios where the human stay in an identical condition. In our daily life, actual ambient environment changes with time, and the duration for heat exposure is case-specific. For occupational scenarios, American Conference of Governmental Industrial Hygienists (ACGIH) maintained standards to manage the duration of work using an empirical equation in terms of WBGT. In the standard, workers are assumed to wear long sleeve shirts and pants, and thus may not be useful for our daily life.

Highly-reliable risk assessment is thus required for different cases and humans (age, gender, morphology, the capability of thermoregulation, etc). It can be useful for risk management and public understanding if the analysis can be conducted in a realistic time.

To assess the temperature elevation, several computational models were proposed by combining thermodynamics and thermoregulation, also with solar radiation. In this study, realistic models, comprised from several million voxels, are used for their flexibility to consider the body surface area-to-mass ratio. The thermoregulation is expressed in terms of core and average skin temperature elevations based on Fiala et al, (2001) and extended to consider the elderly and child. The increase of basal metabolism in exercise is mainly in the muscle or the position-dependent. Thus, the use of anatomical models is more suitable. Contrary, the computational cost for handling such models was substantial; 16 hours in a workstation (CPU: Intel® Xeon® 3.33GHz, 8 cores).

We developed a computational code is vectorised and parallelized, and then implemented on a super-computer SX-ACE to realize fast evaluation for following the temperature and sweating. It took 10 min for all the computation for five different human body models. For exposure to ambient temperature of 37.5 ^{o}C and relative humidity of 60% for 60 min. the temperature elevations in the elderly and child were higher than that in young adult (see Fig. 1). The reason for this difference is the decline of sweating and the body-surface-area to mass ratio, respectively. The core temperature elevation in the models of the elderly and child was twice larger than that of the adult, demonstrating the effectiveness of computational results.

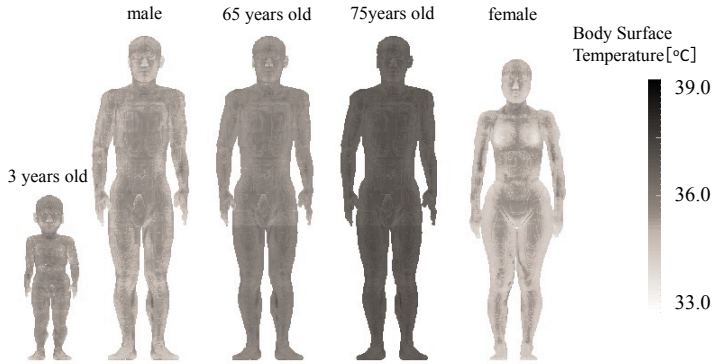


Figure 1: Body surface temperature in different human body models.

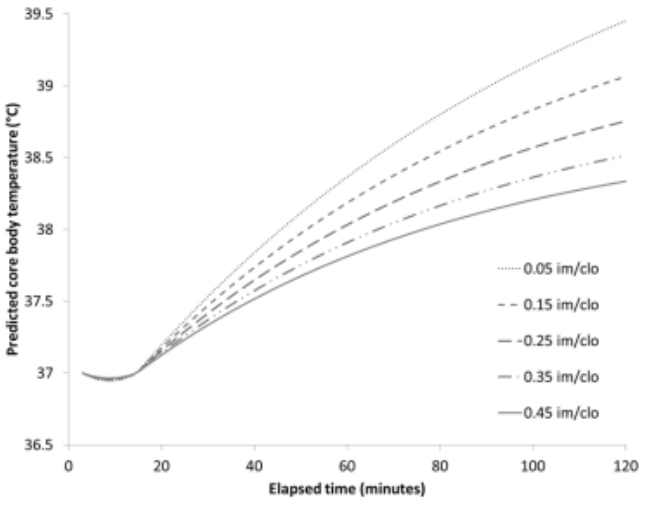
102 POSER SESSION 3

How much of a difference in evaporative potential is important?

Adam Potter[1], Andrew Hunt[2,3], Bruce Cadarette[1], Xiaojiang Xu[1]

[1]United States Army Research Institute of Environmental Medicine (USARIEM), Natick, MA, USA, [2]Queensland University of Technology, Brisbane, QLD, Australia, [3]Defence Science and Technology Group, Melbourne, VIC, Australia

Introduction: Measures of thermal and evaporative resistance (R_{ct} and R_{et}) are often used in combination with thermoregulatory models to predict heat stress and as a measure to compare clothing performance. For the US Army, these values are most commonly converted to units of clo (thermal insulation, 1 clo = 0.155 $m^2 \cdot °C \cdot W^{-1}$) and i_m (moisture permeability index, N.D.) and combined to create a ratio of the two; i_m/clo (evaporative potential). Traditionally, when comparing modeled performance of ensembles, only values of ≥ 0.1 i_m/clo have been considered significant. The purpose of this study is to examine, quantitatively, how true this value is. Methods: Using a biophysics-based thermoregulatory model, core body temperature rise was predicted over 120 minutes; where input conditions were controlled for environment (35 °C, 30 % RH, 1 $^{m/s}$ wind velocity), individual (healthy, acclimated, standard male, 172 cm, 70 Kg), and activity (350 W) and clothing properties were varied for units of i_m/clo by 0.1 (0.05, 0.15, 0.25, 0.35, 0.45). Results: Using a notional limit of 38.5 °C predicted core temperature, each of the levels of i_m/clo was plotted (Fig 1). Increases by 0.1 i_m/clo (improved evaporative potential) resulted in predicted increases in time to reach this 38.5 °C; by 12, 16, 24, and 39 minutes respectively. The pattern of these modeled impacts remains similar across varied environments (e.g., high humidity, temperate) and activity levels; while the exact time effects are either narrower (e.g., in high humid conditions, higher metabolic demand activities) or broader (e.g., in temperate conditions, lower metabolic rate activities). Discussion: This modelling work provides evidence to support the use of a value of ≥ 0.1 i_m/clo for guidance in describing significant differences in ensemble performance related to thermophysiological outcomes. However, it remains important to conduct comprehensive comparisons as to the meaning behind these differences in the context of anticipated use cases and environmental conditions and to properly design human research studies with conditions that ensure observable and significant physiological differences.



Time (minutes) to reach 38.5°C by i_m/clo	
0.05	63
0.15	75
0.25	91
0.35	115
0.45	154

Figure 1: Predicted rise in core body temperature (Tc) over time (minutes) based on clothing evaporative potential (i_m/clo) levels

103 POSER SESSION 3

Influence of thermal balance on reactive hyperaemia

Lydia Tsoutsoubi[1], Leonidas G. Ioannou[1], Eleni Nintou[1], Paraskevi Gkiata[1], Stephen S. Cheung[2], Andreas D. Flouris[1]

[1]FAME Laboratory, Department of Physical Education and Sport Science, University of Thessaly, Trikala, Thessaly, Greece, [2]Department of Physical Education and Kinesiology, Brock University, St. Catharines, Ontario, Canada

Cutaneous microcirculation is vital for the maintenance of heat balance and can be evaluated by assessing post-occlusive reactive hyperaemia changes in skin blood flow (SkBF) using laser-Doppler flowmetry. By heat balance we mean that the internal temperature of the body remains almost constant regardless the environmental conditions. The aim of this study was to investigate changes in SkBF before, during, and after a 5-min arm vascular occlusion (VO) conducted during baseline as well as hot and cold water immersion. Eight male and seven female non-smoking adults (age: 24.9±4.6 yr.; body mass index: 24.9±4.3; body fat: 16.3±9.2%; body surface area: 1.9±0.2 m^2) volunteered for the study. Following a 15-minute baseline period, participants entered a water tank maintained at 42°C and passively rested in a semi supine position until their T_{re} increased by 0.5°C above baseline. Thereafter, they entered a water tank maintained at 12°C until their T_{re} decreased by 0.5°C below baseline. This procedure was repeated twice and an occlusion of the dominant forearm was conducted during the last five minutes of the baseline period as well as the second repetition of water immersions. The arms were always supported at the level of the heart and not immersed in the water. Multivariate analysis of variance demonstrated statistically significant main effect of phase (pre-VO, VO, post-VO) on SkBF as well as significant interaction effect of phase and temperature (baseline, hot, cold) on SkBF ($p<0.001$). Post hoc t tests incorporating a Bonferroni adjustment demonstrated significant differences between pre-VO and VO, as well as VO and post-VO during both the baseline and hot temperatures ($p<0.05$). No such changes were observed during the cold immersion ($p>0.05$), as no reactive hyperaemia was detectable in the laser-Doppler recordings. Significant differences in SkBF during pre-VO and post-VO were observed across all temperature condition comparisons ($p<0.05$). No such differences were detected during VO ($p>0.05$). Post-occlusive reactive hyperaemia was not evident during cold water immersion, was moderately evident during thermoneutrality, and was strongly enhanced following hot water immersion.

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Incidence of heat waves in Cyprus and its association with mortality

Tânia Amorim[1], Leonidas Ioannou[1], George Samoutis[2], Andreas Flouris[1]

[1]FAME Laboratory, Trikala, Greece, [2]University of Nicosia, Nicosia, Cyprus

Extreme weather events, such as heat waves, are predicted to increase with climate change. The aims of this study were to: a) report the incidence of heat waves in Cyprus over a 9-year period, and b) investigate its association with human mortality.

Daily human mortality data for each of the five districts of Cyprus covering a 9-year period (2004-2012) were provided by the Health Monitoring Unit of the Ministry of Health of Cyprus. 24-hour ambient mean temperature was collected from www.wunderground.com for the same time period. Heat waves were defined as the period of three consecutive days where mean temperature was above the 95th percentile and the seven days that followed.

Over the 9-year study period, mean summer temperature (June-August) increased from 31.8±3.8°C (2004) to 33.2±3.7°C (2012) (p<0.001), while the incidence of heat waves during the summer seasons increased by 28% (53 heat waves occurred in 2004 and 68 in 2012, p=0.016). In 2012, all-cause mortality was significantly increased by 12% during the summer months (June-August) compared to the subsequent trimester (September-November) (p=0.003). This was not the case in any of the previously-studied years. The total number of deaths during heat waves in 2012 was increased by 29.8% compared to 2004, yet this difference did not reach statistical significance (p>0.05). Mean temperature was significantly associated with mortality; over a 9-year period an increase of 1°C in mean summer temperature significantly increased mortality rate by 0.8% (OR: 1.008, CI: 1.003-1.012; p<0.001).

In Cyprus, summers are becoming hotter, with higher incidence of heat waves. These extreme heat events contribute for a greater proportion of deaths. Future work is required to identify high-risk sub-groups, as well as to investigate the effects of heat on hospitalizations and non-fatal illness.

Effects of dual-functional vest with body cooling and drinking water supply on the alleviation of heat strain

Do-Hyung Kim, Gyu-Tae Bae, Cheol-Seung Hyun, Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

Body cooling and drinking water supply can alleviate the heat strain of workers in hot environments. In particular, cooling devices for workers who wear personal protective equipment (PPE) like firefighters are required to be light and portable. Wearing cooling vests using cooling packs inside firefighting bunker jackets could cool the body in the beginning stage, but the vest is a burden once the cooling packs are melted inside the firefighters' turnout jacket. Further, firefighters often suffer from dehydration in the line of duty. In this light, we developed a new dual function vest to provide both body cooling and drinking water for firefighters (1090g in total mass with cool packs). The vest had four pockets to keep disposable iced packs (200 ml/pack × 4 packs = 800 ml) and flexible straws from each ice pack were arranged inside the vest to use for drinking just after that the ice began to melt. We investigated the effects of the dual-functional vest for body cooling and water supply on the alleviation of heat strain of workers wearing firefighters' PPE in hot environments. Eight male subjects (23 ± 2.5 yr in age, 68.3 ± 7.6 kg in body weight, and 171.9 ± 3.9 cm in height) participated in four experimental conditions: Control, Cooling Only (CO), Drinking Only (DO), and Cooling & Drinking (CD). Subjects wore firefighters' turnout jacket and pants along with the vest. A trial consisted of 30 min exercise followed by 20 min recovery at 30°C with 50%RH. The results showed that there was no difference in T_{re} among the three conditions, whereas mean Tsk had smaller values for CD compared to the Control (P<0.05, Table 1). Total sweat rate were also lower for DO, CO and CD than control (P<0.05). Subjects expressed less warmer for DO, CO, and CD than control (P<0.05), but warmer for DO when compared to CO or CD (P<0.05). In summary, the double function vest had more superior effects on alleviating heat strain than for the conditions of cooling only or drinking only.

Table1**:** Summary on the physiological responses

	Time(min)	**Control**	**DO**	**CO**	**CD**	***P*-value**
T_{re}_Rest (°C)	5~10th	37.3±0.1	37.4±0.5	37.7±0.3	37.7±0.2	N.S
T_{re}_Exercise (°C)	35~40th	37.9±0.2	37.1±0.6	37.8±0.4	37.6±0.2	N.S
T_{re}_Recovery (°C)	55~60th	37.9±0.2	37.1±0.6	37.8±0.4	37.6±0.2	N.S
Mean T_{sk}_Rest (°C)	5~10th	34.4 ± 0.8[b]	33.9 ± 1.3[ab]	33.8 ± 0.6[ab]	33.3±1.2[a]	*P*<0.05
Mean T_{sk}_Exercise (°C)	35~40th	35.9±1.2	35.5±0.9	35.3±0.7	34.7±1.1	N.S
Mean T_{sk}_Recovery (°C)	55~60th	36.2 ± 1.3[b]	36.2 ± 0.3[b]	35.2 ± 1.1[ab]	34.6±1.2[a]	*P*<0.05
Sweat rate Chest (g/16cm^2/hr)	For 60min	1.42	1.81	1.33	1.20	NS
Sweat rate Back (g/16cm^2/hr)	For 60min	1.23	1.47	1.30	1.28	NS
Thermal sensation Trunk	37thmin	3.6±0.6[c]	1.6±1.3[a]	3.0±0.5[bc]	2.3±0.5[ab]	p < 0.05
Sweat sensation Trunk	37thmin	2.7±0.6	1.8±0.8	2.4±0.7	1.9±0.7	p=0.072

Note: Data are expressed as means and standard deviations (SD); *DO, CO* and *CD* represent Drinking only, Cooling only, and Cooling&Drinking, respectively. *N.S* No significant; [a,b] and [ab] represent significant differences among three conditions by a Tukey's post hoc.

106 POSER SESSION 3

Observation and questionnaire on the relationship between the thermal index ETVO and behavior of people in Kyoto

Kumika Sumisato, Kazuo Nagano

Kyoto Prefectural University, Kyoto, Japan

The weather forecast usually provides only basic information such as daily maximum and minimum temperatures, chance of rain, wind speed, and so on. This information, however, is not always helpful for people to decide how much clothing they should wear or when they should use the air conditioner or heating system. It would be more useful to inform them of the appropriate amount of clothing for the day, and whether they should use the air conditioner or heating system on that day. For this purpose, it is necessary to clarify the patterns of behaviors dependent on the meteorological conditions.The web-based questionnaire for which respondents were asked to select the day(s) of the week that they did the behaviors, was repeated every Sunday for a year, and was open until 111 males and 111 females in Kyoto completed it. The mean daily percentages of each behavior were calculated. The outdoor temperature, humidity, wind velocity, and shortwave and longwave radiation were observed in Kyoto during the questionnaire period. The thermal index ETVO was calculated based on the meteorological data.Figure 1 shows the scatter plots of the percentage of female respondents that use air conditioning in the late summer versus the ETVO. It is obvious that the percentage has a strong correlation with the ETVO. Therefore, non-linear regression was used to measure the association between the ETVO and the percentage. In this study, the start and end dates are defined as the dates at which 80% of the respondents start and end the behavior, respectively. In case of air conditioning, the ETVO on the start and end dates was 30.8 °C and 19.1 °C by means of the equation. In the same manner, the relationship between the observed meteorological conditions and the other 20 behaviors were analyzed.These regression equations can estimate the percentages of the behaviors using the ETVO derived from predicted meteorological items, and can eventually indicate the appropriate periods of the behaviors.

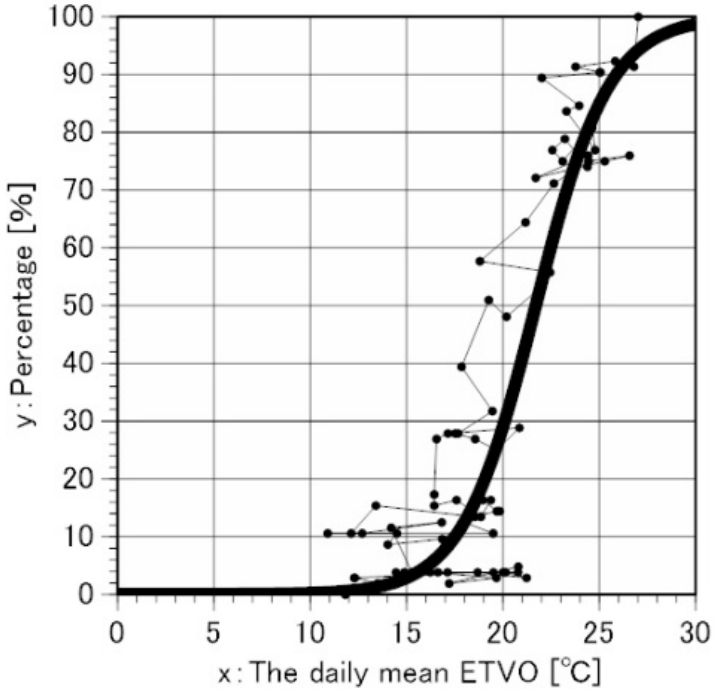

Figure 1: The relationship between the daily mean ETVO and the percentage of female respondents that use an air conditioner in late summer.

y=100/(1+8.80E+4*
Exp(-5.25E-1*x))

R^2 = 7.96E-1

107 POSER SESSION 3

Physical demands and hydration status of grape-picking workers in Europe

Leonidas G. Ioannou[1], Lydia Tsoutsoubi[1], Vyronas Giorkas[1], Giannis Spiropoulos[3], Lars Nybo[2], Andreas D. Flouris[1]

[1]FAME Laboratory, School of Exercise Science, University of Thessaly, Trikala, Thessaly, Greece, [2]Department of Nutrition, Exercise and Sports, August Krogh Building, University of Copenhagen, Copenhagen, Denmark, [3]Centre for Technology Research and Innovation (CETRI), Limassol, Cyprus

Despite the existence of mechanical grape-harvesting machines, grape producers continue to harvest grapes manually because existing mechanical methods break the grape skin, inducing changes in wine quality. Consequently, grape-picking remains a laborious physical task. The aim of this study was to investigate the physical demands of grape picking. This study received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 668786. Seven (five males, two females) healthy, acclimatized, and experienced grape picking workers were monitored during four different days throughout the grape harvest period. Three out of these workers were unavailable to participate in two of the four days. During each recording day, the workers were video monitored from the beginning until the end of the work shift. The metabolic rate (MR) of each activity performed was calculated using the metabolic equivalent levels for occupational activities based on body position, and were grouped in three categories: light to moderate work (0-200 W/m^2), intense work (200-260 W/m^2), very intense work (>260 W/m^2). The difference in mean skin temperature from its baseline value (ΔTsk) was calculated using skin temperatures collected from four sites (arm, chest, thigh, leg). Air temperature was collected using a scientific weather station. Thermal comfort (TC) and thermal sensation (TS) were assessed five times (baseline and every two hours) per work shift, while workers' hydration status [urine specific gravity (USG)] was measured at the start and end of each work shift. No restrictions were placed on water consumption, however we recorded the hourly water intake of each worker. There were statistically significant ($p<0.001$) differences in the ΔT_{sk} of workers between moderate work (1.65±1.75°C), intense work (1.92±1.94°C), and very intense work (2.13±1.73°C). Also, a weak but significant positive relationship was identified between the MR and ΔTsk of the workers ($r=0.11$, $p<0.001$). Although the workers were drinking large amounts of water (2.36±1.13 L/shift), there was a statistically significant increase in USG from the start (1.017±0.008) to the end (1.025±0.008) of the work shifts ($p<0.001$). Indeed, the prevalence of dehydration increased from 36% at the start of the work shift to 100% at the end of the work shifts ($p<0.05$). The amount of water drank was positively related with the MR of the workers ($r=0.65$, $p<0.001$). Finally, air temperature (26.8±4.8°C) was strongly and positively related with the TC and TS of the workers, $p<0.001$. We report that the identified grape-picking work activities affect differently the physical demands experienced by workers.

108 POSER SESSION 3

Conductive heat loss with aluminum sheet in wet condition

Hirokazu Ozaki[1], Youichi Ohnishi[2]

[1]Aeromedical Laboratory, JASDF, Sayama-shi, Saitama, Japan, [2]Advanced Defense Technology Center, ATLA, Meguro-ku, Tokyo, Japan

The aluminum sheet commonly found in survival kits is known to be compact and have a several-fold thermal insulation power greater than a normal blanket, thus it is often employed for a variety of situations from leisure activities to disaster prevention, as well as for rescue of military aircraft pilots who eject into water with their body becoming soaked. When performing such a sea rescue, the survivor is generally given an aluminum sheet to provide thermal insulation in the life raft. In the present study, new findings were obtained regarding such use in a wet environment.

An environmental chamber (Hitachi Plant Technologies, Ltd.) and waterproof sweating thermal manikin (MEASUREMENT TECHNOLOGY NORTHWEST, NEMO) were utilized for measurements in a simulated environment. The wearing conditions were two kinds of immersion suit and flight suit, respectively, in the case of wet and dry, and the case of covering with aluminum sheet and not covering. A suit was placed onto the manikin. The manikin was placed into a life raft, and the state of thermal insulation was measured with 10 liters of water in the life raft and 0.5 liters of water poured into the suit, as well as in a dry state. With the immersion suit, the thermal insulation of the aluminum sheet in the dry state was 3.15 clo, which was 1.6 times greater as compared to that without the aluminum sheet (1.97 clo). On the other hand, the thermal insulation of the sheet when used in the wet condition was only 0.7 times smaller as compared to that without the aluminum sheet (1.32 vs. 0.96 clo). Contrary to our expectation, thermal insulation provided by the aluminum sheet was significantly decreased under the wet condition. A similar tendency was noted in the tests with a flight suit. Our findings showed that heat flux was greater in the wet as compared to the dry condition due to a greater amount of conductive heat loss that occurs in a wet condition.

109 POSER SESSION 3

Impact of combined cool and hypoxic exposures on energy cost during walking in healthy adults

Masahiro Horiuchi[1], Yoko Handa[1], Yoshiyuki Fukuoka[2]

[1]Mt. Fuji Research Institute, Fuji-yoshida, Yamanashi, Japan, [2]Doshisha University, Kyou-tanabe, Kyoto, Japan

It is well known that there is a U-shaped relationship between oxygen consumption during walking per unit distance (Energy cost of walking, Cw; $ml \cdot kg^{-1} \cdot m^{-1}$) and gait speeds (velocity; $m \cdot s^{-1}$) [1]. This indicates that every individual has a particular gait speed that minimizes Cw, which is called the economical speed (ES) [2]. It is possible that ES would be slow under hypoxia because diminished aerobic capacity at high-altitude may cause relatively higher exercise intensity [3]. In addition, environmental temperature also decreases at high-altitude. A previous study did not show any differences in VO_2 during aquatic exercise between hot and cold water [4]. However, little is known about combined effects of cool and hypoxia exposures on energy cost during walking. It was hypothesized that Cw would be higher and ES would be slower under hypoxic condition, but not under cool condition. Eight healthy young males walked at seven speeds from 0.67 to 1.67 $m \cdot s^{-1}$ (four min per stage) on a level gradient under four conditions: thermoneutral room temperature (23 ºC) at normoxia (21% O_2: NN) and hypoxia (13% O_2: NH); cool room temperature (13 ºC) at normoxia (CN) and hypoxia (CH). Gas exchange variables, heart rate (HR), and skin temperatures at four sites (chest, arm, thigh and calf) were measured continuously throughout the study. The ES in each individual was calculated from a U-shaped relationship. We found a significantly slower ES under NH (1.303 ± 0.057 $m \cdot s^{-1}$, mean ± SD) and CH (1.281 ± 0.054 $m \cdot s^{-1}$) compared to NN (1.360 ± 0.076 $m \cdot s^{-1}$) and CN (1.333 ± 0.052 $m \cdot s^{-1}$) ($P < 0.05$), while no effects of environmental temperature on the ES ($P > 0.05$). By contrast, there were no significant differences in the C_W among all conditions ($P>0.05$). Peak HR under NH (160 ± 16 bpm,) and CH (157 ± 14 bpm) was significantly higher than under NN (136 ± 13 bpm) and CN (133 ± 10 bpm) ($P < 0.05$), while no effects of environmental temperature on the peak HR ($P > 0.05$). Mean skin temperature (Tsk) during walking was significantly lower in CN (29.93 ± 0.55 ºC) and CH (30.18 ± 0.72 ºC) than in NN (32.79 ± 0.50 ºC) and NH (32.85 ± 0.37 ºC); however, no effect of hypoxia on Tsk. These results suggested that acute hypoxia slowed ES by ~5%, but environmental temperature did not affect ES.

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Shake-Spear 17: Normoxic and hypoxic peak exercise responses before and after an Antarctic traverse

C. Doug Thake[1], John Hattersley[2,3], Adrain Wilson[2,3], Jamie Facer-Childs[2], Ollie Stoten[4], Chris Imray[2,3]

[1]Coventry University, Coventry, UK, [2]University Hospitals Coventry and Warwickshire, Coventry, UK, [3]University of Warwick, Coventry, UK, [4]Royal Bournemouth & Christchurch Hospitals NHS Foundation, Bournemouth, UK

In February 2017 six British Army reservists became the first ever British team to traverse Antarctica. The team covered 1750km over 66 days reaching altitudes up to 3350m in temperatures between -12 to -57°C. Throughout the expedition the team consumed ≈6500 kcal·day^{-1}. The purpose of this study was to characterise peak physiological responses to exercise in normoxic and hypoxic conditions before and after the expedition. Within two weeks of expedition departure (pre) and return (post) four team members aged 32±10 years undertook incremental exercise tests to volitional exhaustion in normoxia (N) and hypoxia (H) equivalent to 3000m. Data are expressed as median and interquartile range (IQR; Table 1). When Friedman's test returned significance at P<0.1 post hoc Wilcoxon signed rank tests were applied to identify differences between specific trials. The difference between N and H peak oxygen consumption (VO_2peak; L·min^{-1}) was reduced from pre (-26.6[6.1]%, P<0.1) to post (-14.2[7.2]%, P<0.1) expedition. This was due to both a relatively small decline in N VO_2peak (P<0.1) alongside an increase in H VO_2peak (P<0.1) post expedition (Table 1). This difference was greater in H when calculated in relation to an unexpectedly small change in body mass (BM; -3.5[3.4]kg, P<0.1) and nominal variation in fat free mass (FFM; 0.55[1.05kg]; P>0.1). With reference to Table 1 anaerobic threshold (AT) was at ≈70% VO_2peak in N pre and post expedition but declined from ≈80 to 70% VO_2peak in H pre to post (P<0.1), due to the rise in H VO_2peak (P<0.1). The lower respiratory exchange ratio (RER) observed post compared to pre expedition in H (P<0.1) concurrent with no change in pulmonary ventilation (VE) or carbon dioxide production (VCO_2) is indicative of a reduced anaerobic contribution and potentially improved fat usage during hypoxic exercise. Collectively these findings are supportive of anecdotal reports from the team that they have experienced a loss of top end speed but gained endurance. The observation that H VO_2peak improved on the back of a nominal reduction in N VO_2peak over an extended period of physical activity in cold and hypoxic conditions is indicative of potential environment specific metabolic adaptation and warrants further investigation.

Table1: Peak (median, IQR) physiological responses in normoxia and hypoxia (≈3000m) pre and post expedition.

	NORMOXIA			HYPOXIA		
Variable	Pre	Post	%Δ	Pre	Post	%Δ
VO_2 L·min^{-1}*	4.08 (0.22)	3.86 (0.29)¤	-4.2 (2.2)	3.12 (0.33)	3.38 (0.19)¤	8.2 (5.3)
VO_2 ml·kgBM^{-1}·min^{-1}*	50 (8)	49 (3)	-0.1 (6.3)	37 (6)	42 (3)¤	12.9 (10.1)
VO_2 ml·kgFFM^{-1}·min^{-1}*	57 (3)	55 (3)¤	-4.3 (3.6)	43 (4)	47 (3)¤	9.6 (8.3)
VCO_2 L·min^{-1}#	4.52 (0.25)	4.28 (0.44)¤	-3.5 (1.6)	4.18 (0.30)	4.10 (0.15)	0.3 (4.1)
RER*	1.11 (0.04)	1.10 (0.02)	-1.3 (3.0)	1.37 (0.10)	1.26 (0.07)¤	-4.8 (4.6)
VE_{BTPS} L·min^{-1}#	141.3 (6.0)	159.8 (16.5)¤	8.4 (5.1)	150.5 (12.5)	151.5 (13.5)	2.1 (3.1)
AT %VO_2max*	69.7 (3.1)	73.3 (2.2)¤	-	82.6 (6.8)	70 (1.4)¤	-

BM-body mass; FFM-fat free mass; AT-anaerobic threshold; Friedman's test *P<0.05; #P<0.1; Wilcoxon signed rank test pre vs. post ¤P<0.1.

111 POSER SESSION 3

Control strategies for accurate force generation and relaxation in isometric contraction of lower limb

Chiaki Ohtaka[1], Motoko Fujiwara[2]

[1]Nara Women's University, Nara, Japan, [2]Nara Women's University, Nara, Japan

The purpose of this study was to investigate a motor strategy for force generation and relaxation systematically and to elucidate the difficulty of force relaxation in isometric contraction of lower limb.

Fifteen healthy right-footed participants accurately controlled the force of their isometric knee extension response to a go signal to reach a target force level as quickly as possible. They performed the following two tasks: a generation task, in which they increased their force from 0% maximum voluntary contraction (MVC) to 20% MVC (20% magnitude), 40% MVC (40% magnitude), or 60% MVC (60% magnitude), and a relaxation task, in which they decreased their force from 60% MVC to 40% MVC (20% magnitude), 20% MVC (40% magnitude), or 0% MVC (60% magnitude).The force output by each participant was recorded, and the data were analysed in terms of accuracy and quickness. The accuracy was evaluated the difference between the maximum (generation task) or minimum (relaxation task) force and each target force level; constant, absolute, and variable error. The time was evaluated using the reaction time and adjustment time. The velocity of the force control was calculated using the peak velocity and the time needed to reach the peak velocity.

As for the constant error, in the 20% and 40% magnitude, the relaxation task was greater than the generation. Moreover, the 20% and 40% magnitudes were greater than that for the 60% magnitude under the relaxation task. As for the time, under the both tasks, the adjustment time increased with the magnitude, and the reaction time for the 60% magnitude was shorter than that for the 20% and 40% magnitudes. In terms of the velocity, peak velocity increased with the magnitude under the both tasks, and the relaxation task was greater than the generation task. The time to peak velocity for generation task was longer than that for the relaxation task, and 40% and 60% magnitudes were longer than 20% magnitude.

The result of this study showed that it is difficult to accurately of control the force relaxation than generation with a slight magnitude, and the quickness of control the force vary according to the magnitude in lower limb.

112 POSER SESSION 3

Reliability of oxidative stress parameters and repeated 16.1 km time trial performance

Rachel Burke, Damien Gleadall-Siddall, Nikki Simpson, Huw Jones, Mark Fogarty, Andrew Garrett

The University of Hull, Hull, UK

Oxidative stress is an imbalance between the body's production of free radicals and antioxidant defences. Exercise confers oxidative stress due to reactive oxygen species being generated excessively by enhanced oxygen consumption and causes essential antioxidant capacity adaptations. Such excess can damage macromolecules and provide clinical biomarkers for assessing redox homeostasis. Exercise may induce significant but tolerable damage that can in turn lead to beneficial adaptations. This is the concept of hormesis, where an adaptive response occurs and oxidative stress is attenuated. However, there is limited literature regarding the quantification of oxidative stress after repeated exercise. Therefore, the aim of this study was to determine the reliability of exercise-induced oxidative stress markers using a repeated 16.1 km time trial (16.1 TT) performance test. With ethical approval, eleven, physically active, males (Mean [SD]; age: 28.1 [9.9] y, body mass: 77.5 [7.3] kg, height: 179.4 [6.9] cm) completed three 16.1 TTs, using an SRM ergometer, 1 week apart, over 3 weeks. Visit 1 was a familiarisation trial for participants. In Visits 2 and 3 blood was taken using venepuncture at rest and immediately after 16.1 TT. Samples were then analysed for markers of oxidative stress and DNA damage; reactive oxygen species (ROS) generation, lipid hydroperoxides, 8-hydroxy-deoxyguanosine, superoxide dismutase and protein carbonyls. Using high-performance liquid chromatography – mass spectrometry and spectrophotometry respectively. The reliability of oxidative stress markers and 16.1 km TT were then determined from Visits 2 and 3. The CoV (95 % CI), r and P-value were used for data analysis. The repeatability of ROS parameters demonstrated a large CoV of 262 (152 to 805 %); r=0.52; P=0.37; n=9. For within-participant 16.1 TT performance test, there was a small difference of 1.0 (0.7 to 1.8%); r=0.99; P=0.40; n=11. Interestingly, the 16.1 TT performance times of the familiarisation trial in Visit 1 versus Visit 2 was greater at 2.1 (1.5 to 3.8%); r=0.95; P=0.06; n=11. This study indicates measuring exercise induced oxidative stress markers in plasma, one week apart, using a reliable performance test may not be reproducible. Secondly, the 16.1 TT performance test, using an SRM ergometer is a reliable performance measure and highlights the importance of a familiarisation trial for greater accuracy in repeated, performance trials.

113 POSER SESSION 3

The effects of local muscle cooling on motor unit firing properties

Matthew Mallette, Lara Green, Stephen Cheung, Reno Fernley, Allison Boulanger, David Gabriel

Brock University, St. Catharines, Ontario, Canada

Local muscle cooling impairs maximal strength and manual dexterity without altering motor unit firing rates. However, the effect of muscle cooling on the number of active motor units or recruitment threshold is unknown. Therefore, this study non-invasively examined motor unit firing properties after isolated local muscle cooling during submaximal contractions.In 20 participants, surface electromyography (sEMG) was collected on the flexor carpi radialis (FCR), and motor units were examined using a decomposition EMG sensor (dEMG, Delsys, Inc., Natick, MA). Baseline M-waves and maximal voluntary contractions (MVC) were performed prior to forearm immersion in neutral (32°C) water for 10 min or cold (2°C) water for 20 min. After each immersion, 3 M-waves were evoked prior to a single MVC and 3 trapezoidal contractions to 50% of baseline MVC. After completing this contraction set, participants immersed their arm in the other water bath before repeating the contraction set. The order of water bath and contraction type (MVC and 3 trapezoidal contractions) were balanced.At baseline and after the neutral bath, local temperature of the forearm was ~31°C, while it was ~22°C following the cold bath (d≥5.02, P<0.001). Cold MVC force (107.0±23.7N) was lower than baseline (117.1±28.4N, d=0.39, P<0.05) but not neutral (115.8±28.1N). Twitch characteristics were representative of a cooled muscle: lower peak force, longer rates of force development and half-relaxation time. During the 50% MVC trapezoidal contractions, root-mean-square amplitude was not different between temperature conditions (d=0.14, P=0.230). However, mean power frequency was lower during cold (92.16±22.73Hz) compared to neutral (108.17±25.37Hz, d=0.66, P<0.001). Cold moderately increased the number of motor units detected (20±7 cold, 16±5 neutral, d=0.66, P=0.010). A small, non-significant effect was observed in the mean firing rate of the two lowest threshold motor units (21.42±2.84Hz cold, 20.76±2.97Hz neutral, d=0.23, P=0.105). Although the mean recruitment threshold also did not differ (12.9±6.0%MVC cold, 12.6±7.1%MVC neutral, d=0.10, P=0.805), the relationship between the recruitment threshold and motor unit firing rates was steeper in the cold (y=-0.61x+28.5) compared to neutral (y=-0.45x+24.4, P≤0.007). During submaximal voluntary contractions of cold muscle, small non-significant differences in motor unit firing rate and recruitment threshold were found compared to neutral, yet more motor units were detected in the cold and the relationship between their firing rates and recruitment threshold changed. Since maximal force is impaired with muscle cooling, these findings suggest a compensatory increase in the number of active motor units and slight changes in their firing rates and recruitment threshold to achieve the same absolute force in the cold.

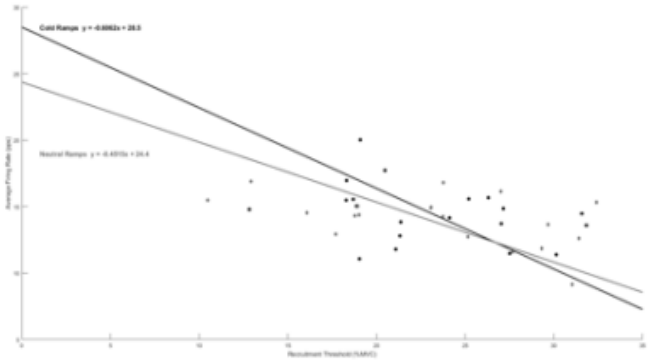

Figure 1: Relationship between motor unit firing rate and recruitment threshold for cold (black) and neutral (grey).

Dissociated dynamics of brachial artery and forearm skin blood flows during sinusoidal leg cycling exercise

Yoshiyuki Fukuba[1], Masaki Fujimoto[1], Masako Endo[1], Hideaki Kashima[1], Naoyuki Hayashi[2], Yoshiyuki Fukuoka[3], Shunsaku Koga[4]

[1]Prefectural University of Hiroshima, Hiroshima, Japan, [2]Tokyo Institute of Technology, Tokyo, Japan, [3]Doshisha University, Kyoto, Japan, [4]Kobe Design University, Kobe, Japan

The recent studies demonstrated that, during prolonged leg cycling exercise, the blood flow (BF) in non-active limb (i.e. brachial artery: BA) was elevated and this was at least in part as a result of thermoregulatory cutaneous vasodilation. It is hypothesized, therefore, that the BF in BA is followed by the work rate (WR) fluctuation sinusoidally and its phase shift is similar to that of forearm skin BF (SBF). To address this hypothesis, we studied the dynamics of the BF in BA and forearm SBF during the sinusoidal WR forcing followed by prolonged constant WR exercise. Nine healthy subjects performed upright leg cycle exercise with a constant WR for 30 min followed by 16-min sine WR exercises of 4-min period fluctuated between 20 W to 60 % VO2max. During protocol, we measured pulmonary gas exchange [breath-by-breath], heart rate (HR) and mean arterial blood pressure (MAP) [Photoplethysmograph], blood velocity (BV) and cross sectional area of BA [Ultrasound Pulsed-Doppler], and forearm and forehead SBF [Laser Doppler] and sweating rate (SR) [Capacitance Hygrometry]. The variable was fitted as y(t)=M+A*sin((2p/T)*t-q), where t: time, A/M: relative amplitude, T: period (=240 s), q: phase shift. Almost variables traced the sine wave adequately. The BF in BA displayed an anti-phase (approx. 180 °) and a large A/M (30 %) whereas those in forearm SBF was dissimilar (approx. 60 °). Thus, it appears unlikely that the change of BF through a conduit artery to the non-working upper limb could be ascribed exclusively to altering the downstream circulation to forearm skin.

115 POSER SESSION 3

Size does matter! Conductive toe skin cooling in matched male and female volunteers

Heather Massey, Katarzyna Lwowska, Liam Colley, Michael Tipton

University of Portsmouth, Portsmouth, UK

Differences were found in the rate of toe skin cooling between unmatched males and females, with a moderate correlation suggesting a relationship to foot volume (Lunt *et al* 2014). To remove the confounding factor of foot dimension, the present study recruited pairs of males and females matched for foot volume. It was hypothesised that the rate of toe skin cooling is related to the dimensions of the foot and not the sex of the person.

Nine males and nine females matched for foot volume (mean [SD] volume 847 [198] cm^3 and 837 [198] cm^3, respectively) gave their informed consent to participate in the ethically approved study. All volunteers cycled at 50W for 12 min and then in a seated posture exposed the soles of their feet to a gradually cooling metal plate (which cooled from 35 ^oC to 15 ^oC at a mean (SD) rate of -1.7(0.2) $^oC.min^{-1}$. Great toe skin temperatures and laser Doppler skin blood flow were measured on the Great toe and 5^{th} (little) toe throughout. Toe skin cooling rates for male and female volunteers matched for foot volume do not differ (Great Toe t=0.714, p=0.486; little toe t=0.861, p=0.402). Foot volume correlated with Great toe and little toe skin cooling (r=0.88, r^2= 0.78; r=0.64, r^2= 0.411 respectively). Overall foot volume was positively correlated to the rate of Great toe skin cooling (r=0.93, r^2=0.87) and moderately so with little toe skin cooling (r=0.55, r^2=0.29).

Pairs of male and female volunteers matched for foot dimensions showed that the rate of toe skin cooling in response to the same cooling stimulus is associated with foot volume. Thus, the hypothesis can be accepted, foot morphology is the main determinant for cooling, not sex.

Reduction of venous return abolishes muscle metaboreflex-mediated rise in cardiac output in exercising humans

Masashi Ichinose[1], Tomoko Ichinose[2], Takeshi Nishiyasu[3]

[1]Meiji University, Tokyo, Japan, [2]Osaka International University, Osaka, Japan, [3]University of Tsukuba, Tsukuba, Japan

Activation of the muscle metaboreflex in dogs during treadmill running via reduction of hindlimb blood flow increases cardiac output (CO) by rise in heart rate (HR) with sustained stroke volume (SV) (1). In addition, increase in venous return would contribute importantly to maintaining CO at higher level (3). Indeed, decrease in venous return by partial occlusion of superior and inferior vena cava completely abolishes the rise in CO (2). However, contribution of venous return for the muscle metaboreflex-mediated CO responses has yet to be elucidated in humans. In the present study, therefore, we investigated the influences of decreases in venous return from exercising limbs on the muscle metaboreflex-mediated CO responses in humans. Subjects (9 males) performed cycling exercise for 8-min at 30% and 60% of VO_2peak (EX30 and EX60), respectively. Beginning 3 min after the start of the exercise, the occlusion cuffs placed on the both thighs were inflated to 80, 100, 120, 140 and 160 mmHg in stepwise fashion with 1-min step durations. The progressive application of thigh cuff pressure was aimed to reduce venous return from exercising limbs as well as to decrease oxygen supply to exercising muscles to activate the muscle metaboreflex. The thigh cuff pressure was not applied in control conditions. The application of thigh cuff pressure progressively increased HR and mean arterial pressure in both intensities (at last 1-min in control vs. thigh cuff pressure conditions in EX30: 97 ± 3 vs. 108 ± 3, 82 ± 3 vs. 104 ± 2, EX60: 140 ± 3 vs. 155 ± 3 beats/min, 95 ± 2 vs. 116 ± 2 mmHg, $p < 0.05$) indicating activation of the muscle metaboreflex. Meanwhile, SV decreased gradually (EX30: 108 ± 6 vs. 96 ± 5, EX60: 119 ± 5 vs. 108 ± 5 ml, $p < 0.05$) reflecting reductions in venous return. Consequently, in despite of the rise in HR, CO was maintained at control level (EX30: 10.4 ± 0.5 vs. 10.3 ± 0.5, EX60: 16.6 ± 0.6 vs. 16.8 ± 0.8 L/min). We conclude that venous return from exercising limbs plays important role in determination of the muscle metaboreflex-mediated CO responses in humans.

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Thermal environment and sleep in winter shelter-analogue settings

Kazuyo Tsuzuki, Yosuke Mochizuki, Kazuki Maeda

Toyohashi University of Technology, Toyohashi, Japan

Japan has suffered from numerous disasters in the past and notably in recent years has suffered from large earthquakes such as the Great East Japan Earthquake in 2011. Public facilities such as gymnasiums and public halls are mainly used as evacuation centers in the event of a disaster, but these facilities are not built assuming an evacuation living environment.

We aimed to examine sleep in shelter-analogue settings in winter evacuation shelters. Twelve young healthy students took part in the sleep study of two nights for seven hours from 0 AM to 7 AM in a gymnasium. One night the subject used a pair of futons and on the other the subject used emergency supplies consisting of four blankets and a set of portable partitions. Air temperature, humidity and air velocity were measured in the area around the sleeping subjects through the night. Sleep parameters, skin temperature (TS), microclimate temperature (MCT), rectal temperature, and heart rate (HR) of the subjects were continuously measured and recorded during the sleeping period. The subjects completed questionnaires relating to thermal comfort and subjective sleep before and after sleep. Sleep parameters measured by actigraphy.

The average air temperature around the head before going to bed was about 5.9 °C, at dawn it was about 3.6 °C, which is about 2 °C lower. The mean MCT was 21.4 °C for blankets and 23.5 °C for futons. The sleep efficiency index (SEI) was about 86% in blankets and about 91% in futons. The mean skin temperature (MST) rose gradually after lights out, stabilized at about 32 °C in case blankets, about 33 °C in futons, and gradually decreased thereafter. The MST was significantly higher in case of futons than blankets in all time zones ($p<0.05$). However, significant differences could not be confirmed in the TS of other parts and in rectal temperature. The subjects felt more coldness on their head and peripheral parts of the body using the emergency blankets than the futon during the sleep. The HR dropped remarkably until 0:45 after lights out, both cases showed almost the same fluctuation. The time fluctuation of LF / HF decreased temporarily after lights out, comparing the average values of LF / HF, which in blankets was significantly higher than that in futons ($p<0.001$). Therefore, sleeping with insufficient bedding is thought to have a greater influence on cardiac autonomic nervous activity. Fatigue was felt more on the lower back and lower extremities from using emergency blankets than the futon after sleep. The SEI and subjective sleep evaluation by OSA questionnaire did not reveal any good correlationship.

The emergency supplies should be examined for their suitability to provide comfortable and healthy sleep in the shelter.

118 POSER SESSION 3

The effects of facial heating during cold exposure on hand/finger temperature, dexterity, and strength

Beau Yurkevicius, Myra Jones, Courtney Cowell, Catherine O'Brien, John Castellani

U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA

Prolonged cold exposure can lead to reduced comfort levels and performance in the hands and fingers. One potential mechanism for this is trigeminal nerve cooling, causing reflex peripheral vasoconstriction and decreased extremity blood flow which lowers finger temperature, dexterity, and comfort. The purpose of this study was to examine if facial warming can reduce reflex peripheral vasoconstriction caused by trigeminal nerve cooling, thereby increasing peripheral temperatures and improving dexterity. Eight volunteers (6M, 2F; 25.6 ± 9.0yr; 169.9 ± 6.2cm; 77.6 ± 16.2kg; 16.4 ± 5.3% fat) underwent 3 separate 120min cold exposure trials (COLD; 0°C; wind speed 1.34m/s; 2 clo cold-weather clothing) with 3 different configurations on the head and face: a) fleece hat (control, CON), b) balaclava (BAL), and c) balaclava with heating (42°C) on the forehead and both cheeks (FACE). Volunteers were seated with hands exposed for the entire duration of COLD. Core and skin temperature measurements were taken continuously, including the forehead and cheek (averaged into T_{face}), hand (T_{hand}), and finger (T_{fing}). Dexterity (Purdue Pegboard (PP) and a military-relevant magazine loading task (MAGLOAD)) and strength (grip and pinch) tests were conducted during baseline (BASE) and at min-90 of COLD. Thermal sensations of the whole body, hands, face, and feet were rated on a scale from 0.0 (unbearably cold) to 8.0 (unbearably hot), with 4.0 rated as comfortable. Data were analyzed using repeated measures analysis of variance with significance set at $p < 0.05$. Results are presented as mean ± SD. BASE core temperature (36.9 ± 0.3°C) was not significantly different at min-120 of COLD. Mean skin temperature at BASE was 31.4 ± 1.6°C and decreased by 4.2°C by min-120. FACE resulted in a higher T_{face} (37.7 ± 0.8°C, $p < 0.001$) vs. CON (26.3 ± 1.5°C) and BAL (25.8 ± 2.0°C) at min-100. BASE T_{hand} and T_{fing} decreased from 32.1 ± 1.6°C and 31.3 ± 2.9°C to 14.6 ± 1.3°C and 11.2 ± 1.3°C at min-100 of COLD, with no differences among trials. Strength and dexterity performances were both affected by COLD with grip, tip, and key pinch strength decreasing, respectively, by 7.9%, 14.7%, and 17.6% and PP and MAGLOAD performance declining by 22.1% and 20.4%, respectively, at min-90, vs. BASE, with no time by trial interactions. Facial thermal sensation was rated as more comfortable at min-120 during FACE (4.1 ± 0.5) vs. CON (3.3 ± 1.2, $p = 0.002$), but not BAL (3.6 ± 1.1, $p = 0.12$). There were no differences among trials for thermal sensation of the whole body, hands, or feet. These findings suggest that maintaining a warm face temperature is not sufficient enough to limit degradation in hand and finger temperature, dexterity, strength, or comfort during cold exposure.

Disclaimer: Authors' views are not official U.S. Army or DoD policy.

119 ORAL 11: Fire Fighters

Influence of sudden ambient temperature change on thermal response of human body dressed in firefighting clothing

Jingxian Xu[1,2], Jun Li[1,2]

[1]College of Fashion and Design, Donghua University, Shanghai, China, [2]Key Laboratory of Clothing Design & Technology, Donghua University, Shanghai, China

To explore the influence of sudden ambient temperature change on thermal response of human body in firefighting clothing, two sets of sudden temperature change experiments were designed using two climate chambers. During the first set of experiment, Chamber1 maintained 40℃ and Chamber2 maintained 23℃. During the second set of experiment, Chamber1 still maintained 40℃, while Chamber2 maintained -10℃. Temperature difference between chambers for the two experiments were 17℃ and 50℃, which respectively simulated difference between inside and outside fireground in spring/summer and autumn/winter season. Six male subjects dressed in four-layer firefighting clothing (I_T=1.85clo) participated in this study. They moved between Chamber1 and Chamber2 back and forth. Their thermal physiological indices (core temperature, skin temperature, heart rate and relative humidity between clothing and body) and thermal sensation were collected during the whole process.

The results indicated that both subjects' physiological and psychological indices changed significantly when air temperature altered suddenly. Especially during the second set of experiment, mean skin temperature of the subjects changed by 6.5℃ and subjective thermal sensation changed by 5 units (ASHARE 7-point scale). Additionally, different body parts tended to show different thermal responses, as clothing thermal and evaporative resistance of individual parts varied significantly. As regards those dressed body parts, skin temperature of the calf presented the most distinctive change of 7.5℃, while chest and back part appeared to have little change. The reason might be that the thermal resistance of chest and back part was the maximum among all the parts. Compared with the first set of experiment, human body responded more significantly during the second set of experiment, especially for shoulder, arm and leg parts where clothing thermal and evaporative resistance were lower. The results suggested that the clothing thermal and evaporative resistance of the limb parts should be enhanced in order to maintain firefighters' thermal and moisture comfort under transient thermal environment.

Body core temperature remains elevated following recovery from firefighting activities in the Australian Defence Force

Andrew Hunt[1,2], Daniel Billing[2]

[1]Queensland University of Technology, Brisbane, QLD, Australia, [2]Defence Science and Technology Group, Melbourne, VIC, Australia

Recovery strategies such as removing excess clothing, resting in the shade, and drinking cold fluids are commonly advised in work places with a high risk of heat-related illnesses. The key assumption of these strategies is that thermal strain is returned to baseline levels and workers are then safe to perform further work bouts. However, recent evidence suggests that the restoration of thermoregulation may be delayed post exercise. Therefore, this study aimed to evaluate the recovery of body core temperature and heart rate following firefighting activities.

Nine male fire fighters of the Australian Defence Force volunteered to participate in this study. Participants were 29.2±2.3 years of age, 177.9±7.7 cm in height, 91.3±8.6 kg in body mass, and had a minimum of 2 years' experience. Urine specific gravity was 1.023±0.011 on the morning of test day. In teams of four, participants completed scenario based training activities lasting 63±11 min. Participants waited at the watch room until the call out was issued. Participants wore complete fire-fighter turn-out gear with Self-Contained Breathing Apparatus (SCBA) during the scenario. Upon completing the scenario firefighters removed their SCBA, helmet and hood, and turn-out jacket and rested in the shade with cold water available for drinking. After debriefing they returned to their stand-by duties at the watch room. Heart rate, body core temperature (ingestible pill), and the environmental conditions were monitored throughout the activities (Air temperature: 29.8±2.5°C; Humidity: 43.1±5.7%; WBGT: 27.6±0.6 °C).

Body core temperature and heart rate were 37.39±0.18 °C and 90.6±11.3 bpm preceding the scenario and peaked at 38.68±0.51 °C 165.4±23.7 bpm during the work period, respectively. The difference in body core temperature from baseline was significantly greater at peak activity compared to the 10, 20, and 30 minute time points after returning to the watch room ($p<0.001$), however, body core temperature remained elevated above baseline for the 30 min post-work period (Figure 1: left). The difference in heart rate from baseline was significantly greater at peak activity and at 10 min into the post-work period compared to the 20 and 30 min time points, with the average heart rate difference returning close to baseline (Figure 1: right).

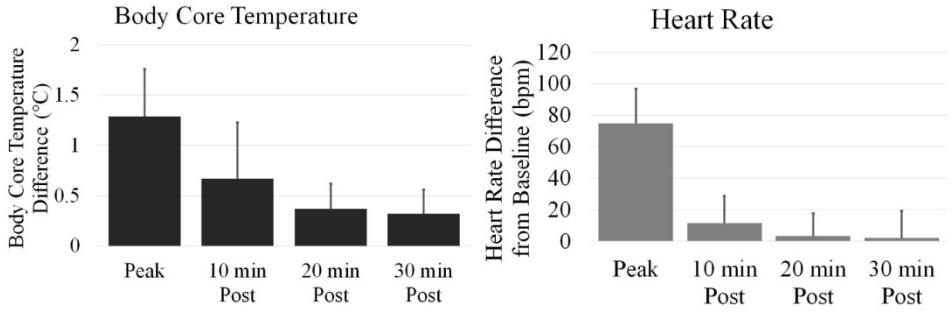

Figure 1: Body core temperature (left) and heart rate (right) difference from baseline.

These findings demonstrate that body core temperature can remain elevated following the recommended recovery strategies of resting in the shade, removing excess clothing and drinking cold fluids. Consequently, fire fighters may be at risk of commencing subsequent work bouts at an elevated body core temperature, which will have important implications for work and rest scheduling to mitigate the risks of heat-related illnesses.

121 ORAL 11: Fire Fighters

Core body temperature dynamics during fire fighter heat exposure training

Piero Fontana[1,2], Braid A. Macrae[1], René M. Rossi[1], Simon Annaheim[1]

[1]Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland, [2]Highperformance Scientific, Wilen b. Wollerau, Switzerland

Firefighters are exposed to harsh environmental conditions during their mission on the fireground. Personal protective clothing (PPC) shields the wearer from external hazards but itself also affects physiological parameters, as demonstrable during laboratory tests in warm and humid environments. Scarce information is available about core body temperature dynamics during heat exposures in fire chambers and subsequent recovery phases. Ten healthy fire fighters (age: 46.9 ± 5.3 years, height: 1.79 ± 0.05 m, weight: 84.3 ± 10.3 kg) performed a two-step intermittent heat exposure protocol, wearing a PPC (VIKING Life-Saving Equipment S/A, Esbjerg, Denmark). Core body temperature could be recorded in four participants using a rectal thermistor (t_{re}; MSR Electronics GmbH, Seuzach, Switzerland). The study protocol involved 15 min of heat exposure (E1; sitting, environmental temperature (t_{env}) approximately 190°C at 1 m above the ground), followed by 15 min of rest outside of the chamber (R1; t_{env} approximately 20°C) and another 15 min in the fire chamber (E2; sitting, t_{env} approximately 155°C at 1 m above the ground in combination with the application of fire water). After E2, participants left the fire chamber and were allowed to take off their PPC (R2). t_{re} increased throughout the experiment from 37.51 ± 0.28°C in minute 1 to 38.34 ± 0.09 °C in minute 45 (P = 0.006). Interestingly, after E1, t_{re} further increased throughout R1 (P = 0.010). Furthermore, t_{re} was higher at minute 45 than at minute 30 (effect of E2, P = 0.008). Also after E2, t_{re} kept increasing (until minute 55; P = 0.001) and then started to decrease again. The rate of t_{re} rise was higher in E2 (0.30 ± 0.08°C·15 min^{-1}) than in E1 (0.19 ± 0.09°C·15 min^{-1}; P = 0.010). Our results show a delayed t_{re} increase during heat exposure as well as a delayed levelling off during recovery phases. An accumulation of body heat and the thermal inertia of the body tissues as a whole may induce prolonged increases in core body temperature (as observed with t_{re}) that outlast the direct heat exposure itself, especially when PPC is still worn during recovery periods. Furthermore, the local thermal inertia of the rectum may cause t_{re} to lag compared to central blood temperature, as observed elsewhere. Either way, the observed delay needs to be taken into account when interpreting real time measurements. We propose that body heat dissipation has to be facilitated whenever possible (e.g. during recovery periods between missions) in order to reduce thermal load. Information about the firefighters' core body temperature and a correct interpretation is crucial to set appropriate care (e.g. local and whole body cooling) to reduce heat stress.

122 ORAL 11: Fire Fighters

Muscular fatigue and recovery after a heavy work bout in the heat: comparison of four recovery interventions on muscle structure and mechanical properties in firefighters

Juha Oksa[1], Sirkka Rissanen[1], Ragnar Viir[2], Hannu Rintamäki[1], Satu Mänttäri[1]

[1]Finnish Institute of Occupational Health, Oulu, Finland, [2]University of Tartu, Tartu, Estonia

Fire fighting is physically and mentally demanding occupation. The combination of strenuous fire fighting activity, hazardous conditions, protective equipment and exposure to heat can cause high physiological strain. Muscular recovery (i.e. recovery from fatigue induced changes in muscle function) after such heavy work bouts until fatigue is known to take several hours. In an effort to hasten the speed of muscular recovery, four different interventions were tested. They were caffeine intake (6 mg/kg), active stretching, cold-water immersion (forearm 5 minutes in 15°C), and contrast water therapy (forearm in 15°C water for 1 minute then another minute in 35°C, repeated 3 times). Thirteen firefighters performed a 20-min heavy work bout at 35 °C. During the work simulation, rectal temperature (T_{re}) and skin temperatures (T_{sk}) were continuously measured. After completing the work, maximal grip force, and structural changes induced by muscle fatigue (muscle circumference, cross-sectional area, thickness, pennation angle, tone, elasticity, and stiffness) were measured from wrist flexor and/or extensor muscles. Recovery was followed 28 hours. At the end of working phase, T_{re} and T_{sk} were 37.9±0.1 and 36.4±0.2 °C, respectively ($p<0.001$ compared to baseline). Maximal grip force decreased by 8.1±1.6 % ($p<0.001$). Pennation angle of flexor muscle increased by 4.4±0.9° ($p<0.001$) and remained elevated for two hours. Significant ($p<0.001$) difference was observed in recovery of pennation angle between different interventions and reference, contrast water therapy being the most efficient ($p=0.007$). Elasticity was reduced in both muscles (17.0±1.8 % in flexor, $p<0.001$; 15.6±2.7 % in extensor, $p<0.001$) compared to baseline. Flexor muscle was hypertonic after work (3.0±1.0 % increase, $p<0.01$) with reduced (13.0±1.2 %, $p<0.001$) stiffness. Significant ($p<0.05$) difference was observed in recovery of flexor elasticity between interventions, contrast water therapy being the most efficient ($p=0.002$). These results provide evidence that after a heavy work bout 1) fatigue induces changes in muscle structure and mechanical properties, 2) several hours is needed for the structural recovery of muscles, and 3) of the interventions tested, contrast water therapy is the most effective method (both subjectively and objectively) to enhance muscle recovery.

123 SYMPOSIUM: Clothing Assessment and development

Clothing Assessment and development: Introduction to the problem

George Havenith[1], Faming Wang[2]

[1]Loughborough University, Loughborough, UK, [2]Hong Kong Ploytechnic University, Hong Kong, Hong Kong

Clothing provides a protective interface between humans and their environments. Assessment of its properties and the implications for wearer protection and comfort has seen a variety of approaches. This symposium will look at approaches through thermal manikins, Infra-Red analysis and assessment of textile properties and their meaning for comfort.

124 SYMPOSIUM: Clothing Assessment and development

Critical assessment of different manikin control options

Faming Wang

Hong Kong Polytechnic University, Hong Kong, Hong Kong

Thermal manikin is one of the most useful devices used for the assessment of heat and mass transfer of the human-clothing-environment system. Thermal manikins are developed with human anatomic shape and they are also designed to mimic human sweating and/or body movement/posture. Thus, thermal manikin tests have been widely used to evaluate clothing comfort and protective performance, indoor/cabin ambient environments as well as to predict human thermophysiological behaviours and perceptual sensations. Based on the objective of the study, four control modes/options may be used: constant temperature mode, constant heat flux mode, comfort mode and thermoregulatory model control mode. In this talk, a critical overview of the four manikin control options will be addressed. The main features, working principle and limitations of each control option will be critically reviewed. Particularly, the recent development in thermoregulatory model controlled manikin (or adaptive manikin) will be presented in detail. It is hoped that this talk will spur debates and discussion on the application of manikins to evaluate clothing and human thermal comfort.

125 SYMPOSIUM: Clothing Assessment and development

Using Infra-Red analysis for sports clothing development

Damien Fournet[1], George Havenith[2]

[1]Decathlon, Lille, France, [2]Loughborough University, Loughborough, UK

Skin temperature has been shown to be a contributing factor to both exercise performance and thermal comfort. Patterns of skin temperature distribution over the whole body can be obtained by using Infra-Red Thermography which has now become a relatively affordable method. Specific image processing technique is required to unveil patterns for a large population and then provide quantitative as well as qualitative temperature results (body maps). Several studies have explored skin temperature patterns in different sporting conditions and climatic conditions. Over the last 10 years, a bodymapping approach has also been implemented in the design of sportswear with a combination of various physiological or perceptual body maps including skin temperature maps. This presentation will cover some key examples of this approach aimed at optimising the skin/clothing interface locally. Clothing development can both make the most of Infra-Red analysis at the products creation phase as well as use this method to evaluate their final physiological benefits in use.

126 SYMPOSIUM: Clothing Assessment and development

Wetness sensation during rest and exercise and the interaction with textiles: how can you feel it?

Margherita Raccuglia, George Havenith

Loughborough University, Loughborough, UK

Providing the body with a physical barrier from environmental factors, the interaction between clothing and the human body has a number of implications in terms of biophysics of heat transfer, temperature regulation and comfort. The sensation of wetness at the skin/clothing interface is known as one of the highest sources of discomfort during wear. Extensive research has been conducted to develop apparatus and test methods able to characterise fabric moisture handling properties. Nevertheless, less is known on how such fabric properties modulate the sensation of skin and clothing wetness and the related sensations of discomfort in humans. Here we report a series of investigations aiming to systematically study the role of fabric thickness, fibre content, fabric surface texture and geometry, as well as fabric surface area on skin wetness perception, in both local body sensorial trials and wear trials. Additionally, the approach adopted to characterise fabric moisture content, i.e. absolute (same µL of water per area (cm^2)) versus relative (same µL of water per unit of fabric volume (cm^3)) has been studied and the implications that fabric total saturation has on skin wetness perception has been explained. Finally, we studied the role that tactile cues, such as sensations of clothing stickiness, has on overall comfort, and whether stickiness sensation directly relates to wetness perception. The current research provides fundamental knowledge that can be applied for the development of evidence-based sportswear and protective clothing as well as new methodologies for the assessment of textile and clothing properties in humans.

127 ORAL 12: Perception 2

Surface heat flux and thermal comfort in women during rest and exercise in a cold environment

Lauren Penko[1], Bart Scicchitano[2], Brandon Watson[1], Corrine Malcolm[1], Robert Gathercole[2], Andreas Jack[2], Matthew White[1]

[1]Simon Fraser University, Burnaby, BC, Canada, [2]lululemon, Vancouver, BC, Canada

PURPOSE: For women at rest and during exercise in a cold environment, first it was assessed if surface heat flux (HF, W/m^2) is a determinant of thermal comfort (TC) and second the strength of the associations between HF and TC was compared to the strength of the associations between surface skin temperature (T_{SK}) and TC. HYPOTHESES: For this group it was hypothesized that HF would be a significant determinant of TC and that HF would show stronger associations to TC than would T_{SK}. METHODS: Eight women who were 33±5.5 (mean±SD) years of age with a weight of 59.3±5.6 kg, a height of 1.65±0.08 m, and a body mass index of 24.4±4.2 kg/m^2 volunteered for the study that was approved by the SFU Office of Research Ethics. Each volunteer after a 24 h reflection period, signed a medical history form, a Physical Activity Readiness Questionnaire (PAR-Q), as well as gave their signed informed consent. On the skin surface in eight locations on the upper body each volunteer was instrumented with HF disks that contained integral skin thermistors. The study consisted of an aerobic capacity test on the first day and a cold exercise trial on a second day. The cold trial started with a 10 min rest period in an ambient temperature (T_{AMB}) of ~ 22°C and RH of 40% that was followed, at T_{AMB} of -4°C, by a 15 min exercise period, a rest period of 10 min and a second 15 min exercise period. In the cold trial during the exercise periods the wind velocity was ~1.7 m/s. Exercise intensity was set at 10% below each volunteer's ventilatory threshold. Each volunteer gave TC votes at 2 to 5 min intervals on a 8 point scale with arbitrary units (AU) where +4 = very, very warm and -4 = very, very cold. The HF and T_{SK} were collected by a data acquisition system controlled by LabVIEW software. A Pearson product-moment correlation analysis was employed for the analysis. With an alpha of 0.05 and a power of 0.8, a correlation coefficient (r) of 0.71 was significant and explained ~50% of the variance between the independent and dependent variable. RESULTS: In the cold trial no correlations between TC and T_{SK} were significant whereas during the rest period at -4°C TC and HF showed negative correlations ranging from r = -0.42 to r =-0.92. Over the rest period at -4°C HF ranged from ~ -87 to -134 W/m^2 and TC ranged from ~+1.5 to -0.5 AU.

CONCLUSION: These preliminary results support in cold conditions, heat flux is a determinant of thermal comfort and its association to thermal comfort was stronger than were associations of thermal comfort and surface skin temperature.

128 ORAL 12: Perception 2

Perception of thermal comfort during skin cooling and heating

Igor Mekjavic, Urša Ciuha, Danny Yogev

Jozef Stefan Institute, Ljubljana, Slovenia

Due to the static and dynamic activity of the cutaneous temperature sensors, the cutaneous thermal afferent information is most likely dependent on the direction of the temperature change, which would suggest different perceptions of thermal comfort during cooling and heat of the skin. This hypothesis was tested in the present study. Subjects (N=12; 6 females and 6 males) donned a water-perfused suit (WPS) in which the temperature of the water perfusing the suit varied in a saw-tooth manner in the range from 27° to 42°C. The rate of change of temperature of the water perfusing the suit (T_{wps}) was 1.2°C.min^{-1}, during both the heating and cooling phases. The trial was repeated thrice, with subjects reporting their perception of temperature and of thermal comfort at each 3°C change in T_{wps}. In addition, subjects were instructed to report when they perceived T_{wps} uncomfortably cool and warm during cooling and heating, respectively. Subjects reproducibly identified the boundaries of their Thermal Comfort Zone (TCZ), defined as the lower (T_{low}) and upper (T_{high}) temperatures at which subjects reported slight discomfort. During the heating phase, T_{low} and T_{high} were 30.0±1.5°C and 35.1±2.9°C, respectively. During the cooling phase, these boundary temperatures of T_{low} and T_{high} were 35.4±1.9°C and 38.7±2.3°C, respectively. The direction of the change in the cutaneous temperature stimulus affects the boundaries of the TCZ, such that they are higher during cooling and lower during heating. These finding are explained on the basis of the neurophysiology of thermal perception

This work was supported, in part, by the European Commission Horizon 2020 Research and Innovation action (project number 668786: Heat Shield)

129 ORAL 12: Perception 2

Comparison of constant *vs*. intermittent forced-air ventilation under body armour and the impact on heat strain, thermal perception and thermal comfort

James R House[1], Daniel White[1], Amy Harwood[1,2], Harrison Cook[1]

[1]*University of Portsmouth, Portsmouth, UK,* [2]*University of Hull, Hull, UK*

We investigated the impact of wearing a forced-air-ventilation system built-into body armour (13kg) on heat strain and thermal perceptions when 18 volunteers (1 female) exercised (60 minutes at 1.07 $L.min^{-1}$ oxygen consumption) then rested (60 minutes) in 40°C, 20% RH air. We hypothesized that: heat strain would be reduced with constant air-ventilation (AV) compared to a no-ventilation control (CON); intermittent air-ventilation, either 1 minute on/off (AV1) or 2 minutes on/off (AV2), would reduce heat strain similarly to AV; AV1 & AV2 would better reduce perceptual strain compared to CON and AV. Compared to CON, during work, none of the AV conditions influenced the rise of rectal temperature (0.93°C to 0.93°C), but mean(SD) rate of heat storage (S) during the last 40 minutes of exercise was reduced from 271(89)W during CON to 227(73)W during AV (*P<0.01*), with that for AV1 and AV2 being intermediate and not different to these. During the last 40 minutes of rest, the mean rate of fall of S was enhanced from CON at 74(79)W to AV at 139(96)W (*P<0.05)*, with AV1 and AV2 being intermediate to both. Heart rate (HR) was lower in AV compared to CON for the last 40 minutes of recovery (*P<0.005*), with HR for AV1 and AV2 being intermediate. After two hours of exercise and recovery, AV resulted in less than half the amount of additional heat stored than CON (*P<0.05*), with AV1 and AV2 being intermediate, but closer to AV than CON. Compared to CON, thermal comfort was improved in AV2 after 20 minutes of work (*P<0.05*), and in AV and AV1 after 40 minutes of work (*P<0.01*). During rest, after 20 minutes AV was more thermally comfortable than CON (*P<0.*05), whilst comfort in AV1 and AV2 were intermediate to AV and CON. Thermal sensation measures indicated that participants felt less hot compared to CON in AV by 20 minutes of work (*P<0.05*), and in AV1 by 40 minutes of work (*P<0.01*). During rest, the participants felt less hot compared to CON after 20 minutes in AV (*P<0.01*), after 40 minutes in AV1 (*P<0.01*), and by the end of rest in AV2 (*P<0.001).* Less sweat was produced, but more evaporated in AV compared to CON (*P<0.01*), resulting in 70% of sweat produced in AV evaporating, but only 53% in CON, AV1 and AV2 being intermediate. Participants preferred all AV compared to CON, with the most preferred being AV2 (*P<0.01*). We conclude that constant AV reduces heat strain, and to a greater extent during recovery than work, with perceptual benefits of AV during work and rest. During work, the perceptual benefits of intermittent AV (AV2 and then AV1) were obvious, whereas during rest constant AV produced better perceptual benefits.

130 ORAL 12: Perception 2

Effects of task and motivation on sensations of discomfort and task performance

Emiel DenHartog[1], Claudy Koerhuis[2]

[1]NC State University, Raleigh, USA, [2]TNO Defense, Safety & Security, Soesterberg, The Netherlands

Knowledge about the influence of comfort and discomfort on human performance is scarce. Therefore it was decided to conduct a pilot study to assess the influence of different types of discomfort on (cognitive) performance.

Eleven healthy male subjects participated in this pilot study. The protocol consisted of three recurring parts, subdivided in tasks (attention task (2x), memory task (both performed on a treadmill, 3-4 km/hour), vigilance and tracking task, fine motor tasks (both performed while sitting on a chair). Prior and after each task, subjective scores were asked (thermal comfort, comfort, localized postural discomfort, mental effort, physical effort). Also objective task performance was measured. The duration of each part was 43 minutes. The total duration of the protocol per condition was 129 minutes. The order of test configurations was randomized.

While significant discomfort was achieved, limited performance decreases were found. Thermal discomfort only influenced the percentage missed stimuli during the vigilance and tracking task: percentage missed stimuli was significant higher in the warm condition ($F=7.430$; $p=0.023$). The type of task did influence the changes in local and whole body comfort scores, increasing during the attention and memory task and decreasing during the vigilance and tracking task and fine motor tasks. Thermal and mechanical discomfort did influence mental effort and physical effort.

Not thermal and mechanical discomfort, but the type of task mainly influenced the changes in comfort- and localized postural discomfort. Changes in scores of comfort increased during easy, less challenging tasks (attention- and memory task). Changes in scores of comfort decreased during challenging and motivational tasks (vigilance and tracking task, fine motor tasks). Thermal and mechanical discomfort did influence mental- and physical effort, but objective performance was minimal during this 2 hour test.

In conclusion: motivation during the challenging tasks significantly suppressed sensations of discomfort, while these sensations of discomfort increased significantly during ‘boring’ tasks. These results showed a significant interaction between, task, motivation and performance.

131 ORAL 12: Perception 2

Comparison of thermal environment, thermal sensation and sleep quality among thermal control patterns in summer sleeping rooms

Noriko Umemiya, Yoshiki Tachibana, Tomohiro Kobayashi, Yusuke Nakayama, Hirona Bessho

Osaka City University, Osaka City, Japan

This survey, with 75 respondents on a total of 343 peak summer days for three years in apartments in Osaka, Japan, compared sleep quality for three thermal control patterns: air-conditioning through the night, window opening through the night, and partial air-conditioning using a timer. The sleeping room temperature and humidity were measured. A new effective temperature of the sleeping room (SET* _total) was calculated using the total thermal insulation value of clothing and bedding. Clothing insulation was estimated according to ISO9920. Air velocity was estimated according to the electric fan use intensity. The thermal environment was expressed as the mean during sleep.

Frequent thermal control patterns were air-conditioning through the night (21.4%) (Condition AC), window opening through the night (18.6%) (WO), partial air-conditioning using a timer (11.2%) (PA). The indoor and outdoor thermal environment, thermal sensation, and sleep quality measured using an OSA subjective evaluation test were compared among three patterns.

Results revealed the following: 1) The outdoor temperature was higher in PA than in WO (p<0.01) and higher in AC than WO (p<0.05). 2) The indoor SET*_total was higher in WO than in PA (p<0.01) and higher in PA than in AC (p<0.01). Nevertheless, no significant difference was found among thermal sensations associated with the three conditions. Moreover, sleep quality measured by OSA test was higher, it means that the sleep quality was better, in WO than in AC (p<0.01). 4) As Figure 1 shows, OSA score was low and unrelated to the indoor SET*_total in AC. It worsened as the indoor thermal environment became hotter in WO. But it became better in PA when indoor SET*_total exceeded 31°C. 5) Sleep quality was better in PA than in WO and AC when the outdoor temperature exceeded 27.9°C.

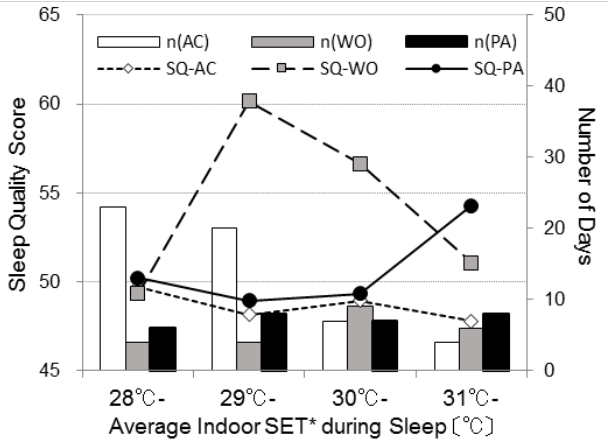

Figure 1: Relation between Indoor SET* and OSA Score

132 ORAL 13: Heat adaptation

Effectiveness of short-term heat acclimation on intermittent exercise in the heat with moderately-trained females controlling for menstrual cycle phase

Jarrod Gritt, Edward Dodd, Victoria Biddlecombe, Damien Gleadall-Siddall, Rachel Burke, Richard Turpin, Jake Shaw, James Bray, Huw Jones, Grant Abt, Andrew Garrett

The University of Hull, Hull, UK

Repeated heat exposure can facilitate physiological adaptation to the heat during intermittent exercise but there is limited information on female cohorts. This has implications for the health and safety guidelines for females during heat exposure. Studies using short-term heat acclimation (STHA) with dehydration, have been reported to improve the physiological responses and performance during heat exposure but have tended to use male participants. Therefore, the aims of this study were to investigate the efficacy of STHA over 5-days (with permissive dehydration), using the controlled-hyperthermia technique, on an intermittent, heat stress test (HST), using a female cohort.

Eight, healthy, active, moderately-trained females (Mean [SD]; age 22.6 [3.0] y; stature 166.2 [6.0] cm; body mass 62.3 [9.0] kg; VO_{2max} 43.2 [8.2] $mL \cdot kg^{-1} \cdot min^{-1}$) participated. The HST (31.0°C; 45%rh) consisted of 9x5min (45 mins) of intermittent exercise (individualised standing, walking, jogging, low-, medium-, and high-intensity running on a motorised treadmill) finishing with a 6s maximal sprint on a cycle ergometer (WattBike). The exercise intensities were adapted from the match-play dynamics of female collegiate football players (1). Participants completed two HSTs (HST1 and HST2) separated by one week, with no STHA, as a control (C) trial. This was followed by 90 min dehydration, heat acclimation (no fluid intake) for 5 consecutive days (39.5°C; 60%rh), using the controlled-hyperthermia technique (~rectal temperature [T_{re}] 38.5°C). Participants completed a final HST (HST3), within one week of the STHA. The HST2 and HST3 trials were in the third week of menstrual phase. Determined by self-reported menstrual cycle questionnaire and plasma 17β-estradiol.

Pre (HST2) vs post (HST3) STHA there was a reduction in T_{re} at 45-min by 0.20°C (95%CI -0.30 to -0.05°C; P=0.01; ES=1.13); mean skin temperature (-0.50; -1.00 to -0.05°C; P=0.06; ES=0.80) and mean body temperature (-0.20; -0.30 to -0.10°C, P=0.001; ES=1.28). There was limited change (P>0.05) for these measures in the HST1 vs HST2 C trial. Resting cardiac frequency decreased -11 $b \cdot min^{-1}$ (-16 to -4 $b \cdot min^{-1}$; P=0.004, ES= 0.81) and by -3 $b \cdot min^{-1}$ at 45-min (-10 to 3 $b \cdot min^{-1}$; P=0.06, ES= 0.64) but limited change in C (P>0.05). There was an increase in %PV change post STHA by 7.0% (-0.4 to 14.5%, P=0.004, ES=1.27) but limited change in C (P>0.05). There was an increase in mean average power across all nine maximal sprints by 56W (-26 to 139W; P=0.03; ES=0.69) but limited change in C (P>0.05).

Short-term heat acclimation (5-days) using controlled-hyperthermia leads to physiological adaptation during intermittent exercise in the heat, in moderately trained females when controlling for menstrual cycle phase.

133 ORAL 13: Heat adaptation

Heat acclimation for female endurance performance in hot and normothermic conditions

Nathalie Kirby, Rebekah Lucas, Samuel Lucas

University of Birmingham, Birmingham, UK

Heat acclimation (HA) is a well-recognised means of improving temperature regulation and heat tolerance in occupational (i.e., military, firefighters) and athletic settings; yet research to date has primarily focused on male cohorts. Recent research indicates females may require longer acclimation protocols or additional heat exposure for stable adaptation to chronic heat stress. Furthermore, HA is now recognised for its ergogenic potential, therefore female cohorts should be tested alongside males in a way that reflects their now similar participation and success in high-level sport. Therefore, the purpose of this study was to quantify physiological adaptations (e.g., cardiovascular strain, body temperature and fluid-regulatory responses) and improvements in female athletic performance (i.e., time trial distance and power output) in both hot and normothermic conditions following 5- and 10-days of HA. Seven female recreational endurance athletes (mean ± SD age 28 ± 5 years, mass 60.9 ± 5.2 kg, VO_{2max} 45.4 ± 5.2 mL/kg/min) completed a 15-minute time trial style performance test (TT) in hot (HTT; 35°C, 30%RH) and normothermic conditions (NTT; 15°C, 30%RH), before (1) and after short-term (STHA; 4-5 days; (2)) plus long-term (LTHA; 9-10 days; (3)) isothermic HA (where rectal temperature (T_{rec}) was maintained at ~38.5°C for 90-min of exercise in 40°C, 30%RH) with permissive dehydration. Data were compared using a one-way ANOVA. TTs were performed on a Velotron cycle ergometer. Distance cycled during the 15-minute TT improved by 210 ± 150 m (2.4%; P=0.038) in normothermic conditions and by 260 ± 150 m (3.3%; P=0.017) in the heat following LTHA. Mean power output increased by 10.7 ± 7.7 W (6.8%; P= 0.040) in normothermic conditions and 10.4 ± 7.4 W (5.5%; P=0.015) in the heat following LTHA. Area under the curve (AUC) differences were observed in power output across the TT in both NTT1 vs. NTT3 (P=0.034) and HTT1 vs. HTT3 (P=0.016). Body mass loss from 2.6 ± 0.5% to 3.2 ± 0.5% (P=0.034) after HA day 1 and 10, respectively; with sweat rate relative to body surface area increasing from 613 ± 105g/h/m^2 on HA Day 1 to 772 ± 114g/h/m^2 on HA Day 10 (P=0.018). Active Sweat Glands/Sq. Inch also increased from 395 ± 135 during HTT1 to 494 ± 157 during HTT3 (P=0.016). T_{re} was lower (AUC; P=0.036) during NTT3 vs. NTT1. Other thermoregulatory, cardiovascular, and blood lactate measures were not different between TTs (P>0.05). No significant performance or physiological improvements were observed following STHA (P>0.05). In conclusion, the lack of physiological or performance effect following STHA mirrors recent research, indicating that females require LTHA to achieve the physiological adaptations necessary for performance improvements in the heat. Meaningful performance improvements in normothermic conditions following 10-days HA warrant further research into HA's ergogenic potential for female athletes.

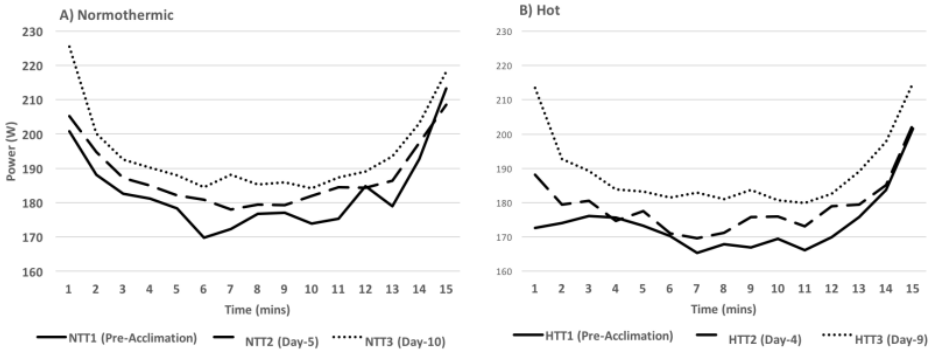

Figure 1: Power output during a 15-minute cycling time trial in normothermic (A) and hot (B) conditions. Time trials were performed pre-acclimation, and after 4-5 days plus 9-10 days heat acclimation

134 ORAL 13: Heat adaptation

Does heat acclimation improve whole-body heat loss in older men?

Martin Poirier, Sean Notley, Andrew D'Souza, Glen Kenny

University of Ottawa, Ottawa, Ontario, Canada

It is well known that heat acclimation increases the body's physiological capacity to dissipate heat in young adults, with the magnitude of improvements becoming greater at higher levels of heat stress. However, it remains unclear whether whole-body heat dissipation is enhanced following a 7-day heat acclimation in older adults. Therefore, we examined changes in whole-body heat loss during exercise performed at progressively greater rates of metabolic heat production in the heat prior to and following heat acclimation in older habitually active men. Seven older males (age, 60 ± 5 yrs; body surface area, 1.9 ± 0.1 m^2; $\dot{V}O_{2peak}$, 44.9 ± 9.4 mLO^{-2}•kg^{-1}•min^{-1}) underwent a 7-day heat acclimation protocol consisting of 90 min of semi-recumbent cycling at ~50% of $\dot{V}O_{2peak}$. Prior to (day 0) and following (day 8) heat acclimation, whole-body heat exchange (evaporative and dry heat loss) was measured using direct calorimetry during three 30-min bouts of cycling performed at progressively greater fixed rates of metabolic heat production of 150 (Ex1), 200 (Ex2), and 250 $W \cdot m^{-2}$ (Ex3), each separated by 15 min of recovery. These rates of metabolic production were equivalent to ~32, ~43, and 56% of $\dot{V}O_{2peak,}$ respectively. All trials were performed in hot, dry conditions (40°C, ~20% relative humidity). By design, metabolic heat production was similar prior to and following heat acclimation for all exercise bouts (P=0.209). Dry heat gain remained unchanged by heat acclimation for all exercise bouts (P=0.234). Consequently, the net heat load (metabolic plus dry heat gain) during all exercise bouts was similar prior to and following heat acclimation (P=0.511). While no difference in evaporative heat loss was observed at the end of Ex1 (P=0.121), improvements were evident at the end of Ex2 (day 0: 218 ± 12 $W \cdot m^{-2}$; day 8: 237 ± 15 $W \cdot m^{-2}$, p=0.009) and Ex3 (day 0: 261 ± 26 $W \cdot m^{-2}$; day 8: 279 ± 17 $W \cdot m^{-2}$, p=0.037) following heat acclimation. These improvements in evaporative capacity equate to a relative increase of 9 ± 6 % for Ex2 and 7± 7 % for Ex3. Our preliminary findings indicate that heat acclimation improves whole-body evaporative heat loss in habitually active older men, albeit these improvements are only evident at metabolic heat loads ≥200 $W \cdot m^{-2}$.

135 ORAL 13: Heat adaptation

Divergent physiological adaptations from short-term heat acclimation in dry vs humid conditions at equivalent heat index: no performance change in temperate conditions

Sam Tebeck[1,2], Jonathan Buckley[2], Clint Bellenger[1,2], Jamie Stanley[1]

[1]South Austalian Sports Institute, Adelaide, South Australia, Australia, [2]University of South Australia, Adelaide, South Australia, Australia

Short-term heat acclimation (STHA) is attractive for athletic preparation because it involves repeated exposure to heat stress over the course of ~7 days. However, the effect of different hot environmental conditions on resultant adaptations is unclear. The primary aim of this study was to compare a humid vs. dry STHA protocol standardised by heat index (HI) on endurance cycling performance in temperate conditions. A secondary aim was to investigate potential differences in physiological adaptations arising from the two conditions. In a cross-over design, 11 well-trained male cyclists/triathletes completed 2 x 5-day exposures in random order which elicited iso-thermic heat strain (core temperature clamped at ~38.5°C) at a HI of 44, in either 32˚C and 80% RH (humid) or 43˚C and 20% RH (dry) separated by 30-days. Both humid and dry protocols induced similar physiological responses representative of heat acclimation including reduced heart rate for given workload in the heat. Differences in endurance cycling performance in temperate conditions measured through a 4 min maximal power, power associated with blood lactate threshold and maximal oxygen uptake were unclear for within- and between-condition comparisons. Following dry vs. humid STHA, under temperate conditions gross efficiency was very likely improved [between-condition effect size (90% confidence interval) [-0.65 (-1.03, -0.27)], oxygen uptake was likely reduced for a given workload [0.57 (0.07, 1.06)] and energy expenditure likely reduced [0.47 (0.19, 0.76)]. Sweat rate change was likely increased post-dry heat acclimation but unclear following humid heat acclimation [0.50 (0.18, 0.82)]. Increases in plasma volume at day 5 of acclimation were not different between dry and humid [-0.7% (-6.8, 5.80)], but were possibly retained for longer (at 3-4 days) following humid compared with dry STHA [+4.5% (-3.4, 11.9)] (Figure 1). In conclusion, STHA induced multiple physiological adaptations, divergent between humid and dry conditions. These physiological adaptations did not translate to improved endurance cycling performance in temperate conditions. However, may potentially be utilised to benefit subsequent training.

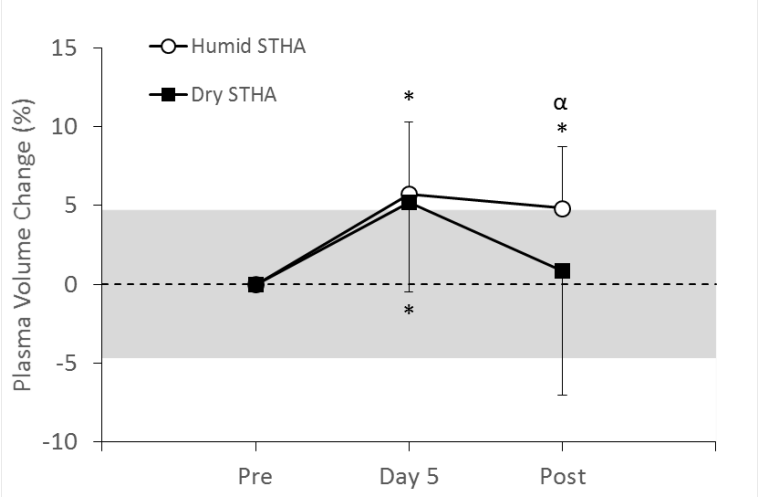

Figure 1: Plasma volume (PV) expansion from pre-heat acclimation (Pre), day 5 of heat acclimation (Day 5) and post-heat acclimation (Post) measurement taken on the 3rd or 4th day after acclimation. Data are represented as % change ± 90% confidence interval, bi-directional error bars are omitted for clarity. Within- and between-condition changes are expressed qualitatively. *α* possible between-condition difference.* possible within-condition difference when compared to Pre. The grey shaded area represents the coefficient of variation for the test.

136 ORAL 13: Heat adaptation

Effectiveness of short-term heat acclimation on intermittent exercise in the heat with moderately-trained males

Andrew Garrett, Fiona Nation, Matt Birkett, Damien Gleadall-Siddall, Rachel Burke, Jarrod Gritt, Christopher Towlson, James Bray, Huw Jones, Grant Abt

The University of Hull, Hull, UK

It is well-established that repetition of heat stress exposure facilitates adaptations to the heat but the protocols used for this purpose have tended to be of a fixed exercise intensity, continuous, involve long-term duration (>7 days) and use hydration. Therefore, the aims of this study were to determine if short-term (5-day) heat acclimation (STHA) with dehydration would reduce physiological strain and improve intermittent exercise tolerance under heat stress.

Ten, healthy, active, moderately-trained, males (mean [SD]; age 25.6 [8.9] y; stature 180.7 [5.6] cm; body mass 83.2 [10.8] kg; VO_{2max} 45.3 [6.5] $mL.kg^{-1}.min^{-1}$; resting cardiac output 6.3 [1.8] $L.min^{-1}$), participated in a STHA programme. The STHA consisted of 90 mins dehydration (no fluid intake), heat acclimation for 5 consecutive days (39.5°C; 60%rh), using the controlled-hyperthermia technique (~rectal temperature [T_{re}] 38.5°C) [1]. Pre and post STHA, a heat stress test (HST) (35°C; 45%rh) was performed consisting of 45 mins of intermittent exercise (nine stages of 5 mins) including resting, walking, moderate-high intensity running), on a motorised treadmill; and nine 6 s maximal sprints on a Watt Bike, as a repeated, maximal sprint performance test. The HST was followed by a running, endurance test to exhaustion. The HST was adapted from exercise intensities of professional football players [2]. A number of blood plasma constituents were measured: percent plasma volume (%PV), aldosterone, total protein, albumin, Na^+, K^+, Cl^-, cortisol and HSP70. Data analysis was by paired t-test. Reported as the mean differences with 95% confidence intervals (95%CI) together with Cohen's *d* effect size for magnitude of change.

Post STHA, there was a decrease of -0.20 T_{re} at 45-min in the HST (95%CI -0.40 to -0.05°C; P=0.03; ES=-0.56); mean skin temperature (-0.80; -1.30 to -0.30°C; P=0.007; ES=-1.46) and mean body temperature (-0.30; -0.50 to -0.10°C, P=0.01; ES=-0.75). Similarly, cardiac frequency (-3: -5 to -1 $b.min^{-1}$; P=0.01; ES=-0.20) and RPE (-2: -3 to -1 units; P=0.01; ES=-0.56) were reduced. Mean average power (MavP) increased (P<0.05) in sprints 7 (111: 25 to 197 W; ES=0.93), 8 (87: -8 to 182 W; ES=0.52) and 9 (240: 9 and 489 W; ES=0.77). A tendency for increased time to exhaustion (167: -15 to 350 s; ES=0.63) was observed (P=0.06).

Short-term heat acclimation (5 days) with dehydration, using the controlled-hyperthermia technique, is effective for physiological adaptations during intermittent exercise in a hot environment.

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137 POSER SESSION 4

Classification of manual dexterity and mobility for firefighter's protective gloves using Don-doff, ASTM dexterity, Minnesota dexterity, Bennett hand tool and ASTM torque tests

Gyu-Tae Bae, Do-Hyung Kim, Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

The purpose of the present study was to propose a new classification guideline to evaluate the dexterity and mobility of firefighter's protective gloves. Our first step was to evaluate the mobility of firefighting gloves using a don-doff test for 13 firefighting gloves from Korea, Japan, Europe and US. The don-doff test is a test to measure time taking to put on and take off gloves (ISO 15383, NFPA 1971). Gloves that displayed lining faults during the don-doff test were eliminated for the next test. Eight male firefighters (43.4 ± 7.0 yr , 173.1 ± 4.4 cm, and 79.9 ± 9.2 kg) participated in both dry and wet glove conditions. The gloves were soaked in water for 2 minutes and then drained for 2 minutes to create wet conditions (NFPA 2013). For the second step, we developed three new types of firefighting gloves which were improved based on the results from the first experiment. The three new types of gloves were evaluated for mobility and dexterity using the identical five tests. Three of the eight firefighters (47.3 ± 5.0 yr in age, 178.6 ± 2.9 cm in height, 88.9 ± 7.8 kg in body mass) participated in the second experiment. As a result of the first experiment, we concluded that 1) the mobility and dexterity tests for firefighting gloves should include the wet test rather than the dry test; 2) Proper size and materials were factors for improving performance from the dexterity tests; 3) Incomplete sewing (to separate lining from out layer around fingers) caused failures in the don-and doff test; and 4) The don-doff test in a wet condition should be the first step for a mobility evaluation, followed by the second step tests of dexterity evaluation: the ASTM dexterity, Minnesota dexterity, and Bennett hand tool test. As a result of the second experiment with newly developed firefighting gloves, we suggested a classification guideline for evaluating the mobility and dexterity of firefighter's protective gloves according to the five test methods (Table 1). Any firefighting gloves that are classified as 'Class C' are not recommended for firefighters. Through the first and second experiments, we developed a simplified test method combined with the ASTM dexterity, Minnesota dexterity, and Bennett hand tool test. Finally, we suggested a combined dexterity test kit for evaluating the dexterity of firefighter's protective gloves.

Table 1: Classification for evaluating the mobility and dexterity of firefighter's protective gloves

Step	Test	Class A	Class B	Class C
1st step	Don & Doff test	Time <15s	15s<Time≤20s	Time≥20s
2nd step	ASTM dexterity test	0<BHC*≤2.0	2.0<BHC≤4	4<BHC
	Minnesota dexterity test	0<BHC≤1.3	1.3<BHC≤1.5	1.5<BHC
	Bennett hand tool test	0<BHC≤1.3	1.3<BHC≤1.5	1.5<BHC
3rd step	ASTM torque test	90≤%BHC	60≤%BHC<90	%BHC<60

*BHC (Bare hand control ratio) $=DTT_g/DTT_b$. Where, DTT_g: consumed time to finish the wear test with gloves on. DTT_b: consumed time to finish the wear test with bare hands.

This research was supported by the Fire Fighting Safety &119 Rescue Technology Research and Development Program (MPSS-Fire Fighting Safety-2015-76; MPSS-Fire Fighting Safety-2015-82)

138 POSER SESSION 4

Maximum heart rate as a correction factor in predicting firefighters' rectal temperature using heart rate

Siyeon Kim, Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

Heart rate has not been widely utilized as a predictor of core temperature due to complex intervention with numerous between-/within-subject variables. This study aimed to investigate potent correction factors which could reduce systemic errors in predictive model of firefighters' core temperature by heart rate. Among various factors related to heart rate, between-subject variables involving cardiovascular responses in different ways were preferentially selected: age, physical fitness (VO_{2max}, HR_{max}), and heat tolerance. Five middle-aged male firefighters, five young male firefighters and six young male students participated in three experimental trials: 1) measurement of VO_{2max} and HR_{max}, 2) heat tolerance test (HTT), and 3) intermittent exercise while wearing firefighters' PPE (FFT). In HTT, participants walked for 2 hours on a treadmill at 5 km/h with 2% slope at an air temperature of 40^{o}C and 40%RH while wearing light clothing. In FFT, participants repeated 10 min walking followed by 5 min post-exercise rest 3 times after initial stabilization for 10 min in 28^{o}C and 40 %RH. Throughout HTT, rectal temperature (T_{re}) and heart rate were continuously measured, whereas skin temperature on seven regions and oxygen consumption were additionally measured in FFT along with continuously measured T_{re} and heart rate. Heat tolerance was relatively evaluated by criteria of increase in Tre and heart rate. In FFT, experimental data measured only during rest period were analysed. In order to get stabilized data, 1 min averaged data at least 3 min after finishing each exercise period was used. The individual predictive equation of Tre by heart rate was calculated by simple linear regression analysis. From the result, the slope of the line and T_{re} value when heart rate was 120 bpm (T_{120}) was calculated and used as dependent variables. Kruskal-Wallis test and Pearson's correlation test were conducted, and multiple linear regression was utilized to demonstrate the improvement in prediction of rectal temperature with the additional variable. As a result, no significant effect by age, VO_{2max}, and heat tolerance on individual predictive equation was found ($p > 0.05$), but HR_{max} solely presented a significant correlation with T_{120} ($r = - 0.687$, $p = 0.007$), not slope. Multiple linear regression with HR_{max} showed improved coefficient determination ($R^2 = 0.803$, $p < 0.001$), when compared with simple linear regression ($R^2 = 0.774$, $p < 0.001$). On the other hand, age-predicted HR_{max} did not show any improvement in R^2. The current result suggests that HR_{max} can be used as a correction factor to improve predictive equations of core temperature by heart rate measured during rest time with less emphasis on other variables (age, VO_{2max}, heat tolerance) as predictors.

This research was supported by the Fire Fighting Safety &119 Rescue Technology Research and Development Program (MPSS-Fire Fighting Safety-2015-76; MPSS-Fire Fighting Safety-2015-82)

139 POSER SESSION 4

Firefighter personal protective equipment and burn injuries: an empirical study in Korea

Do-Hee Kim[1,2], Siyeon Kim[2], Hyo-Hyun Lee[2], Joo-Young Lee[2,1]

[1]Research Institute of Human Ecology, Seoul National University, Seoul, Republic of Korea, [2]COMFORT Laboratory, Seoul National University, Seoul, Republic of Korea

The purpose of this study was to investigate opinions on present firefighter's personal protective equipment (PPE) and their burn injury experiences during the line of duty. Data were collected by a questionnaire for a representative quota sample of firefighters in 15 administrative districts in Korea in April, 2016. The questionnaire was designed in three parts: 1) demographic and anthropometric information, 2) opinions on firefighter PPE currently worn, and 3) burn injuries experienced in firefighting. A total of 1,050 printed copies of questionnaires were distributed to professional firefighters and 981 questionnaires were used in the final analysis. The main findings were as follows: The majority of respondents selected 'protection from fire and flame' as the most important performance factor of PPE. About 95% responded 'always equipped' for helmets, protective gloves, and turnout gear while firefighting. In the case of station uniforms and fire hoods, however, the answer to 'always equipped' was relatively low because firefighters felt discomfort or inconvenience by wearing the station uniform or fire protective hoods. Fire protective gloves were mainly discontented items and the 78.6% of respondents selected their gloves as the equipment that was the most easily damaged. It is also noteworthy that a large number of firefighters reported their PPE damage, mobility decline and heat strain caused by wearing PPE, whereas a relatively small number of respondents reported the experience of burns. Just 16.1% of total respondents reported burn injuries including first-to-third degree burns while firefighting. This incidence rate from the present survey was higher than values in previous studies. Only 3.6% of the total respondents who had experienced burns, however, said that they had received support from public funds for burn treatment, while the majority of them did not treat burns or treated with self-medication, and 22% had treated on their own. Regarding burn size, nearly 90% of respondents experienced less than 1% total body surface area burns. The most common region of burn injury was the hand and wrist, followed by the face and neck. Most of the burns on these regions occurred despite wearing gloves and helmets. Space between gloves and sleeves could cause burns on the hands and wrists. The hem of the fire hood where there is also a soft underbelly was a common area for burns. Relatively few burns around the trunk were reported. Despite the low incidence of burn injury, it was revealed that the hand, wrist, face and neck were the most vulnerable for burns. Because the body regions were functionally important to keep manual dexterity and visibility while firefighting, it is required to prevent burns to the above mentioned regions by technically well-made PPE. (This research was supported by MPSS- Fire Fighting Safety-2015-82.)

140 POSER SESSION 4

Fire service instructors' working practices: A United Kingdom Survey

Emily Watkins, Mark Hayes, Peter Watt, Alan Richardson

University of Brighton, Eastbourne, East Sussex, UK

Fire Service Instructors (FSI) experience high levels of physiological and perceptual strain on a regular basis, due to their frequent exposure to live fire situations. Consequently, they are at risk of exertional heat illness and cardiovascular events, and may experience physiological and immunological stress similar to overtraining. FSI have also made anecdotal reports of ill health, however symptoms have not been formally documented across different Fire Services. Analysis of the symptoms experienced and working practice of FSI will inform interventions aimed at minimising health risks. The aim of this work was to collect data on FSI health and working practice.

An online survey, consisting of 37 questions, was distributed via email and social media to United Kingdom (UK) FSI. Questions were grouped into 6 sections: demographics, exposure types, preparation, recovery, health, and additional comments. Categorical data responses are reported in frequencies and percentages, and Pearson's chi square analysis conducted to measure the associations between variables, with significance set at $p<0.05$.

Seventy-three (37%) UK FSI responded to the survey (age: 43 ± 7 yrs, time in job: 4 ± 4 yrs). Breathing Apparatus training was the most common heat exposure experienced, with 26 (41.9%) FSI having completed 6-10 of these exposures in the previous month. The combined number of exposures experienced ranged from 2-10 per week. However, 19 (31.3%) FSI had no limit to the number of heat exposures. Few FSI followed hydration guidelines (23, 38.7%), or pre or post cooling methods (14, 24.6%). New symptoms of ill health were reported by 28 (46.7%) FSI, with key themes being: fatigue, headaches, broken sleep and heart palpitations. FSI with ≥6 Breathing Apparatus training heat exposures per month were 2.9 times (p = 0.047) more likely to experience new symptoms.

In summary, a large proportion of FSI are experiencing new symptoms of illness after starting their career, and whilst some guidelines exist for hydration and exposure limits, they are not universally in place to reduce the risk of future health problems. Greater dissemination of research findings to the Fire Service is also needed, as survey responses suggest information is not reaching, or being used, by the end user.

141 POSER SESSION 4

The impact of shape memory alloy size on the protective performance of fabrics used in fire-fighter's protective clothing

Yehu Lu[1,2], Nini Ma[1], Lijun Wang[1], Shuai Wang[1]

[1]College of Textile and Clothing Engineering, Soochow University, Suzhou, China, [2]National Engineering Laboratory for Modern Silk, Soochow University, Suzhou, China

Fire-fighters and emergency rescuers often suffer a lot of hazards, including the heat (fire, radiation and convection), the biological (blood borne and pathogens), the chemical (skin contact), the physical (impact, debris and rough surface) and the environmental (extreme temperature and high humidity) disasters. Factors affecting the rescue time and efficiency are the thermal protection and comfort property of protective clothing. The protective performance of fire-fighters' protective clothing can be improved by increasing the thickness of the fabric and the number of layers, however, this has the adverse effect of increasing the thermal load on the wearer, therefore, inducing heat stress which can impair the wearer's ability to perform their task effectively and efficiently.

To improve the environmental adaptability, shape memory alloy (SMA) springs were applied between moisture barrier and thermal liner to develop novel fabric combinations of fire-fighters' protective clothing with the function of thermal dynamic adjustment. There are 3 deformation heights of SMA springs, i.e., 0, 16 and 32 mm respectively, and 3 different arrangements, thus 7 fabric combinations in total were produced. The protective performance of these fabric combinations were tested in hot surface contact and thermal radiation tests. The results indicated that the SMA could effectively improve the protective performance of fabric combinations, and the height of SMA spring affected the air gap distribution, thus determined the heat insulating property. Moreover, the impact of deformation height of SMA spring was affected by the arrangement. The research findings may be helpful to engineer optimized deformation height with superior arrangement of SMA springs in the fabric system, and develop high performance smart fire-fighters' protective clothing.

Effects of combined cooling applications before and during exercise on heat strain while wearing protective clothing

Ken Tokizawa[1], Su-young Son[1,2], Tatsuo Oka[1], Akinori Yasuda[1]

[1]National Institute of Occupational Safety and Health, Japan, Kawasaki, Japan, [2]Kyungpook National University, Daegu, Republic of Korea

Pre-cooling is a popular strategy for alleviating heat strain. Because whole body water immersion that commonly used to precool in experimental studies is not always possible in all field settings, we have previously examined effects of fanning + spraying and hands + feet-cooling on heat strain while wearing protective clothing. The practical pre-cooling reduced core temperature elevation during exercise by nearly half compared with no-cooling trial. In the present study, we evaluated effects of combined applications of the practical pre-cooling and wearing a tube-lined perfusion vest using field-portable cooler during exercise on heat strain. Eight males engaged in 60 min of walking (3 km/h) in a hot environment (33°C, 60%RH) while wearing protective clothing under three separate conditions: no-cooling control (CON), wearing a tube-lined perfusion vest during walking (VEST), and pre-cooling (fanning to the face, hands and feet cooling, and wearing the vest) for 30 min before walking and wearing the vest during walking (PC+VEST). Rectal temperature increased by 0.8 ± 0.1°C during walking in the CON. The increase in the VEST was lower than in CON (0.6 ± 0.1°C, $p < 0.05$), and further reduction was observed in the PC+VEST (0.2 ± 0.1°C, $p < 0.05$). Sweat rate on the chest and percentage reduction in body weight were also inhibited in the VEST compared with the CON ($p < 0.05$, respectively). In the PC+VEST, the inhibitions were greater than in the VEST ($p < 0.05$, respectively). Thermal sensation and pleasantness by ratings of visual analogue scale were lower in the VEST and the PC+VEST than in the CON ($p < 0.05$), whereas no differences in the perceptions were observed between the VEST and the PC+VEST. These results suggest that combined applications of the pre-cooling and wearing a tube-lined perfusion vest during exercise can additively inhibit core temperature elevation and dehydration in the heat.

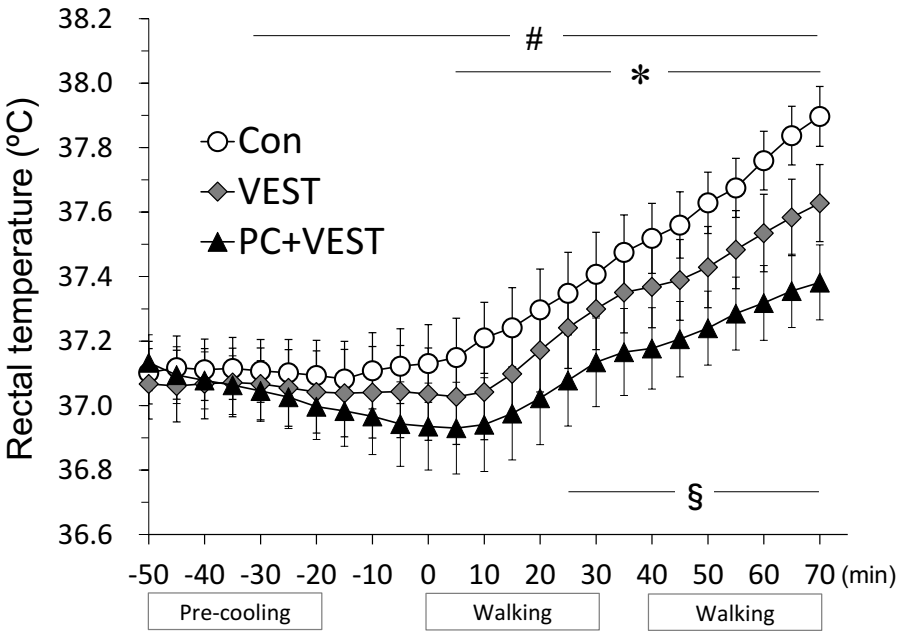

Figure 1: Rectal temperature responses in the non-cooling control (Con), wearing a tube-lined perfusion best during walking (VEST), and pre-cooling and wearing the vest (PC+VEST) trials. *Different ($p < 0.05$) between Con and VEST; #different ($p < 0.05$) between Con and PC+VEST; §different ($p < 0.05$) between VEST and PC+VEST.

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Effects of layering on thermal insulation and vapor permeability

Adam Potter, Julio Gonzalez

United States Army Research Institute of Environmental Medicine (USARIEM), Natick, MA, USA

Thermal insulation of clothing depends largely on the air trapped between the skin and the clothing layers. Textile from clothing layers and the air between layers provide insulation. Along with insulation, one thick layer or several thinner layers both provide specific benefits of convenience (less layers = less clothing to deal with; more layers = more flexibility for tailored use). The purpose of this work is to examine the effects of layers and air gaps on thermal insulation and vapor permeability. Standard tests for the thermal and evaporative resistances (R_{ct} and R_{et}) were conducted (ASTM F1291-10 & ASTM F2370-10) for eight military ensembles within climate controlled environmental chambers. Each of the eight ensembles varied in the types of material and number of layers (2 - 5 layers); while one included a 6th layer in the form of ballistic armor. Thermal insulation (clo) ranged from 1.30 – 2.71 (1.87 ± 0.57), vapor permeability (i_m) 0.32 – 0.55 (0.41 ± 0.08), and evaporative potential (i_m/clo) ranged from 0.14 – 0.40 (0.24 ± 0.09). The tests showed generally that with the increasing number of layers came increases in thermal insulation and decreases in evaporative potential (Fig 1). No large differences were found between ensembles of similar combined sizes, implying that thermal insulation is provided mostly by the amount of trapped air in an ensemble rather than the number of layers. This is supported by the data comparing Ensemble 4 to Ensemble 8 (Ensemble 4 + body armor); where the additional weight of the body armor compressed the air spaces and thus reduced the thermal insulation while still decreasing the evaporative potential. As physics-based measures, the repeatability of manikin derived values is high, making differences between these measures relatively absolute. That said, the absence or inclusion of statistical significance may or may not translate to meaningful physiological outcomes. Vapor permeability depends highly on the type of textile and less dependent on the amount of air space. This work provides some quantitative evidence that the thermal insulation is highly dependent on the addition of air volume within clothing ensembles.

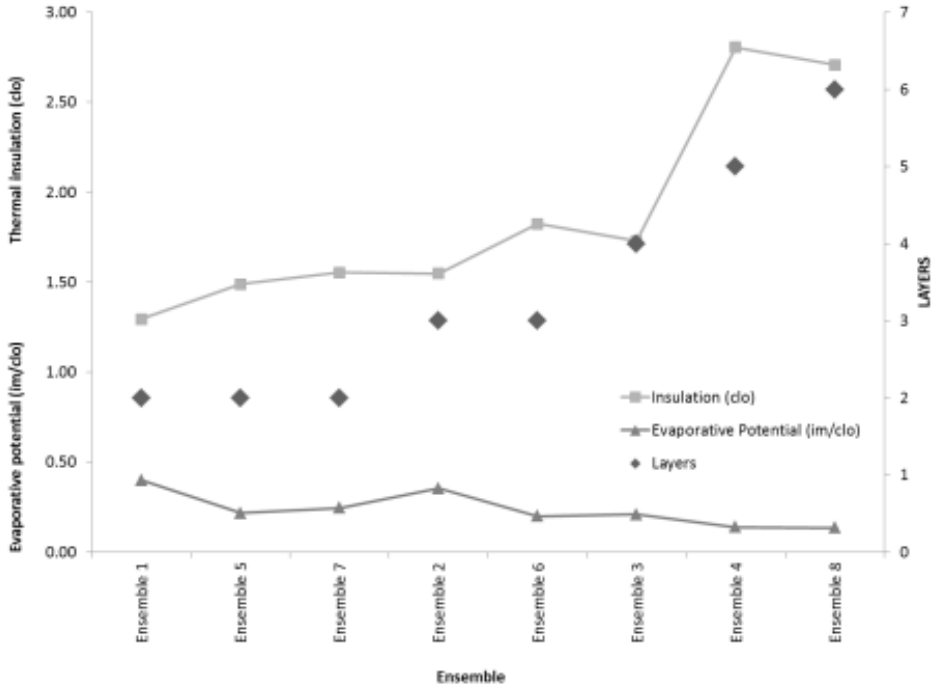

Figure 1: Plot of thermal insulation (clo) and evaporative potential (i_m/clo) sorted by number of layers

Airflow in the microenvironment under sportswear generated by running motion

Rui Miyazawa[1], Tomonori Sakoi[1], Satoshi Hosoya[1], Ikue Mori[2]

[1]Shinshu University, Ueda, Japan, [2]AIST, Tsukuba, Japan

Body motion causes the shape change of clothing. For a cyclic motion such as running, the motion speed toward one direction and that of the opposite direction differ. This difference may emphasize the airflow in the microenvironment under clothing to flow in one direction. The purpose of this study is to confirm whether predominant airflow in one direction occurs by the cyclic body motion.To encourage the airflow in the microenvironment, we prepared a gym clothing having ventilation sections in front and back, Subject wore this clothing and ran on a treadmill at the speed of 8 km/hr. The airflow of the surrounding environment was kept calm. Airflow in the microenvironment was estimated by use of a tracer gas. The gas supply point was set at the position at 20 cm below the armpit and 20 cm from the front median sagittal plane. The sampling points of air were set at 3 points, x0, x1, and x2 (−2 cm, 2cm, 5cm to downward from the gas supply point, respectively) For each sampling point, the tracer gas concentration of the sampled air was measured determined by the average for 10 minutes. Two subjects participated in the experiments. The results are shown on Fig. 1.The concentrations at x1 was higher than that at x0 even the distance of both points from the gas supply point were the same. Therefore, it can be concluded that air flow from front to back occurred. This can be explained as follows: When pulling the arm behind, clothing attaches to the human body from front to back and pushed the air inside the microenvironment to the back. When returning the arm to front, opposite airflow occurs. The air permeability of textile is high for laminar slow flow and low for turbulent high speed flow. The speed to push the arm behind is higher than the speed returning to the original position. The difference in speed was one of the possible reasons to cause predominant air flow toward the rear direction in the microenvironment for the running subjects.In this study, we confirmed that body motion accompanied by treadmill running caused predominant airflow from front to back direction in the microenvironment a gym clothing even in calm air environment.

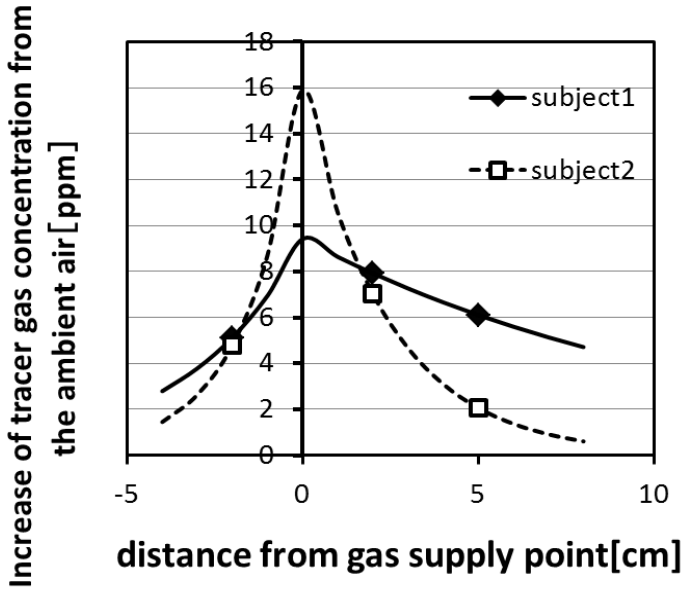

Figure 1: Gas concentration measured at the ventral side

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Physiological and logistic considerations in the integration of females in the IDF combat units

Daniel Moran[1,2], Yoram Epstein[3], Ran Yanovich[3]

[1]Ariel University, Ariel, Israel, [2]Washington College of Education, Yavne, Israel, [3]Heller Institute, Sheba Medical Center, Israel

The purpose of this study was to examine the feasibility of females to serving in the Israeli Defence Forces (IDF) sex integrated combat units.

A total of 246 healthy recruits (188 females and 58 males) entering a 4-month basic training (BT) program in a sex integrated combat unit volunteered for this study. Pre and post BT measurements of bone quality (by pQCT), maximal aerobic capacity (VO_{2max}), anaerobic capacity (Wingate test), and upper body strength (push-ups repetitions) were collected.

All measures of bone geometry and strength pre BT were significantly greater in males than in females ($p<0.0001$) (e.g., trabecular volumetric bone mineral density by 8.4%). VO_{2max} and anaerobic capacity were higher for males by 22.1% and 28.6%, respectively ($p<0.0001$). Upper muscle strength was higher by 13.1% in males. To note, there was a general overlap in these measurements of 10% between females and males. The top 10% females overlapped with the lower 10% of the males in aerobic capacity, anaerobic test, and bone strength. For both sexes, measurements of aerobic capacity, anaerobic capacity, and upper body muscle strength were significantly higher ($p>0.05$) post BT than pre BT. However, the gap between males and females remained significant.

Physiological point of view - Most females exhibit lower bone quality, lower aerobic and anaerobic capacities, and lower muscle strength. These results question the feasibility of integrating females into combat professions. Nevertheless, there are females who are physiologically fit enough who can serve and probably succeed in various combat professions. Logistic point of view - In Israel, all male and female 18 years old are required to do compulsory service. In principal, fit females should be allowed to serve in all combat professions. However, combining a small percentage of females in a masculine combat unit raises two main issues that need to be considered: cost effectiveness of the integration and the ability to cope with the demands of heavy infantry or Special Forces units.

The ability to integrate females in combat professions should be assessed on the resources (i.e., cost-effectiveness) which are needed to train female soldiers to the level necessary to gain the physical capabilities required from combat soldiers.

The effect of high-intensity short-term heat acclimation on exercise capacity in the heat in trained cyclists

Tom Reeve[1], Fernando Teles[1], Manuela Chianca[1], Ralph Gordon[1], Paul Laursen[2], Jason Lee[3,4], Christopher Tyler[1]

[1]University of Roehampton, London, UK, [2]Auckland University of Technology, Auckland, New Zealand, [3]DSO National Laboratories, Singapore, Singapore, [4]National University of Singapore, Singapore, Singapore

Exercise performance and capacity are impaired in hot environments due to greater physiological and perceptual strain. Heat acclimation (HA) can reduce the strain and exercise impairment; however, it is often time-consuming (7+ d). Shorter (5 d) HA interventions appear effective although many are still inefficient - using prolonged heat exposure and low intensity exercise. HA effectiveness appears dependent upon the thermal impulse experienced and therefore increasing the exercise intensity may reduce the HA duration required. The aim of the current study was to investigate the effectiveness of high-intensity short-term HA.

13 male cyclists (VO2max: 60 ± 9 ml.kg-1.min-1) undertook two heat stress tests (HSTs) - cycling to volitional exhaustion in the heat (35°C; 50% rh). One HST was performed ~3 days before (HST1) and one ~3 days after (HST2) 5 consecutive days of high-intensity HA. HA involved 30 min of heat exposure (35°C; 50% rh): 6 min warm-up (50% Wmax) followed by 12 x 1 min 100% Wmax sprints interspersed by 1 min recovery bouts. Exercise capacity, rectal temperature (Tr), mean skin temperature (Tsk), mean body temperature (Tb), heart rate (HR), and thermal sensation (TS) were recorded pre- and post-HST. Aldosterone and plasma volume were measured pre-HST, and rating of perceived exertion (RPE) was recorded at termination. Hedges' g effect sizes were calculated.

Cycling capacity was reduced following high-intensity HA (77.2 ± 34.2 vs. 56.2 ± 24.4 min; g = 0.68). Resting Tr (37.0 ± 0.3 vs. 36.9 ± 0.2°C; g = 0.67), Tsk (34.0 ± 0.5 vs. 33.8 ± 0.6°C; g = 0.43), Tb (36.0 ± 0.3 vs. 35.8 ± 0.3°C; g = 0.68), HR (77 ± 19 vs. 73 ± 15 b.min-1; g = 0.26), and plasma volume (57 ± 4 vs. 56 ± 3%; g = 0.45) were higher in HST1 vs. HST2, respectively. Resting aldosterone (202 ± 59 vs. 211 ± 77 pg.ml-1; g = 0.13) and TS (4.5 [4.0 – 5.0] vs. 4.5 [4.0 – 5.0]; g < 0.01) were similar in HST1 and HST2. Exercise was terminated at a lower Tr (39.0 ± 0.5 vs. 38.9 ± 0.5°C; g = 0.30), Tb (37.7 ± 0.5 vs. 37.6 ± 0.5°C; g = 0.24), and TS (8.0 [7.5 – 8.0] vs. 7.5 [6.5 – 7.5]; g = 1.1), but a higher HR (160 ± 16 vs. 166 ± 17 b.min-1; g = 0.32) and RPE (19.0 [18.8 – 20.0] vs. 19.5 [19.0 – 20.0]; g = 0.61) in HST2. Tsk was similar (35.2 ± 0.7 vs. 35.3 ± 0.8°C; g = 0.17) at volitional termination.

Despite inducing beneficial physiological changes, the high-intensity HA impaired subsequent exercise capacity. ~3 days of rest following the 5th day of high-intensity HA might not have provided the participants with sufficient recovery.

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Effects of 14-day acclimation to cold and heat on cold tolerance in males

Joonhee Park, Sora Shin, Sungjin Park, Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

According to the Köppen-Geiger climate classification, Korea is classified as Dwa and Dfa which has hot summer and cold winter. Because Koreans are exposed to a wide range of ambient temperature during a year from about -15 to 35^{o}C, both heat wave and cold wave become a threat for people who are vulnerable to extremes of heat or cold. We investigated the effects of parallel acclimation to cold and heat on cold tolerance for males. The parallel acclimation training lasted for a consecutive 14 days for eight healthy males (24.1 ± 3.8 yr in age, 174±5 cm in height, 72.6±12.3 kg in body mass, and 1.9±0.1 m^2 in BSA) and the daily acclimation program consisted of two hours for cold exposure in the morning and two hours for heat exposure in the afternoon. In the morning, all participants were exposed to a cold environment (10^{o}C in air temperature and 40%RH in air humidity) and kept a sitting position for two hours. After the termination of 2-hr cold exposure, subjects had lunch and took a break for about two hours for recovery. Thereafter they had exercise- and passive-heat acclimation training for two hours in the afternoon: two-bouts of 45-min treadmill exercise (5.3 $km \cdot hr^{-1}$) and 15-min rest in a hot environment (30^{o}C in T_a and 60% RH). Before and after the parallel acclimation training of 14 days, subjects participated in cold tolerance tests. A significant difference was found in rectal temperature between pre- and post-tests: 37.22 ± 0.16^{o}C for the pre-test and 37.09 ± 0.22^{o}C for post-test (P=0.027). However, mean skin temperature showed no significant differences between pre- and post- tests: 27.29 ± 0.84^{o}C for the pre- test and 27.17 ± 0.48^{o}C for the post-test. Heart rate and blood pressures in the post-test were lower than those in the pre-test (all P<0.05). No significant difference was found in energy expenditure between pre- and post- tests. Participants felt less cold in the post than in the pre-test (P<0.05) while there was no significant difference in thermal comfort. These results indicate the possibility of improvement in cold tolerance under both cold and heat exposure in daily life.

Sex differences in the development of peripheral sudomotor sensitivity to acetylcholine

Hiroyuki Ueda[1], Tomoko Ichinose-Kuwahara[2], Chucheep Praputpittaya[3], Narihiko Kondo[4], Yoshimitsu Inoue[2]

[1]Osaka Shin-ai college, Osaka, Japan, [2]Osaka International University, Osaka, Japan, [3]Mae Fah Luang University, Chiangrai, Thailand, [4]Kobe University, Kobe, Japan

The present study examined sex differences in the development of the sweat gland response to acetylcholine (ACh). Sweating responses were induced on the forearm and thigh in 6–24-year-old (grouped as follows; 8, 11, 13, 15, and 20 yr) Thai males and females(n=130 in total) by ACh iontophoresis using a 10% solution at 2 mA for 5 min at 26ºC and 50% relative humidity. The ACh-induced sweating rate (SR) on the forearm and thigh of males increased from the ages of 15 and 13 yr, respectively. Little growth-related increase in SR was found in females. Thus, the SR in males was significantly greater than that in females beginning at 13 yr. Sweat output per a gland (SGO) on the forearm and thigh increased beginning at 13 yr in males. SGO on the forearm and thigh increased in females from 8–11 years old, but no significant age difference was detected. Results showed that SGO on the forearm and thigh was significantly greater in males than in females beginning at 13 and 15 yr, respectively (Fig.1). The number of active sweat glands per unit area decreased with age in both sexes. Our findings demonstrate no sex differences in sweat gland function in prepubertal children. Although functional sweat glands develop after puberty in boys and girls, less development occurs in girls than that in boys. Therefore, the sex differences in the sweat gland function appear after puberty.

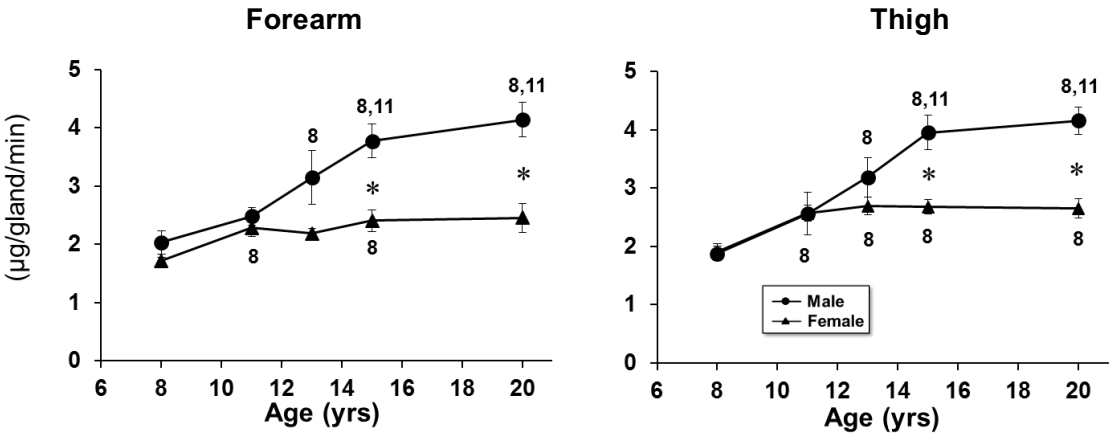

Figure 1: Sweat gland output (SGO) on the forearm and thigh during the acetylcholine iontophoresis test over the age in each sex. Values are means ± SEM. Numbers indicate a significant age difference at $P < 0.05$. * Significantly different between female and male subjects in each age group at $P < 0.05$.

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Seasonal changes in environmental temperature increase UCP1 in subcutaneous white adipocytes

Maria Vliora[1], Petros C. Dinas[1,4], Leonidas Ioannou[1], Eleni Nintou[1], Marnie Granzotto[2], Marco Rossato[2], Roberto Vettor[2], Athanasios Z. Jamurtas[3], Yannis Koutedakis[3,4], George S. Metsios[4], Andreas D. Flouris[1]

[1]FAME Laboratory, Department of Physical Education and Sport Science, University of Thessaly, Trikala, Greece, [2]Department of Medicine – DIMED, Internal Medicine 3, University of Padova, Padova, Italy, [3]School of Physical Education and Sport Science, University of Thessaly, Trikala, Greece, [4]Institute of Sport, Faculty of Education Health and Wellbeing, University of Wolverhampton, Walsall, UK

Uncoupling protein one (UCP1) dissipates chemical energy in the mitochondria of brown adipocytes to produce heat in response to cold exposure. In humans, this process may increase daily resting energy expenditure by up to 28%, which may contribute to body weight loss. White adipose tissue (WAT) may also express UCP1, indicating a brown adipose-like phenotype with a thermogenic capacity. The aim of this study was to examine whether seasonal changes in environmental temperature affect UCP1 mRNA and/or protein expression in subcutaneous WAT. We evaluated 29 healthy non-smoking adult men (age: 35.22±6.86; BMI: 27.26±4.17) who signed an ethically approved written consent form. To assess UCP1 mRNA and protein expression in WAT cells, the participants underwent three repeated subcutaneous WAT biopsies at baseline and after two and four months. We also obtained daily mean air temperature from a weather station near the area that the participants lived, for the entire experimental period. UCP1 mRNA was significantly higher during the spring (air temperature: 14.69±4.25°C) than during summer (air temperature: 25.99±2.47°C; P=0.02). Receiver Operating Characteristics (ROC) curve analyses revealed that UCP1 protein levels were increased when the environmental temperature was ≤7.8°C (P=0.05; sensitivity=0.89; specificity=0.36) and/or when the difference in the environmental temperature between two consecutive biopsies was ≥3.5°C (P=0.002; sensitivity=0.84; specificity=0.63). The same analysis indicated that UCP1 mRNA was increased when the actual environmental temperature was ≤15.51°C (P=0.07; sensitivity=0.71; specificity=0.57) and/or when the difference in the environmental temperature between two consecutive biopsies was ≥5.1°C (P=0.05; sensitivity=0.41; specificity=0.85). We conclude that seasonal changes in environmental temperature affect both UCP1 mRNA and protein expression in subcutaneous adipose tissue in humans. These observations should be taken into consideration when evaluating non-shivering thermogenesis in human.

The relationship between body water content measured by bioelectric impedance analysis and whole body sweat loss and body temperature in response to heat exposure

Norikazu Ohnishi[1], Erika Nagasoe[1], Wakana Nakai[1], Naoki Nishimura[2], Takaaki Matsumoto[3], Naotoshi Sugimoto[4]

[1]Mie Prefectural College Of Nursing, Tsu, Mie, Japan, [2]Nihon Fukushi University, Mihama, Aichi, Japan, [3]Chukyo University, Toyota, Aichi, Japan, [4]Kanazawa University, Kanazawa, Ishikawa, Japan

Dehydration often potentiates the rise in body temperature in a hot climate or/and during exercise with inhibiting evaporative heat loss by sweating. Accordingly, assessing one's hydration level is thought to provide important information for preventing heat illness. The bioelectric impedance analysis (BIA) method, which measures bioelectrical impedance to an injected constant current, is expected to be useful as a non-invasive and inexpensive technique for assessing the water content of the body. Furthermore, the multi-frequency BIA technique allows evaluation of the amount of extracellular water (ECW), total body water (TBW) and intracellular water (ICW = TBW – ECW) by applying the alternating current at a particular high and low frequency. The aim of the present study is to evaluate whether the BIA method could significantly provide the information of hydration state as an indicator for the assessment of heat tolerance, by investigating the relationship among each of the body water content measured by the BIA method and whole body sweat loss measured by weight change and rise in body temperature in response to heat exposure. The experiments were conducted on healthy adult 3 male and 10 female subjects who were asked to sit in the resting position in a climatic chamber, with room temperature set at 38.5 degree C and 60% relative humidity, for 90 minutes. The contents of TBW, ECW and ICW were measured using a body composition analyser (MLT-550N, SK Medical Electronics, Japan), and body weight and urine volume were measured with the accuracy of 1 g just before and after heat exposure. Tympanic temperature was continuously recorded using a thermistor thermometer during heat exposure. The TBW loss was calculated from the sum of the urine volume and the whole-body sweat loss, which is calculated as the difference in body weights before and after heat exposure. The relationship of these parameters in response to heat exposure was compared. There was a tendency to indicate a positive linear correlation between TBW measured by the BIA method before the heat exposure and whole-body sweat loss and a negative linear correlation between ECF measured before the heat exposure and the change in tympanic temperature. However, the changes in the body water content measured by the BIA method did not reflect the absolute value of the TBW loss. These results suggest that the multi-frequency BIA method could indicate the relative change in the hydration state in response to heat exposure. Nonetheless, more studies would be required to use this procedure with precise accuracy.

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Body regional heat pain thresholds in Korean young males by methods of limit and level

Sungjin Park, Sang-Hyun Roh, Do-Hyung Kim, Dahee Jung, Joo-Yong Lee

Seoul national university, Seoul, Republic of Korea

Heat pain sensation is delivered to give an important message to protect our body from noxious heat. Cutaneous thermal thresholds have been measured by the method of level or limit. The purpose of this study was to examine body regional heat pain thresholds using the method of limit and level. A total of 16 young males (23.2 ± 3.2 yr, 174.9 ± 4.9 cm, 70.1 ± 8.6 kg, and 1.85 ± 0.12 m^2) participated in this study by lying in a supine position at an air temperature of 28^oC and 35%RH. A thermal stimulator (Intercross-210, Intercross Co., Japan) was used and the temperature increase of the probe was set at 0.1$^oC \cdot s^{-1}$ starting temperature of 33^oC for the method of limit (Figure. 1 Left). Method of level utilizes stimuli of predetermined levels of intensity and duration. The thermode was set at temperature of 33^oC for a baseline and it is increased to the first stimuli of 44^oC from the baseline temperature at the rate of 10$^oC \cdot sec^{-1}$, maintains for 3 seconds and went back to the baseline temperature of 33^oC. Interstimulus intervals were 5 seconds. Subsequent stimuli were of progressively 0.5^oC higher intensity (Figure 1 Right). All measurements were repeated three times on the 14 body regions. The results showed that 1) pain thresholds were approximately 3~4^oC greater for the method of level than for the method of limit and this result corresponded to all 14 body regions (all $P<0.05$); 2) the correlation coefficient (r) between values by the two methods was 0.819 ($N=14$, $P<0.01$); 3) lower body regions (the thigh, calf and sole) had higher heat pain thresholds than upper body regions (the neck, chest, forearm and waist) by both methods; and 4) body regional subcutaneous fat thickness showed no relationships with heat pain thresholds except for the upper arm ($r=0.596$, $P=0.015$, $N=16$).

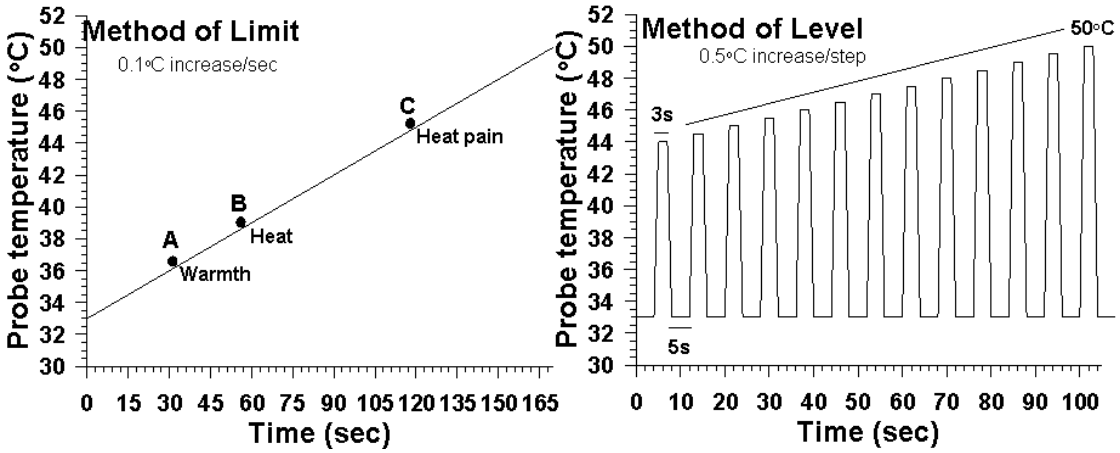

Figure 1: Method of limit (left) and method of level (right) in this study.

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Thermal perceptions of individuals with a spinal cord injury

Katy Griggs[1,2], George Havenith[2], Mike Price[3], Vicky Goosey-Tolfrey[1]

[1]Peter Harrison Centre for Disability Sport, School of Sport, Health and Exercise Sciences, Loughborough University, Loughborough, UK, [2]Environmental Ergonomics Research Centre, Design School, Loughborough University, Loughborough, UK, [3]Department of Biomolecular and Sports Science, Coventry University, Coventry, UK

Introduction: Individuals with a spinal cord injury (SCI) have a loss of sweating capacity and vasomotor control below their lesion level. As the level of the SCI increases, afferent information in relation to the thermal state of their body reduces, as a result of the decreased area of sensate skin. This study aimed to investigate how physiological and perceptual responses are altered at rest as a consequence of an SCI and the effect lesion level has on these responses. Methods: 23 male participants volunteered for the study; eight able-bodied individuals (AB), eight individuals with paraplegia (PA, injury to the thoracic, lumbar or sacral segments of the spinal cord) and seven individuals with tetraplegia (TP, injury to the cervical segments of the spinal cord). Participants initially rested in a climatic chamber (37.2 ± 0.2°C and 20% relative humidity (RH)) for 20 minutes. Following this, the RH of the environment was increased using a stepwise protocol by 5% every 7 minutes (ambient temperature remained constant) up until 65% RH. Gastrointestinal temperature (Tgi) and mean skin temperature (Tsk) were measured throughout whilst perceptual responses of whole body thermal sensation, thermal comfort and wetness sensation were recorded before each increment in RH. Results: TP had a greater change in Tgi compared to AB ($p=0.01$), whilst both PA and TP had a greater increase in Tsk compared to AB ($p=0.01$). There were no significant differences between groups for thermal sensation ("hot" at 65% RH) or thermal comfort ("slightly uncomfortable" at 65% RH). Wetness sensation was significantly higher in TP than AB at 30-35% RH and 50-65% RH ($p<0.001$). Discussion: Despite TP having a greater change in both Tgi and Tsk compared to AB and a greater change in Tsk in PA than AB, all groups perceived to be under a similar amount of thermal strain. Thus these data indicate that individuals with an SCI may be unable to judge the magnitude of their thermal strain. Wetness sensation was lower in TP compared to AB likely due to their loss/minimal sweating capacity and small body surface area of sensate skin. Further work is needed to understand whether thermal perceptions of individuals with an SCI are related to their body's thermal state, regional perceptual responses are more closely related to their physiological responses or if individuals are able to perceive dynamic changes in Tgi and Tsk.

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Role of cyclooxygenase in the vascular responses to extremity cooling in Caucasian and African descent males

Matthew Maley[1,2], Jim House[1], Mike Tipton[1], Clare Eglin[1]

[1]University of Portsmouth, Portsmouth, UK, [2]Queensland University of Technology, Brisbane, QLD, Australia

Compared with Caucasians (CAU), African descent (AFD) individuals are more susceptible to non-freezing cold injury (NFCI) (DeGroot et al., 2003), perhaps due to experiencing greater cutaneous vasoconstriction and cooler finger skin temperatures during extremity cooling (Maley et al., 2014). Given that AFD have greater levels of oxidative stress, perhaps produced through the enzyme cyclooxygenase (COX) (Vanhoutte, 2011), and that COX produces the vasoconstrictor thromboxane A_2, it is possible that this enzyme may contribute to the accentuated vasoconstrictor response in AFD during local cooling.

Using a placebo-controlled, crossover design the present study tested the hypothesis that COX may, in part, be responsible for the exaggerated vasoconstrictor response to local cooling in AFD. Twelve AFD and twelve CAU young healthy males completed foot cooling and hand cooling (separately, in 8 °C water for 30 minutes, hand / foot in a plastic bag during immersion) with spontaneous rewarming in 30 °C air following placebo or aspirin (COX inhibition) treatment. Skin blood flow, expressed as cutaneous vascular conductance (flux•mmHg^{-1}), and skin temperature (T_{sk}) were measured throughout.

Toe skin blood flow and T_{sk} did not differ between ethnicities during foot cooling. However, responses to hand cooling differed between ethnicities. Responses to both foot and hand cooling principally did not differ between placebo and COX inhibition. Specifically, during hand cooling following placebo, AFD experienced a lower minimum finger skin blood flow (0.5 [0.1] *vs.* 0.8 [0.2] flux•mmHg^{-1}, $P < 0.001$) and a lower minimum finger T_{sk} (9.5 [1.4] °C *vs.* 10.7 [1.3] °C, $P = 0.039$) compared with CAU. During spontaneous rewarming average skin blood flow was also lower in AFD than CAU (2.8 [1.6] *vs.* 4.3 [1.0] flux•mmHg^{-1}, $P < 0.001$).

These data provide further support that AFD experience an exaggerated response to hand cooling; however, the results demonstrate the COX pathway is not the primary reason for the exaggerated responses in AFD and increased susceptibility to NFCI.

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Subjective preferences of varying menthol mouthwash concentrations

Russ Best[1,2], Nicolas Berger[2]

[1]*WINTEC, Hamilton, Waikato, New Zealand,* [2]*Teesside University, Middlesbrough, UK*

Menthol is a widely used, naturally occurring monoterpene alcohol that elicits a feeling of coolness and freshness upon application to the oral cavity, or skin (Stevens & Best, 2016). Recently menthol has demonstrated improvements in time to exhaustion (Mündel & Jones, 2010) and time trial performance (Stevens et al., 2015), but no investigations have been conducted to ascertain the preferred concentration of menthol mouth swill(s).

Menthol crystals were dissolved in ethanol to a 5% concentration. The solution was diluted to experimental concentrations (n = 11; 0.05-0.105% menthol at 0.05% increments). Participants (n = 21) swilled each test solution (25ml) for 10 seconds, randomised via Latin square design. Solutions were expectorated and participants rated the qualities of each solution using 150mm visual analogue scales. Participants rated each solution for smell, taste, mouth feel, freshness and irritation to produce a total score, per concentration.

Data were analysed via a one way repeated measures ANOVA, with magnitude of the effect calculated ($\eta^2_{partial}$). Mauchly's test indicated that sphericity had been violated, χ^2 (54) = 94.11, p = 0.001, therefore a Greenhouse-Geisser (ε = 0.470) correction was applied. There were no significant main differences between menthol mouth swill concentrations, F (4.695,93.903) = 0.974, p = 0.435, but a small effect was observed $\eta^2_{partial}$ = 0.046.

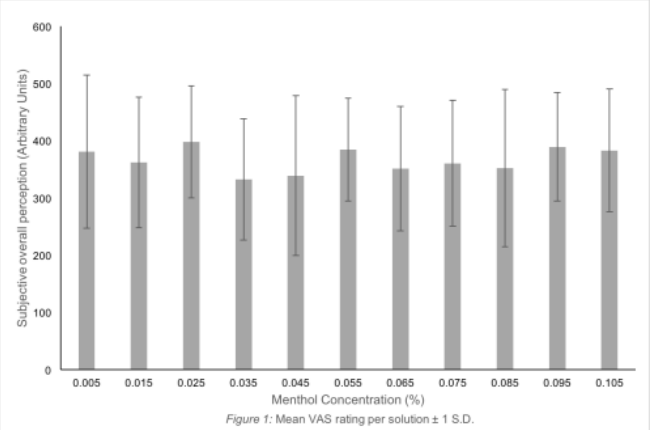

Figure 1: Mean VAS rating per solution ± 1 S.D.

Participant preference did not differ significantly between menthol concentrations, suggesting that researchers investigating the effects of menthol mouth swilling during sports performance are free to use the menthol concentration deemed most appropriate for investigation, or self-selected by athletes. Further research should investigate pairwise comparisons between menthol concentrations, and the factors which contribute to individual preference.

155 POSER SESSION 4

The effect of ambient temperature deception on perceived exertion and physiological variables during fixed-intensity cycling in the heat

David N. Borg[1], Ian B. Stewart[1], Joseph T. Costello[2], Chris C. Drovandi[3,4], Geoffrey G. Minett[1]

[1]Institute of Health and Biomedical Innovation and School of Exercise and Nutrition Sciences, Queensland University of Technology, Brisbane, Queensland, Australia, [2]Extreme Environments Laboratory, Department of Sport and Exercise Science, University of Portsmouth, Portsmouth, UK, [3]School of Mathematical Sciences, Queensland University of Technology, Brisbane, Queensland, Australia, [4]Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers, Brisbane, Queensland, Australia

Perceived exertion is thought to play an important role in the regulation of exercise. Borg's 15-point (6-20) rating of perceived exertion (RPE) scale is the standard method for measuring whole-body perceptions of exertion. Despite the simplicity of its measurement, the precise factors which modulate the RPE are unclear, with multiple physiological and psychological inputs and environmental factors all thought to contribute. The covert manipulation of body and ambient temperature (T_a) by means of deception has previously been shown to lower RPE when cycling in the heat compared to a condition where accurate temperature feedback was provided. The current study examined the effect of only T_a deception on the RPE and physiological variables during fixed-rate cycling performance in the heat. It was hypothesised that the direction of deception (told T_a was higher or lower) would lead to the same direction change in RPE with no change in physiological variables.

Eleven male recreational cyclists [mean±standard deviation; age: 26.8±4.1 years; height: 184.5±8.0 cm; body mass: 81.1±13.3 kg; VO_{2peak}: 53.3±6.1 ml·kg^{-1}·min^{-1}; VO_{2peak} power: 382±66 W; 4±1 training sessions·wk; 347±203 training min·wk] completed 30 min of cycling at 50% VO_{2peak} power, once in a thermoneutral environment (CON: 24 °C; 60% RH) and three times in the heat (33 °C; 60% RH). During one of the hot trials, cyclists were informed of the true T_a. In the other two hot trials, participants were told the T_a was either 5 °C hotter (DEC_{HIGH}: 38 °C) or 5 °C cooler (DEC_{LOW}: 28 °C). During trials, RPE, respiratory gas exchange, heart rate, rectal and skin temperature were recorded at 5 min intervals, and voluntary force and activation of the quadriceps were assessed pre- and post-cycling. All variables were compared using a two-way repeated measures ANOVA (condition x time). Where significance was obtained, Tukey's Honestly Significant Difference post hoc test was undertaken.

All participants reported being unaware of the T_a deception. RPE responses were significantly ($P<0.05$) higher in each of HOT (13.0±1.5), DEC_{LOW} (13.0±1.7) and DEC_{HIGH} (13.1±1.8) compared to CON (11.8±1.5); but no differences between HOT, DEC_{LOW} and DEC_{HIGH} were observed. Similarly, all physiological variables were significantly different ($P<0.05$) in HOT, DEC_{LOW} and DEC_{HIGH} compared to CON, but no differences were observed between HOT, DEC_{LOW} and DEC_{HIGH}. Voluntary force and activation were not different between CON, HOT, DEC_{LOW} and DEC_{HIGH}.

Despite the successful deception of T_a, RPE responses and physiological variables remained unaffected during 30 min of fixed-intensity cycling in the heat. This study suggests that the use of T_a alone does not provide a strong enough stimulus to alter RPE or physiology during fixed-intensity exercise in the heat.

156 ORAL 14: Temperature regulation 3

Regional sweat distribution in young and older individuals

Nicole Coull, Anna West, Patrick Wheeler, Simon Hodder, George Havenith

Loughborough University, Loughborough, UK

Sweating is the primary avenue of heat loss from the body during exercise and exposure to hot environments. However, ageing is associated with thermoregulatory decline, including attenuation of the sweat gland response, which may put older individuals at risk of heat-induced illness. There is currently limited data assessing whole body sweat distribution between young and older age groups with previous research focusing on a select number of regions. As the world is rapidly ageing, it is vital that more information is provided in this area. Therefore, this study investigated the regional and age-related differences in sweat rates in young and older individuals, using a body mapping approach.14 young (18-30yrs) and 14 older (60-80yrs) healthy males volunteered for the study. All individuals attended a pre-test session and two main experimental trials. The main trials were split into two sessions, one to collect sweat from the torso, arms and hands and the other from the legs and feet. A modified absorbent technique was used to collect sweat in this study (Smith and Havenith, 2011, 2012). During the main trials participants rested for 30-min in an environmental chamber (32°C/50%RH) in a seated position before exercising for 25-min at 200W/m2 on a treadmill. Participants then dismounted the treadmill and absorbent sweat pads were applied to the skin for a 5-min sweat collection period, during which participants exercised again. The absorbent sweat pads were weighed pre-post application to calculate regional sweat loss. Measures of core temperature, skin temperature, heart rate, thermal sensation and comfort were also recorded during the trial. Preliminary results (young; n=14 and older; n=13) indicate that older individuals had a significantly lower gross sweat loss (273.9 ± 51.7g vs 376.3 ± 64.4g) during the trials compared to their younger counterparts ($p<0.05$). The highest sweat rates were observed at the upper and mid back and lowest at the extremities in both age groups. Younger individuals had higher sweat rates at the posterior torso and legs compared to the older group. Older individuals had a significantly higher change in core temperature than the young (0.5°C vs 0.2°C), despite rating lower values for thermal sensation and comfort throughout the trials ($p<0.05$). In summary, older individuals had a lower sweat loss and consequently a higher heat gain than the younger group, despite feeling considerably cooler and more comfortable. The current study provides detailed regional sweat maps for a young and older population group (50 regions). These data show that despite similar low and high sweat regions, there were regional differences between age groups over the body. This information may be used for public health guidance during heat waves and also aid the design of clothing which could be tailored for individual needs.

157 ORAL 14: Temperature regulation 3

Hypohydration impairs whole-body evaporative heat loss during exercise in the heat

Robert D. Meade, Sheila Dervis, Andrew W. D'Souza, Kion Hatam, Glen P. Kenny

University of Ottawa, Ottawa, Ontario, Canada

Hypohydration impairs sweating and skin blood flow during exercise, leading to highly elevated body temperatures. However, the direct influence of these alterations on whole-body evaporative and dry heat loss and whether the resultant impairments in body heat and temperature regulation vary as function of the exercise induced heat load is currently unknown. We evaluated the influence of hypohydration (~5%) on whole-body evaporative and dry heat loss during moderate and high exercise heat loads. On two separate occasions, five young males (age: 25±3 yrs) performed a dehydration protocol consisting of intermittent treadmill walking in the heat (40°C). Participants then rested in a thermoneutral room for four hours and received either 1) intravenous infusion (0.9% saline) to replace lost fluid (euhydrated condition; EUH) or 2) no infusion (hypohydrated condition; HYP). Thereafter, participants were transferred to a whole-body direct calorimeter and performed two 30-min bouts of cycling at moderate (heat production of 175 $W \cdot m^2$; MOD) and high (heat production of 275 $W \cdot m^2$; HIGH) work rates, each followed by a 15-min recovery, in the heat (40°C). Fluid loss was estimated by change in body weight (ΔBW) while changes in plasma volume (ΔPV) were determined from venous blood samples. Metabolic heat production (indirect calorimetry) and whole-body evaporative and dry heat loss (direct calorimetry) were used to calculate body heat storage. Rectal temperature was measured continuously. Post-dehydration ΔBW was -3.9±0.3% and -4.3±0.6% in EUH and HYP, respectively, and similar between conditions (P=0.18). Prior to the heat stress test, BW had returned to baseline in EUH (-0.3±0.6%; P=0.47) but remained reduced in HYP (-5.0±0.5%; P<0.01). Likewise, PV was similar to baseline prior to the heat stress test in EUH (ΔPW: 2.8±5.2%; P=0.35), where it remained during MOD (-0.2±3.3%; P=0.91) but was reduced from baseline during HIGH (-8.7±3.7%; P<0.01). By contrast, PV was reduced compared to baseline resting prior to the heat stress test (-11.9±4.7%; P<0.01) and during each exercise bout (MOD: -16.9±1.5%; HIGH: -21.9±2.6%; both P<0.01) in HYP. The reduction in PV was greater in HYP compared to EUH at all time points (all P<0.01). Evaporative heat loss during exercise was elevated in EUH (MOD: 426±7 W; HIGH: 588±37 W) relative to HYP (MOD: 401±14 W; HIGH: 557±52 W; both P≤0.04); however, no differences in dry heat loss were noted (both P≥0.70). Body heat storage was elevated in HYP compared to EUH during MOD (EUH: 65±22 kJ, HYP: 109±31 kJ; P<0.01) and HIGH (EUH: 109±38 kJ, HYP: 159±42 kJ; P<0.01). This was paralleled by greater increases in rectal temperature in HYP during HIGH (EUH: 0.71±0.20°C; HYP: 1.04±0.26°C; P=0.02) but not MOD (EUH: 0.25±0.11°C; HYP: 0.43±0.16°C; P=0.07). Thus, hypohydration impairs evaporative (but not dry) heat loss at moderate and high exercise heat loads, resulting in elevated thermal strain.

158 ORAL 14: Temperature regulation 3

Sweat distribution and perceived wetness across the human foot

Anna West[1], James Tarrier[2], Simon Hodder[1], George Havenith[1]

[1]Loughborough University, Loughborough, UK, [2]adidas Future, Herzogenaurach, Germany

Investigations of intra-segmental sweat distribution at the foot (Taylor *et al.,* 2006; Smith *et al.,* 2013) consistently report sweat rates to be greatest from the dorsal surface compared to the plantar surface (~70% and ~30% respectively). However, detailed comparisons of foot sweat rates from existing literature are difficult due to differing ambient temperatures, heating techniques, exercise modes and socks/footwear used. In addition, the relationship between sweating on the foot and perceived skin wetness is unknown. This study investigated regional foot sweat distribution to aid footwear design and assessed the relationship between sweat distribution and perceived wetness.

14 trained female runners performed 60minutes of treadmill running with ambient conditions of 25°C, 50% RH. 35minutes of running were performed at a low intensity (55% maximal heart rate) followed by 25minutes at a higher intensity (75% maximal heart rate). Sweat rates from the right foot were measured at 14 zones using technical absorbent material and a 100% cotton sock applied during the last 5minutes of each work intensity. Local sweat rates were derived from changes in pad mass. Infrared images pre and post pad application were recorded to evaluate local and mean foot skin temperature. Wetness perception was assessed prior to pad application. Participants exercised in standardised clothing, socks and running shoes.

Heart rates averaged 134±3 bpm and 157±2 bpm during low and high exercise intensities respectively. Corresponding core temperatures were 37.8±0.2°C and 37.9±0.2. Participants presented evidence for a non-uniform distribution of sweating on the foot. Highest local sweat rates were observed from the medial ankle, medial dorsal and central dorsal. Lowest local sweat rates were observed from the toes. Sweat rate increased significantly with exercise intensity at the central dorsal, toe 3, lateral and medial ankle (p<0.05). Data from grouped zones indicated a similar sweat distribution pattern from low to high exercise intensity.

Participants sensed differences in wetness at different zones (dorsal, toes, heel, sole; p<0.01) with wetness perception increasing significantly with exercise intensity (p<0.05). Despite the toes having the lowest sweat rates, they were perceived as being one of the wettest zones during both exercise intensities.

The present study provides a detailed view of sweating across the foot surface for trained female runners. In accordance with previous studies, sweat rates were greater from the dorsal surface compared to the plantar surface. However, previous reports of sweat rates levelling off with increased exercise intensity were not observed across all foot zones.

Perceptions of wetness increased with exercise intensity across all zones but sensations of wetness did not correspond with areas of high sweat production. It is important to consider that footwear comfort may not be dominated by a single zone and possibly not the zone with the highest sweat production.

159 ORAL 14: Temperature regulation 3

No sweat boys! Think x-linked hypohidrotic ectodermal dysplasia

Heather Massey[1], Danielli Mello[1,2], Liam Colley[1], Jim House[1], Michael Tipton[1]

[1]University of Portsmouth, Portsmouth, UK, [2]Physical Education College of Brazilian Army, Rio de Janeiro, Brazil

X-Linked Hypohidrotic Ectodermal Dysplasia (XLHED) is a rare genetic disorder diagnosed from sparse hair; few and often pointed teeth; and diminished or absent sweat function. Little is known about their thermoregulation. Vasomotion may also be affected (Brengleman, 1981), limiting opportunities for heat loss and increasing mortality rates (Clarke, 1987). This study assessed heat loss in children with XLHED whilst intermittently treadmill walking and running in 30^{o}C, 60% RH air, and during subsequent recovery. Six boys with XLHED (median(range) age 12(8 to 13) years gave their assent (parental consent) and volunteered for this ethically approved study. Insulated auditory canal temperature (T_{ac}) and index finger pad and forearm laser Doppler skin blood flow were measured. Whole body sweating was calculated by naked weighing before and after heat exposure. Two 20-min bouts of exercise were performed with 20-min passive recovery in the first rest period and hand immersion (12-15 ^{o}C) or whole body spraying and fanning (volunteer's preference) in the second recovery period. Median (range) T_{ac} change was 2.58 ^{o}C.hr^{-1} (1.68 to 3.48 ^{o}C.hr^{-1}) for the first exercise session and 2.22 ^{o}C.hr^{-1} (1.83 to 2.55 ^{o}C.hr^{-1}) for the second exercise session. One volunteer was stopped at a T_{ac} of 38.5 ^{o}C (the stopping criterion for this study) during the second exercise session. The mean cooling rate during passive recovery was -0.84 ^{o}C.hr^{-1} (+0.51 to -1.44 ^{o}C.hr^{-1}) and during the cooling intervention was -2.31 ^{o}C.hr^{-1} (-1.47 to -4.08 ^{o}C.hr^{-1}). Whole body sweat rate was 0.17 L.hr^{-1} (0.05 to 0.24 L.hr^{-1}) and skin blood flow was (Finger 375 Laser Doppler units [LDU] [67 to 646 LDU], Forearm 83 LDU [14 to 562 LDU]). Children with XLHED have a rapid increase in T_{ac} and low sweat response. Skin blood flow was elevated by increased deep body temperature, in addition vasodilatation was present and maintained during cooling interventions. Despite diminished sweating, people with XLHED can lose excess heat using active cooling interventions. It remains to be seen how the changes in T_{ac} compare to healthy weight and height matched controls.

160 ORAL 14: Temperature regulation 3

Thermoregulatory responses during eccentric downhill running exercise in trained men

Ahmad Munir Che Muhamed[1], Al-Hafiz Abu Bakar[1], Harris Kamal Kamaruddin[1], Kazunori Nosaka[2], Narihiko Kondo[3]

[1]Advanced Medical and Dental Institute, Universiti Sains Malaysia, Penang, Malaysia, [2]School of Medical and Health Sciences Edith Cowan University, Perth, Australia, [3]Faculty of Human Development, Kobe University, Kobe, Japan

It has been documented that downhill running increases heat strain among non-heat-acclimated runners. However, the effects of a single bout of downhill running on thermoregulatory responses [e.g., local sweat rate, skin blood flow] among heat acclimated runners remains largely unclear. Therefore, the purpose of this study was to examine thermoregulatory responses during eccentric downhill running exercise (ECC) in comparison to level running (LR) in trained male runners. Seven well-trained heat acclimated male runners (age: 23 ± 3 years; height: 172 ± 6 cm; weight: 58.6 ± 5 kg; VO_2max: 56.8 ± 4.5 mL/kg/min; body surface area: 1.7 ± 0.1 m^2; percent body fat: 8.1 ± 2.3%) were recruited for this study. Each runner performed two 45-minute bouts of running (54-56% VO_2max) in a thermoneutral (20°C, 40% relative humidity) condition; one bout of ECC at 10% decline and another bout of LR at 0% separated by at least 12 days in a randomised order. Body (Tb), rectal (Tre), skin (Tsk) temperatures were recorded during exercise at 5 min intervals. Local sweat rate (LSR), activated sweat gland (ASG), sweat gland output (SGO) and skin blood flow (SkBF) were recorded on the forearm and chest at 5, 25 and 45 min of exercise. Whole body sweating rate (SR) was estimated from nude body mass losses during exercise. Data were analysed using a two-way repeated measure ANOVA. There was no significant difference in the metabolic heat production during the ECC and LR trials (941.8 ± 129.9 $W.m^{-2}$ vs. 984.0 ± 128.0 $W.m^{-2}$; p=0.615). There was a significant main effect of the exercise on Tb (p=0.005) and Tre (p=0.001). At the end of exercise, Tre was significantly higher in the ECC trial as compared to LR (38.7 ± 0.3 ^{0}C vs. 38.1 ± 0.3 ^{0}C; p=0.009). The SR between the ECC and LR trial was not significantly different (1.11 ± 0.32 l/min vs. 0.85 ± 0.47 l/min; p=0.321). No significant main effect on LSR for both forearm (p=0.868) and chest (p=0.857) region was found. Similarly, there was no significant main effect for ASG (forearm; p=0.302 and chest; p=0.394) and SGO (forearm; p=0.502 and chest; p=0.307). The SkBF was not significantly different between the two trials (forearm; p=0.446 and chest; p=0.338). The present study demonstrated that despite running at a similar level of metabolic heat production, a greater level of heat strain was experienced during ECC exercise. This was reflected in 0.6 ^{0}C higher Tre in the ECC than the LR. The present study demonstrated that ECC exercise adversely alters thermoregulatory effector responses. The underlying mechanism for this observation remains unclear. However, the inflammatory responses associated with ECC exercise could be linked to the reduced capacity of thermoregulatory responses as previously proposed.

161 SYMPOSIUM: Thermoregulation in Asians

Thermoregulation in Asians. Introduction to the problem

Jason Lee[1], Joo-Young Lee[2]

[1]DSO National Laboratories, Singapore, Singapore, [2]Seoul National University, Seoul, Republic of Korea

A combination of factors, including ethnicity, may influence an individual's response to cold and heat stress. This symposium will cover aspects of thermoregulation specific to natives originated from Asian countries. Acute responses and chronic adaptations to the cold and heat specific to these populations will be discussed. Through this session, we seek to elicit more questions from the information to be presented resulting in prospective research efforts to affirm current understanding and elucidate new insights to thermoregulatory responses and adaptations in the Asian populations.

162 SYMPOSIUM: Thermoregulation in Asians

Cold adaptation, aging, and Korean women divers (haenyeos)

Joo-Young Lee

Seoul National University, Seoul, Republic of Korea

We have been studying the thermoregulatory responses of Korean breath-hold women divers, called haenyeos, in terms of aging and cold adaptation. During the 1960s to the 1980s, haenyeos received attention from environmental physiologists due to their unique ability to endure cold water while wearing only a thin cotton bathing suit. However, their overall cold-adaptive traits have disappeared since they began to wear wetsuits and research has waned since the 1980s. For social and economic reasons, the number of haenyeos rapidly decreased from 14,143 in 1970 to 4,005 in 2015 and the average age of haenyeos is about 75 years old at present. For the past several years, we revisited and explored older haenyeos in terms of environmental physiology, beginning with questionnaire and field studies and later advancing to thermal tolerance tests in conjunction with cutaneous thermal threshold tests in a climatic chamber. Older non-diving females and young non-diving females were compared with older haenyeos in the controlled experiments. Our findings were that older haenyeos still retain local cold tolerance on the extremities despite aging. Finger cold tests supported more superior local cold tolerance for older haenyeos than for older non-diving females. However, thermal perception in cold reflected aging effects rather than local cold acclimatization. An interesting finding was the possibility of positive cross-adaptation, which might be supported by greater heat tolerance, and cutaneous warm perception thresholds of older haenyeos adapted to cold water. It was known that cold-adaptive traits of haenyeos disappeared, but we confirmed that cold-adaptive traits are still retained on the face and hands, which could be interpreted by a switch to local adaptation from the overall adaptation to cold. Further studies on cross-adaptation between chronic cold stress and heat tolerance are needed.

163 SYMPOSIUM: Thermoregulation in Asians

Multiple organs coordination for cold induced thermogenesis in Japanese males

Hitoshi Wakabayashi[1], Kentaro Matsumoto[1], Yusuke Kobori[1], Masayuki Saito[1], Mami Matsushita[2], Toshimitsu Kameya[3]

[1]Hokkaido University, Hokkaido, Japan, [2]Tenshi College, Hokkaido, Japan, [3]LSI Sapporo Clinic, Hokkaido, Japan

Human brown adipose tissue (BAT) has been reconfirmed as one of the major organs for cold induced thermogenesis (CIT) and energy expenditure. Based on the studies conducted in several countries, it was indicated that Japanese showed smaller amount of active BAT and larger individual variation, compared to European populations. Recent study investigated the association between the uncoupling protein 1 (UCP1) genotype and non-shivering thermogenesis (NST) during mild cold exposure in humans (Nishimura et al. 2017), and they revealed significant correlation between the frequency of the haplotype with the highest NST and living latitudes, using the 1000 Genomes Project database. Concerning these findings, Asian population might have lower BAT activity compared to Northern Europeans. However, other organs could have greater contribution in compensating for the lesser BAT activity in the Asian population. The contribution of human skeletal muscle for the CIT was investigated in several studies (Blondin et al. 2015, 2017), and the functional interplay between BAT and skeletal muscle was reported in animal study (Bal et al. 2017). Our research group recently started studies on the multiple organs coordination for CIT in Japanese population. It was hypothesized that there would be greater contribution of skeletal muscle (and/or other organs like liver and white adipose tissue) to NST in people who show less activity of BAT. All participants wearing light cloth conducted fluorodeoxyglucose (FDG)-PET/CT after 2-hour mild cold exposure in 19°C room which induced only NST without any shivering. Mean value of standardized glucose uptake (SUVmean) in multiple organs (BAT, white adipose tissue, skeletal muscles and liver) was investigated. Average value of the SUVmean of the BAT was significantly greater than those of other organs. However, concerning the volume and whole body distribution, total amount of glucose uptake and thermogenesis in skeletal muscle would account for large component of NST. The SUVmean of the rectus abdominis and liver was negatively correlated with SUVmean of BAT. This might indicate the coordination of multiple organs thermogenesis to maintain the homeostasis in body temperature regulation. Further studies are needed and on-going to clarify variations in the multiple organs coordination in CIT.

164 SYMPOSIUM: Thermoregulation in Asians

Thermoregulatory responses during exercise in hot-dry and warm-humid environment in Indonesian males

Titis Wijayanto[1], Su Young Son[2], Akira Yasukouchi[3], Yutaka Tochihara[3]

[1]Universitas Gadjah Mada, Yogyakarta, Indonesia, [2]Kyungpook National University, Daegu, Republic of Korea, [3]Kyushu University, Fukuoka, Japan

Different combination of air temperature (T_{air}) and relative humidity (RH), either hot-humid or hot-dry can result in identical wet bulb globe temperature (WBGT) index, but with markedly different physiological responses. Tropical natives have been reported to have physiological adaptation in humid-heat environment. Whether this physiological adaption will also be an advantage for them in dissipating heat during exercise in dry-heat environment however is unknown. This study investigated the effect of a warm-humid (WH) compared with hot-dry (HD) environment with identical WBGT index on physiological responses during exercise in tropical natives from Indonesia. Nine Indonesian males (mean±SD of age = 22.0±1.3 years, body height = 169.8±1.7 cm, body mass = 66.5±2.1 kg and peak oxygen uptake (VO_{2peak}) = 34.7±0.9 mL min^{-1} kg^{-1}) participated in this study as subjects. They performed exercise at 55% peak oxygen uptake for 60 min followed by a 30-min recovery in two environment conditions: WH (T_{air} = 31°C and 75% RH) and HD (T_{air} =38°C and 30% RH), on separated days and in random order. The results showed no significant differences in rectal temperature during exercise or recovery between WH and HD. Heart rate at the end of exercise did not differ between HD and WH (P>0.05). However, heart rate was significantly higher in HD than in WH condition at the end of recovery period (P<0.05). Mean skin temperature was higher in HD condition than in WH condition at the end of exercise (DH = 35.7±0.08ºC and WH = 35.15±0.18ºC; P<0.05) and at the end of recovery period (HD = 35.6±0.14ºC and WH = 34.4±0.2ºC; P<0.01). Total body mass loss was significantly greater in HD condition than in WH condition (HD = 624±31 g h^{-1} and WH = 429±43 g h^{-1}; P<0.05). Subjective data showed that exercise in WH condition was sensed to be hotter than in HD condition (P=0.05). Subjects also reported greater skin wetness sensation in WH condition than in HD condition (P<0.05). However, there was no significant difference in thermal comfort between WH and HD (P>0.05). From these results it may be concluded that exercise in hot dry environment created in greater physiological challenge for Indonesians than in warm humid environment. In contrary, subjects reported greater subjective discomfort during exercise in warm humid environment compared to those in hot dry environment.

165 SYMPOSIUM: Thermoregulation in Asians

Eccrine sweat gland function of tropical natives during exercise in hot-humid and hot-dry environments

Ahmad Munir Che Muhamed, Aifana Roslan, Nurdiana Zainol, Hazwani Hanafi

Universiti Sains Malaysia, George Town, Malaysia

As tropical natives, Malaysians have a lesser sweat rate compared to their Japanese counterparts (temperate natives) during heat stress. It remains unclear if the capacity of eccrine sweat glands of Malaysians is affected when performing exercise in a hot-humid as compared to a hot-dry environment. Sixteen male elite cyclists (mean ± SD age 26 ± 6 years; height 169 ± 5 cm; body mass 66.2 ± 4.4 kg; $\dot{V}O_2$ max 4.93 ± 0.77 l.min^{-1}) performed 60 minutes of submaximal cycling exercise at an intensity of 70%VO_2max followed by a 10 km time-trial (TT_{10km}) in a hot humid (HH: 33.0 ± 0.3°C and 80 ± 1.6%rh) and a hot dry (HD: 33.0 ± 0.3°C and 40 ± 1.3%rh) conditions. Rectal temperature (T_{re}), mean skin temperatures ($\overline{T}_{sk}$) , heart rate (HR), rating of perceived exertion (RPE) and rating of thermal comfort (RTC) were continuously monitored throughout exercise. Local sweat rate (LSR), activated sweat gland (ASG), sweat glands output (SGO) were intermittently recorded on the chest and forearm in each trial. The TT_{10km} performance was significantly reduced in the HH compared to the HD conditions (11.67 ± 1.94 min vs 10.15 ± 1.05 min; $p < 0.01$). During the submaximal exercise, a significantly higher LSR was recorded in the HH compared to the HD on the chest (4.21 ± 0.90 vs 3.50 ± 0.57 mg/cm^2/min; $p < 0.05$) and forearm (3.08 ± 0.72 vs 2.62 ± 0.54 mg/cm^2/min; $p < 0.05$). SGO on the chest and forearm rose steadily in the HH condition. The ASG was not significantly different between HH and HD conditions. It was evident that athletes who were naturally acclimatized to the tropics were able to produce a higher sweat rate during exercise in HH condition as shown in the increase in SGO. Despite the ability to generate higher LSR in the HH condition during the submaximal exercise phase, the TT_{10km} performance deteriorated when compared to the HD condition. It was evident that a decline in the efficiency of sweat evaporation in a humid condition was a limiting factor to exercise and not the inability to secrete sweat.

166 ORAL 15: Modelling and Design

Clothing design parameters that affect estimation of clothing insulation change due to posture and motion

Kalev Kuklane[1], George Havenith[2]

[1]Lund University, Lund, Sweden, [2]Loughborough University, Loughborough, UK

Clothing insulation is one of the basic parameters that affects human heat exchange with the environment. There are available standard methods to measure individual clothing items and combinations' insulation (EN 15831), and standards that present databases and allow summing individual items insulation (ISO 9920). The latter does not account for many effects that occur when dressing the clothing ensemble, e.g. tucking shirt into pants or not, compression of layers, clothing design features. An aim of this study was to study and evaluate textile and clothing design parameters that may affect clothing combinations' insulation while using data from available clothing studies. Such an overview would support preparations for improving the summation method, and motion and wind corrections. This would allow more accurate risk assessment and selection of appropriate protective, functional clothing for work tasks in any environments, thus, diminishing the thermal stress. The methods included a revision of available clothing databases where more or less detailed data on clothing items and combination parameters was available. According to earlier results, 67 % of summation results were over 10 % different and 24 % were 20 % or more different from ensemble measurement results. A variety of parameters that were of interest for the summation method or wind and motion effect correction were defined, and if possible, measured, e.g. number of layers, their thickness etc. Draping, stiffness of layers and compressibility could be of interest but were not covered in this preliminary work. The present evaluation did show that in addition to basic factors defined in ISO 9920 for correcting for wind and motion – total clothing insulation, air velocity and walking speed, also posture, number of layers, their thickness (possible relation to draping and stiffness of layers) and looseness of lower body layers around hips had significant influence on predictions. About 20 % of all total resultant clothing insulation predictions, while considering the listed parameters still exceeded 10 % difference with measured values compared to 43 % of corresponding ISO 9920 corrections. More detailed information on clothing components design and use may allow improved insulation estimations. A calculation error of less than 10 % could be acceptable, while less than 5 % would be preferable for physiological modelling purposes.

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Prediction of thermopysiological responses to local skin cooling using the Fiala thermophysiological model

Nina Bogerd, Kaspar M.B. Jansen

TU Delft, Delft, The Netherlands

Human participants are employed to determine thermal responses to wearing a personal cooling system. Alternatively, advanced mathematical models of human thermoregulation could be utilized to simulate the responses. However, such simulations need to be validated against human subject data. This is done with comparing experimental data to a corresponding simulation of a virtual exposure. In present study we used Fiala thermophsyiological model to virtually expose participants to local cooling using personal cooling systems. In detail, we simulated values of rectal temperature (T_{re}) and local skin temperatures on nine body locations. Cooling of two distinctive intensities was provided to torso for 45 min by evaporative cooling shirt and an ice vest, respectively. In the condition with no cooling, sport shirt was applied. The ambient conditions and activity level did not differ among the three conditions[1]. We calculated mean standard deviation (sd) of the data obtained on eight male participants tested for each condition and root mean square deviation (rmsd) of the simulated values to evaluate the average difference between the measured and simulated values. When rmsd ≤ sd it was considered that the simulation was predicted successfully[2].Simulated values for T_{re} coincided with measured values for the three conditions (Table 1). The simulated values of skin temperatures of forehead, upper arm and calf did not coincide with the measured values. Skin temperatures at lower arm and thigh, failed to be simulated successfully for both cooling systems. And scapular skin temperature failed to be simulated for sport shirt and hand skin temperature for or ice vest condition.The results show that the model successfully simulated $T_{re,}$ but not skin temperatures upon wearing personal cooling systems. The simulations of the skin temperatures increasingly disagree with increased cooling intensity (sport shirt to evaporative vest to ice vest) with the decrease in skin temperature being overestimated. In the human subject study, the temperature on the torso was measured with sensors directly exposed to the cooling. This may have resulted in an underestimation of human torso temperature. Further, unsuccessful simulations could also be ascribed to limited ability of the model to simulate skin temperatures upon local cooling.

Table 1: Standard deviations (sd) for measured values and root mean square deviation (rmsd) of the simulated values for sport shirt, evaporative cooling shirt and ice vest. Asterisk * indicates the unsuccessful predictions.

		Tre	Forehead	scapulae	chest	torso	arm up	arm low	hand	thigh	calf
Sport Shirt	sd	0.28	0.40	0.45	0.58	0.49	0.50	1.17	1.29	0.98	0.56
	rmsd	0.13	1.06*	0.65*	0.58	0.21	0.63*	0.65	0.36	0.40	2.39*
Evaporative Shirt	sd	0.28	0.57	1.06	1.21	0.81	0.50	0.53	1.82	0.99	0.59
	rmsd	0.06	2.30*	0.99	0.95	0.44	1.14*	0.64*	0.72	1.01*	0.93*
Ice Vest	sd	0.18	0.27	3.33	3.00	2.47	0.50	0.50	0.76	0.45	0.42
	rmsd	0.05	3.61*	0.70	1.82	1.00	2.30*	2.30*	2.09*	2.27*	0.82*

1.Bogerd N, Perret C, Bogerd CP, Rossi MR & Daanen HAM (2010) The effect of precooling intensity on cooling efficiency and exercise performance. J Sports Sci 28: 771-779

2.Psikuta A, Wang L-C & Rossi RM (2013) Validation of the thermophysiological model by Fiala for prediction of local skin temperatures.

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Human thermoregulatory model based estimation of metabolic rate from core body temperature

Alexander Welles[1], Mark Buller[1], David Looney[1], William Rumpler[2], Reed Hoyt[1]

[1]U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA, [2]U.S. Department of Agriculture, Beltsville, MD, USA

Introduction: Metabolic energy expenditure is a physiological measure of importance to several scientific fields including nutrition, athletic performance, and thermoregulatory modelling. However, accurate measurement of metabolic rate ($\dot{M}$) can be challenging as the equipment required (e.g., gas exchange analyzers, facemasks, and whole room calorimeters) can limit the type and intensity of activity during measurement. The use of existing validated rational thermoregulatory models may provide a means to accurately estimate $\dot{M}$ from measures of core body temperature (T_{CR}). This work presents such an adaptation to a previously validated thermoregulatory model that effectively reverses its use from estimating T_{CR} from $\dot{M}$ to estimating $\dot{M}$ from T_{CR}. Methods: Fifteen test volunteers (age = 23 ± 3 yr, ht = 1.73 ± 0.07 m, mass = 68.6 ± 8.7 kg, body fat = 16.7 ± 7.3 %; mean ± SD) participated in up to three treadmill exercise tasks (32 trials) by completing 8.04 km of movement in 1 h (Air temp. = 22˚C, 50%RH, wind speed < 0.35 ms^{-1}) while wearing a long sleeved nylon jacket and pants ($I_{tot,clo}$ = 1.22, I_m = 0.41). Core body temperatures were recorded by ingested thermometer pill, and $\dot{M}$ data were measured via whole room calorimetry. The SCENARIO thermoregulatory model was used to estimate T_{CR} values from range of $\dot{M}$ inputs while holding all other inputs (environmental, worn ensemble, volunteer anthropometrics) constant. At each time-step, the $\dot{M}$ producing the estimated T_{CR} with the lowest absolute error relative to observed values for that time-step was used as the estimated value. Results: root mean square error (RMSE) and bias between mean observed and mean $\dot{M}$ were 130 ± 23 W and 33 ± 55 W respectively. The RMSE for total energy expenditure by exercise period was 0.30 ± 0.49 MJ. The RMSE between mean observed and estimated T_{CR} was 0.08 ± 0.05 ˚C with a 0.05 ± 0.04˚C bias. Discussion: Metabolic rates estimated from observed T_{CR} had a positive bias reflected in the overall overestimation of mean total energy expenditure. Underestimation appears to occur as $\dot{M}$ increases, and overestimation occurs as $\dot{M}$ decreases. This may be in part due to lags associated with the use of 5 minute time-steps and SCENARIO's modelling of vasodilation. In conclusion, these results suggest that thermoregulatory modelling can be used to estimate $\dot{M}$ from T_{CR}. This technique may be useful in field studies or circumstances where direct measurements of $\dot{M}$ are impractical.

Disclaimer: The opinions or assertions contained herein are the private views of the authors and should not be construed as official or reflecting the views of the Army or the Department of Defense.

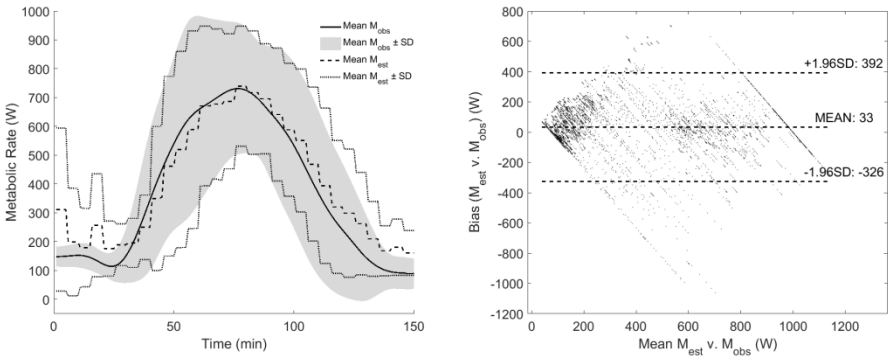

Figure 1: Mean ± 1 standard deviation (SD) (left) and Bland Altman Plot (right) of Observed (Obs.) and Estimated (Est.) Metabolic Rate.

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Analysis of thermal comfort and draft discomfort in a transient and asymmetric environment

Mark Hepokoski[1], Allen Curran[1], Scott Peck[1], Richard Burke[2]

[1]ThermoAnalytics, Inc., Calumet, MI, USA, [2]Thermetrics, LLC, Seattle, WA, USA

Thermal comfort models are often employed by engineers and architects for the design and optimization of climate control systems. Many environment-based comfort models (e.g., PMV) attempt to find a direct correlation between ambient conditions and thermal sensation. However, the more accurate simulation techniques (e.g., the Berkeley Comfort Model) consider the thermophysiology of the human body to predict temporal changes in skin and core temperatures and subsequently correlate these with thermal sensation to predict human perception of thermal comfort. Given that modern physiological models rely exclusively on the relationship between body temperature and sensation, they are not inherently capable of considering the effect of air movement on discomfort, which is also influenced by the response of subcutaneous mechanoreceptors rather than thermoreceptors alone.

Discomfort due to draft is a significant concern in the design of climate control systems since they often rely on the movement of air to attain and maintain a thermally comfortable environment. This study demonstrates the application of a draft discomfort model and a thermal comfort model within a transient and asymmetric environment. A passive sensor manikin (HVAC Manikin, Thermetrics LLC) was used to measure the boundary conditions (air temperature, air velocity, radiant heat flux, and relative humidity) as they would act upon a representative human form. A methodology is presented that illustrates how the measurements obtained under transient and asymmetric conditions can be processed as input to the draft discomfort model (Fanger et al. 1989). Thermal comfort (Zhang et al. 2010) was also predicted by applying manikin boundary condition measurements to a thermophysiological simulation (Hepokoski et al. 2016). Model predictions of thermal sensation, thermal comfort and draft discomfort are compared to human subject responses that were obtained within an equivalent thermal environment. This study serves to underscore the importance of considering both a physiology-based thermal comfort model and an environment-based draft discomfort model to assess complex thermal scenarios.

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Skin temperature measurement using contact thermometry: A systematic review of validity and comparability between setups

Braid MacRae[1,2], Simon Annaheim[1], Christina Spengler[2,3], René Rossi[1]

[1]Empa—Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Biomimetic Membranes and Textiles, St. Gallen, Switzerland, [2]Exercise Physiology Lab, Institute of Human Movement Sciences and Sport, ETH Zurich, Zurich, Switzerland, [3]Zurich Center for Integrative Human Physiology (ZIHP), University of Zurich, Zurich, Switzerland

For reasons including the skin's role in thermoregulation, skin temperature is an important parameter and is measured in various research, clinical, sporting, and occupational settings. Using contact temperature sensors affixed directly to the skin surface is common but the influence of setup variables on the measured outcomes requires clarification. We sought to systematically review published studies of measurements from contact T_{skin} sensors considering sensor-surface equilibrium temperature and surface temperature disturbance, and considering whether setup variables (sensor type, attachments, applied pressure, or environmental conditions) meaningfully influence the measured temperature. Ovid Medline and Scopus were used (1960 to July 2016) and published research studies comparing contact T_{skin} sensor measurements in vivo or using appropriate physical models were included. Comparisons of temperature measurements were expressed, where possible, as mean difference and 95% limits of agreement (LoA). Meta-analyses were not performed due to the lack of a common reference condition. Twenty one studies were included representing a range of sensor setups and conditions of measurement. Results from these studies indicated minor (<0.5°C) to practically meaningful (>0.5°C) measurement bias within the subgroups of attachment type, applied pressure, environmental conditions, and sensor type. 95% LoA were often, but not always, <1.0°C. Setup variables and conditions of use can bias the measured temperature from contact T_{skin} sensors and thus key setup variables need to be considered and consistently reported. This work serves to provide a base from which users of contact T_{skin} measurements can make better-informed decisions about setup of the sensor-attachment system with relevance to their particular measurement objectives and the expected measurement conditions. Further, we propose that skin temperature measurements can be improved with regard to 1) comparability between different sensor setups and 2) with regard to absolute temperature, each using corrections based on measurements from a physical model developed in our lab including accurate control of a homogeneous surface temperature.

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Effect of passive heat stress on cerebral blood flow responsiveness across the menstrual cycle and between the sexes

Bethany Skinner, Samuel J. E. Lucas, Rebekah A. I. Lucas

University of Birmingham, Birmingham, UK

Passive heat stress affects key regulators of cerebral blood flow (CBF), particularly arterial blood pressure and arterial carbon dioxide content (PCO_2) as a consequence of blood redistribution and hyperthermic-induced hyperventilation. Fluctuations in females' sex hormones during the menstrual cycle have been shown to have numerous effects on physiological variables associated with CBF (e.g. sympathetic neural control of blood pressure). Furthermore, there remains conflicting findings regarding whether heat stress alters cerebrovascular responsiveness to CO_2 and, more specifically, how this may change for females throughout the menstrual cycle. Changes in cerebrovascular-CO_2 responsiveness during passive heat stress could affect CBF functional reserve in extreme environments and increase the risk of brain hypo- and/or hyper-perfusion-related events (e.g., fainting, stroke). Therefore, the purpose of this study was to determine the effect of passive heat stress on cerebrovascular responsiveness to both hyper and hypocapnia across the menstrual cycle, and to determine differences between the sexes.

Five females (25 ± 6 yr; 70.7 ± 10.2 kg) are partway through completion of three-repeat trials, at their early follicular, ovulatory and mid-luteal phase. Six males (22 ± 3 yr; 72.1 ± 4.3 kg) are completing two-repeat trials, at least two weeks apart. To determine cerebrovascular-CO_2 responsiveness, middle and posterior cerebral artery blood velocity is being measured during hypercapnic (2 and 5% CO_2 inspiration) and hypocapnic (two levels of voluntary hyperventilation) responsiveness tests under normothermia and passive heat stress conditions (+~1°C in core temperature) using a water perfusion suit. Cerebrovascular-CO_2 responsiveness will be derived from 1) change in middle cerebral artery velocity (MCA*v*) and posterior cerebral artery velocity (PCA*v*) and 2) change in cerebrovascular conductance (CVC; artery velocity/mean arterial pressure) per mm Hg change in end-tidal CO_2.

Data are still being collected at the time of abstract submission and preliminary results will be presented at the conference.

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The influence of high intensity intermittent exercise in the heat on neuromuscular and cognitive function

Rachel Malcolm[1], Simon Cooper[1], Jonathan Folland[2], Christopher Tyler[3], Caroline Sunderland[1]

[1]Nottingham Tren University, Nottingham, UK, [2]Loughborough University, Loughborough, UK, [3]University of Roehampton, London, UK

There are both physical and cognitive demands placed on team sport athletes, presenting a unique challenge in terms of optimising performance (Bishop & Girard, 2013). Football, hockey and rugby will take place in the heat at the Tokyo 2020 Olympics. To the authors knowledge, there is no information available about the effects of high intensity intermittent activity (similar to that in team games) performed in the heat on neuromuscular and cognitive function, a void in the literature that this study will address.

Sixteen participants (age:22±2 years, VO_2 max:53±7 ml·kg·min^{-1}) completed a hot (33°C, 50% Rh) and moderate (15°C, 50% Rh) trial in a randomised crossover design. In each trial participants completed a simulation of a football match (2 x 45 min) on a treadmill (Greig et al, 2006), modified to reflect an individual's fitness. Measurements of cortical voluntary activation (VA) and peripheral VA of the knee extensors, using transcranial magnetic stimulation and peripheral nerve stimulation respectively, were completed. Cognitive function tests: Visual search; Stroop; Corsi blocks and Rapid visual information processing (RVIP) (to assess perception, executive function, visuo-spatial memory and sustained attention respectively) were completed. Measurements were taken at baseline, half time and post-match. Cognitive function data were analysed in R using mixed effect models and physiological data were analysed in SPSS using ANOVA, both using a repeated measures trial*time design.

Cortical and peripheral VA were lower in the heat (main effect of trial: cortical VA, P=0.016; peripheral VA, P=0.001). Peripheral VA was maintained from half time to full time in the moderate condition, yet continued to decrease in the heat (trial*time interaction, P=0.003), an effect not seen for cortical VA (trial*time interaction, P=0.142). Core temperature and heart rate were both greater in the hot trial (main effects of trial, P≤0.007).

Response times on the complex level of the Stroop test and the simple level of the visual search test slowed from baseline to full time in the heat compared to the moderate trial (trial*time interactions, P≤0.004). Accuracy declined on the simple level of the visual search test from baseline to half time and full time in the hot trial, whilst accuracy was maintained on the moderate trial (trial*time interactions, P≤0.032). Accuracy on the complex level of the visual search test deteriorated in the heat but improved on the moderate trial from baseline to half time (trial*time interaction, P= 0.009). Overall, accuracy was lower on the hot trial for the RVIP test (main effect of trial, P = 0.025), whilst the Corsi Blocks test was unaffected.

Neuromuscular and cognitive function deteriorates when intermittent exercise is coupled with heat stress. The task dependant influence for neural resources, was highlighted, by only the domains of perception and executive function being negatively influenced.

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Differential regulation of body and brain temperature during hyperthermia in humans

Ivan Cherh Chiet Low[1], Xiang Ren Tan[1], Mary C. Stephenson[3], Tuck Wah Soong[1], Jason Kai Wei Lee[2]

[1]National University of Singapore, Singapore, Singapore, [2]DSO National Laboratory, Singapore, Singapore, [3]Agency for Science Technology and Research, Singapore, Singapore

Physical and cognitive performance are impaired during hyperthermia. Increasing evidence suggests hyperthermia-induced fatigue is at least in part contributed by central factors. While high brain temperature (T_{br}) is frequently attributed as a factor inducing central fatigue, there have yet been any studies directly evaluating T_{br} in relative to core temperature during hyperthermic conditions in humans.

Using ^{1}H Magnetic Resonance Spectroscopy (^{1}H-MRS) and Arterial Spin Labelling (ASL) MRI, this study sought to evaluate the changes in regional T_{br} and cerebral blood flow (CBF) at the motor cortex following passive or exertional hyperthermia in human volunteers. Ten moderately-trained athletes (mean ± SD: age 23.6±1.7 years; body fat 9.3±2.0%; VO_2max 58±6 ml kg^{-1} min^{-1}) underwent ASL and ^{1}H-MRS scan while donning a warm (41°C) water-perfused thermal suit in a familiarization and four randomized, counterbalanced trials. Rectal temperature (T_{re}) was continuously monitored during trials using a MRI-compatible fibre optic rectal probe. ASL/MRS scans were conducted before and after (a) running on a motorized treadmill at 70% VO2max with ingestion of ambient water (EX) or (b) ice slurry (ICE), (c) passive heating via warm water immersion at 41°C (PAH), or (d) rest (CON). MRI data were analysed using paired student t-test. $P < 0.05$ was considered significant for ASL data while MRS data was Bonferroni-corrected with $p < 0.01$ considered as significant.

Participants started all trials euhydrated (mean serum osmolality: 292 ± 1 mOsmol/kg; p= 0.719), with similar baseline HR (66 ± 2 beats/min; p=0.908) and T_{re} (36.9 ± 0.1°C; p=0.431). Post-intervention T_{re} for EX (39.4 ± 0.2°C) was similar to PAH trial (39.3 ± 0.2°C; p = 0.59) but higher than ICE (39.0 ± 0.2°C; p = 0.01) and CON trials (36.5 ± 0.2°C; p < 0.01). On average, baseline T_{br} was 0.6°C higher than baseline T_{re} across all trials (37.3±0.4°C vs 36.7±0.2°C; p < 0.001). T_{br} during post-intervention MRS scan was similar to T_{re} for EX (38.6±0.4°C vs 38.6±0.2°C; p = 0.887) and ICE (37.9±0.5°C vs 38.0±0.4°C; p = 0.574) but was significantly lower than T_{re} in PAH trials (38.3±0.4°C vs 38.8±0.3°C; p < 0.01). T_{br} remains higher than T_{re} in CON trials (37.2±0.5°C vs 36.1±0.3°C; p < 0.001). Importantly, the rise in post-heating T_{br} was significantly lower than the rise in post-heating T_{re} in PAH trials (Δ0.9±0.5°C vs Δ2.1±0.2°C; p < 0.001). Moreover, this blunted rise in T_{br} corresponded with a 27% decline in regional CBF (p < 0.05) of the motor cortex in PAH trial.

Our work suggests that T_{br} is differentially regulated from T_{re} particularly during passive heat stress. T_{br} appears to be regulated in a narrower homeostatic range than T_{re}, suggesting the existence of a possible supra-spinal thermoregulatory mechanism involving changes in regional CBF in response to passive hyperthermia.

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The influence of passive heat stress on cognitive function

Rachel Malcolm[1], Simon Cooper[1], Jonathan Folland[2], Christopher Tyler[3], Caroline Sunderland[1]

[1]Nottingham Tren University, Nottingham, UK, [2]Loughborough University, Loughborough, UK, [3]University of Roehampton, London, UK

It is widely understood that the physiological responses to heat can influence cerebral blood flow (Wilson et al, 2006; Bain et al, 2015); however, findings regarding the influence of passive heat exposure on cognitive function remain equivocal due to a number of methodological issues including variation in the domains of cognition examined. Therefore, the aim of the present study was to examine the effects of passive heating on cognitive function across a breadth of domains.Forty-one male participants completed a battery of cognitive function tests including Visual Search, Stroop, Corsi Blocks and Rapid Visual Information Processing (RVIP) tests (to assess perception, executive function, visuo-spatial memory and sustained attention respectively). Tests were completed prior to and following 1 hour of passive rest in either hot (39.6 ± 0.4 °C, 50.8 ± 2.3 % Rh) or moderate (21.2 ± 1.8 °C, 41.9 ± 11.4 % Rh) conditions in a randomised, order-balanced, crossover design. Perceptions of heat stress, arousal and feeling were assessed alongside physiological measures including core temperature, skin temperature and heart rate, at baseline and throughout the protocol. Cognitive function data were analysed in R using mixed effect models and physiological data were analysed in SPSS using ANOVA, both employing a repeated measures trial*time approach.The cognitive function data is presented in table 1. Response times were significantly slower in the hot trial on the simple (main effect of trial, P<0.001) and complex (main effect of trial, P<0.001) levels of the Stroop test and the simple level of the visual search test (main effect of trial, P<0.001). However, there were no differences in the change from baseline to 1h between trials (trial*time interactions, all P>0.05). Participants demonstrated superior accuracy on the simple level of the Visual Search test in the hot trial (main effect of trial, P=0.035). Participants also demonstrated an improvement in accuracy on the complex level of the visual search test following 60 minutes passive heat exposure, whilst a decrement was seen across the trial in the moderate condition (time*trial interaction, P=0.029). No differences in performance were observed on the RVIP or Corsi Blocks tests (all P>0.05). Perceptions of thermal sensation, feeling and arousal were lower in the hot trial, whilst skin temperature and heart rate were higher (main effects of trial, all P<0.001). However, core temperature was unaffected (main effect of trial, P=0.07). The findings of the present study suggest that response times slowed in the heat for perception and executive function tasks, whilst no change in performance occurred in tasks requiring visuo-spatial memory and sustained attention. An improvement in accuracy on perceptual tasks may suggest a compensatory speed-accuracy trade-off effect occurring within this domain, further highlighting the task dependant nature of heat stress on cognition.

Table 1: Cognitive function data (mean ± SD) across the hot and moderate trials. * Significant main effect of trial $^{+}$ Significant trial*time interaction

Test	Variable	Test level	Hot		Moderate	
			Pre	Post	Pre	Post
Visual Search	Response Time (ms)	Simple	349 ± 46	359 ± 61	330 ± 46	333 ± 47*
		Complex	1270 ± 281	1307 ± 300	1213 ± 268	1180 ± 240
	Accuracy (%)	Simple	98.9±0.0	98.1±0.0	97.8±0.0	96.9±0.0*
		Complex	96.8±0.0	98.1±0.0	97.7±0.0	97.0±0.0^{+}
Stroop test	Response Time (ms)	Simple	665 ± 105	657 ± 129	618 ± 74	638 ± 95*
		Complex	894 ± 196	851 ± 200	842 ± 182	826 ± 175*
	Accuracy (%)	Simple	97.9±0.0	97.3±0.0	98.9±0.0	97.0±0.1
		Complex	96.3±0.0	94.0±0.0	94.8±0.1	95.1±0.1
Corsi Blocks	Sequence length		5.9±0.8	5.9±0.9	6.0±0.7	6.1±0.9
RVIP	Response Time (ms)		460 ± 151	504 ± 53	486 ± 126	485 ± 59
	Accuracy (%)		55.1±0.2	56.1±0.2	54.1±0.2	57.1±0.2

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K_V, K_{ATP}, and K_{Ca} channels are involved in cutaneous reactive hyperemia but not venous occlusion induced cutaneous vasoconstriction in young adults

Naoto Fujii[1,2], Masashi Ichinose[3], Takeshi Nishiyasu[1], Brendan McNeely[2], Glen Kenny[2]

[1]Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan, [2]Human and Environmental Physiology Research Unit, University of Ottawa, Ottawa, Canada, [3]Human Integrative Physiology Laboratory, School of Business Administration, Meiji University, Tokyo, Japan

Assessing cutaneous vascular responses in vivo is commonly used as a non-invasive measure to examine microvascular function in humans. Previous work assessing cutaneous vascular function have included cutaneous reactive hyperemia, which occurs after a period of arterial occlusion and cutaneous vasoconstriction induced by venous occlusion. Previous studies examining the mechanisms underpinning these responses have shown that nitric oxide synthase (NOS) and cyclooxygenase (COX) do not contribute to cutaneous reactive hyperemia, while Ca^{2+}-activated K^+ (K_{Ca}) channels mediate a large portion of this response. However, whether other K^+ channels such as ATP-sensitive K^+ (K_{ATP}) and voltage-gated K^+ (K_V) channels regulate cutaneous reactive hyperemia remains unknown. Further, to the best of our knowledge, there are no studies that have examined whether NOS, COX, K_V, K_{ATP}, and K_{Ca} channels are involved in the regulation of cutaneous vasoconstriction during venous occlusion.

Using intradermal microdialysis, we evaluated forearm cutaneous vascular conductance (CVC) in two separate protocols in young adults. In protocol 1 (n=15), four separate sites were infused with 1) lactated Ringer (Control), 2) 50 mM tetraethylammonium (K_{Ca} channel blocker), 3) 5 mM glybenclamide (K_{ATP} channel blocker), or 4) 10 mM 4-aminopyridine (K_V channel blocker). In protocol 2 (n=12), three sites were infused with 1) lactated Ringer (Control), 2) 10 mM N^{ω}-nitro-$_L$-arginine (NOS inhibitor) or 3) 10 mM ketorolac (COX inhibitor). At all sites, the peak value for CVC after the arterial occlusion and subsequent reduction in CVC during venous occlusion were assessed. These data are presented as change from baseline.

Peak CVC after arterial occlusion was attenuated by K_{Ca} and K_{ATP} channel blockers, while Kv channel blockade augmented CVC relative to the Control site (all $P \leq 0.05$). However, none of the K^+ channel blockers had an effect on the reduction in CVC during venous occlusion (all $P > 0.05$). Neither NOS nor COX inhibition affected peak CVC after arterial occlusion or the reduction in CVC induced by venous occlusion (all $P > 0.05$).

We show that cutaneous reactive hyperemia is in part mediated by the activation of K_{ATP} and K_{Ca} channels, but is limited by the activation of K_V channels. However, we demonstrate that the K^+ channels examined in the present study do not contribute to cutaneous vasoconstriction induced by venous occlusion. Further, neither NOS nor COX is involved in the cutaneous reactive hyperemia and venous occlusion induced cutaneous vasoconstriction.

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The effect of acute beetroot juice supplementation on the responses to local cooling and endothelial function in cold sensitive individuals

Clare Eglin[1], Joseph Costello[1], Stephen Bailey[2], Daniel Bailey[1], Heather Massey[1], Anthony Shepherd[1]

[1]University of Portsmouth, Portsmouth, UK, [2]Loughborough University, Loughborough, UK

Individuals with cold sensitivity have reduced skin blood flow which could be due to an attenuated release of nitric oxide (NO). Beetroot has a high concentration of inorganic nitrate and is thought to benefit cardiovascular health through increased NO-mediated vasodilation. Using a placebo-controlled, double blind, randomised, crossover design, this study tested the hypothesis that acute concentrated beetroot juice (CBJ) supplementation would increase the rate of cutaneous rewarming following a local cold challenge and augment endothelium-dependent vasodilation in individuals with cold sensitivity. Thirteen cold sensitive individuals consumed 140 ml of either CBJ or nitrate-depleted CBJ (Placebo) 90 min prior to testing. Participants completed foot and hand cooling (separately, in 15 °C water for 2 minutes) with spontaneous rewarming in 30 °C air. Endothelial function was assessed at the forearm, finger and foot by iontophoresis of 1% w/v acetylcholine using laser Doppler flowmetry. Resting blood pressure and the skin temperature during and following cooling (Figure 1) were the same in CBJ and Placebo. CBJ did not affect the maximum response to acetylcholine in the forearm, finger or foot (2.0 [1.0] vs 2.3 [0.7] flux.mmHg^{-1}, 3.3 [1.6] vs 3.1 [1.5] flux.mmHg^{-1}, 1.2 [0.8] vs 1.0 [0.7] flux.mmHg^{-1}; all P>0.05). Acute CBJ supplementation did not improve extremity rewarming, endothelial function or lower blood pressure in individuals with cold sensitivity.

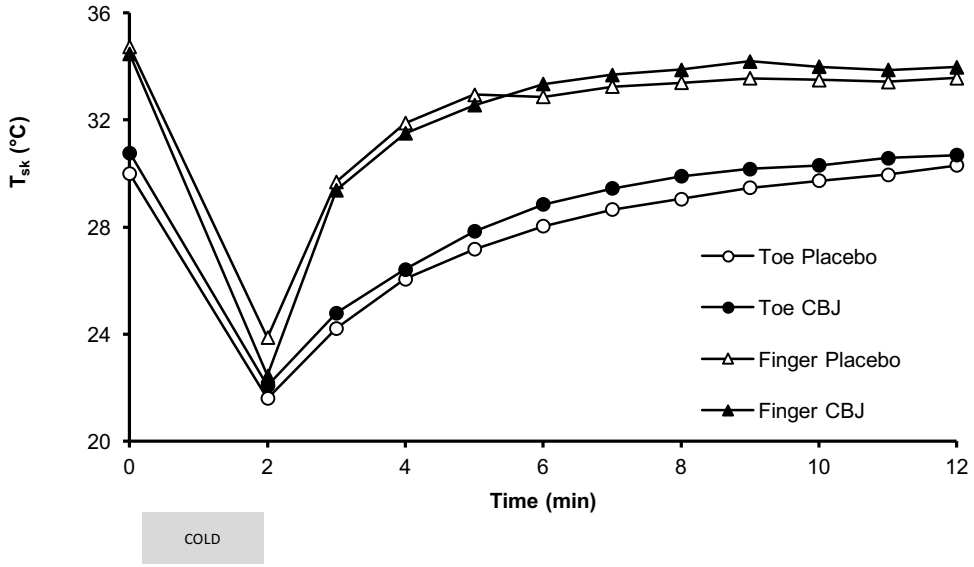

Figure 1: Effect of CBJ on mean toe and finger skin temperature during extremity cooling.

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Relationship between endothelium-dependent vasodilation and cold-induced vasodilation

Takafumi Maeda

Faculty of Design, Kyushu University, Fukuoka, Japan

It is well known that the cold-induced vasodilation (CIVD) is one of the indexes for local cold tolerance. CIVD was affected by many factors such as age, living climate, smoking, and physical fitness status, etc. Some previous study has reported the positive correlation between an aerobic capacity and the CIVD response of finger during cold water immersion. However, the mechanism of the relation is not clear yet as well as the mechanism of the CIVD response. It is thought that the clarification of these mechanisms is needed for evaluation of the individual difference of CIVD response. The purpose of the present study was to clarify the relationships among CIVD response, maximum oxygen uptake, and endothelium-dependent vasodilation (EDVD). CIVD and EDVD responses and maximum oxygen uptake were measured in 35 healthy males (mean age ± SD: 23.4 ± 2.5 years old) on separate days. CIVD was estimated by measurement of skin temperature (Tsk) on the palmar side of the distal phalanx of right index finger before, during, and after immersion into ice water for 30min. EDVD was estimated by the increasing in forearm blood flow measured with strain gauge plethysmograph at reactive hyperemia, which reflect vascular endothelial function. Maximum oxygen uptake was measured from the expired gas at the exhaustion during an incremental exercise (+20watt/min, 50rpm) using bicycle ergometer. The maximum Tsk and the increase in Tsk from minimum to maximum, which were indexes of CIVD responses, were correlated positively with not only maximum oxygen uptake, but also EDVD estimated by increase in forearm blood flow at reactive hyperemia. These findings suggested that individuals with higher levels of aerobic capacity had profitable response of CIVD because they had also good function of vascular endothelium, resulting in the individual differences of CIVD. However, it will need further study looking at the trigger of CIVD responses for deeply understanding of CIVD mechanisms.

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Effect of nitrate supplementation on vascular function, oxidative stress and a 16.1 km time trial in a normoxic environment with a younger active population

Rachel Burke, Joseph Snowdon, Huw Jones, Mark Fogarty, Andrew Garrett

The University of Hull, Hull, UK

Dietary nitrate is growing in popularity as a sports nutrition and therapeutic supplement. Research has demonstrated the nitrate-nitrite-nitric oxide pathway to have a range of beneficial vascular effects. Including increased blood flow, reducing blood pressure, improving endothelial function and enhancing exercise performance in healthy individuals. Watercress is a green leafy vegetable with a rich source of nitrate and contains nutritional compounds such as beta-carotene and alpha-tocopherol which increase protection against oxidative stress. Therefore, the aims of this study were to compare the acute effects of nitrate matched supplements on vascular and oxidative stress parameters at rest and following a 16.1 km cycling time trial (16.1 km TT). Nine, healthy, active males (mean [SD]; age: 31.2 [7.8] y, body mass: 74.9 [7.3] kg, stature: 178.7 [6.1], VO_{2peak}: 52.4 [6.2] $mL \cdot min^{-1} \cdot kg^{-1}$) were assigned in a randomised, single-blind crossover design to consume nitrate (containing 400 mg) matched supplements: watercress juice, beetroot juice, sodium nitrate and water (acting as a negative control), two hours before the completion of a 16.1 km TT. Venepuncture and cardiac output were performed on three occasions: baseline, 2 hours post-ingestion and post-exercise. Samples were then analysed for markers of cardiovascular and oxidative stress markers. Blood pressure and forearm venous occlusion plethysmography were obtained at baseline and 2 hours post-ingestion only. The CoV (95% CI) for the 16.1 km TT performance test was reported as 1.0 (0.7 to 1.8%) in a previous reliability study. The 16.1 km TT performance was significantly different for the supplements $\chi^2(3) = 8.33$, ($p=0.04$). Watercress supplementation demonstrated a 1.8% performance improvement compared to the water trial and had the fastest time (27.35 [1.1] mins), compared with beetroot juice (27.57 [1.28] mins), sodium nitrate (27.53 [0.95] mins) and water (control) (28.05 [1.01] mins). Watercress supplementation was the only supplement to indicate an increase in forearm blood flow volume (+0.18 [0.03] $\%.min^{-1}$), from baseline to two hours post-ingestion but this was not significant ($P=0.73$). Beetroot decreased but was equivocal (-0.88 [0.30] $\%.min^{-1}$) ($P=0.25$). Sodium nitrate tended to decrease (-0.60 [0.04] %.min-^{1}) ($P=0.07$) and water significantly decreased (-0.61 [0.01] $\%.min^{-1}$) ($P=0.03$). These results suggest that there is potentially a synergistic effect between the nitrate content and polyphenols in watercress which may have enhanced cycling performance in a young healthy active population.

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Effect of sportswear cover area on thermoregulation during running

zejing Qi, qinmei Du, shu Jiang, xiaoqun Dai

Soochow University, College of Textile and Clothing Engineering, Soochow, China

During exercise, body heat production increases and sweat rate also increases. To keep constant body core temperature, additional heat needs to be diffused quickly. Sweat also needs to be taken away to keep skin dry and cool down the body. In such apparent and latent heat transfer, clothing plays a complicated role. Clothing is regarded as a barrier for heat and moisture transfer. However, wearing clothing might enhance the efficiency of evaporative cooling. Not all the amount of sweat is effective in cooling, sweat simply dropping down from the body surface makes no contribution. Garments can absorb sweat before it drops. The sweat held in garments can then evaporate from its outer surface and thus increase evaporation rate. This implicates that the area of garments covering the body can make difference on thermoregulation. To investigate such effect, five young male subjects participated running trials in a mild environment(20ºC, 60%RH, 0.4m/s airflow). Three sports ensembles of three levels of surface areas were tested: Long: a long sleeve T-shirts and a pair of long pants; Short: a short sleeve T-shirts and a; Brief: just a pair of short pants. The exercise protocol consisted of 15min sitting rest, 5min walking at 6km/h for warming up and 30min running at 9km/h, followed by 5min walking at 6km/h and 10min sitting rest. The mean skin temperature (Tsk), rectal temperature (Tre), heart rate (HR), and body weight loss were measured. The results are presented in Fig.1. Because of the largest surface area, Tsk of Long kept higher than Tsk of Short and Tsk brief. The difference of Tre among ensembles was not big as that of Tsk. Although Tre of Long during the start rest and the end rest periods was obviously higher than that of Short and Brief, the difference decreased during the running period. Moreover, the Tre rise of Long during the whole period was significantly lower than that of Short and Brief. It indicated that the large surface area of Long increased the evaporative heat loss during the running period. Although the averaged HR of Long was higher than that of Short and Brief, the difference was not significant. More subjects needed to be recruited for the study. Further study will be carried out in a hot environment.

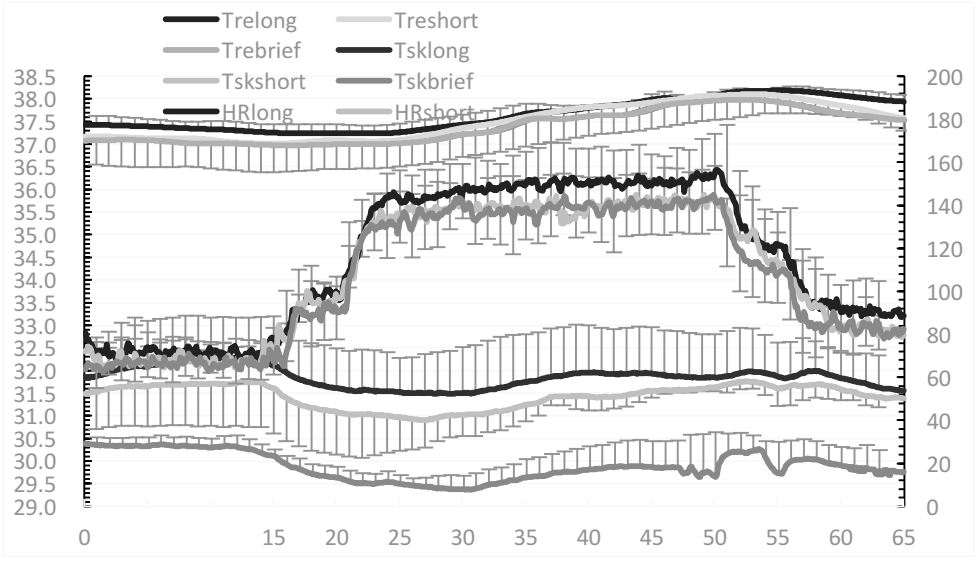

Figure 1: changes in Tsk、Tre and HR during trial

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The influence of sports bra on thermoregulation during running in heat

Qinmei Du, Zejing Qi, Zeyang Zhang, Xiaoqun Dai

Soochow University, Suzhou, China

Wearing sports bras can reduce the breast movement during exercise. To provide firm support to breasts, sports bras are very tight-fit and usually consist of multi-layer (shell fabric and cup pads) that prevents heat and moisture transfer. Therefore, a sports bra can represent a physical advantage but a thermal disadvantage. There are few papers addressing the thermal influence of this extra garment layer for women. In this study, the effect of sports bra design on thermoregulation during running was investigated. Five female undergraduates of breast size 75 B volunteered to participate the wear trials in a warm environment (30ºC, 44%RH; 0.4m/s airflow). Two sports bras were tested together with a short sleeve T-shirt and a pair of short pants respectively. The two sports bras were of a same design. For bra SW, a wicking and quick-dry knitted polyester material was used for the shell and a vertical layered nonwoven material was used for the cup pad. For bra CW, an ordinary knitted polyester material was used for the shell and a 3D sandwich knitted fabric, which is easy for liquid water to transfer, was used as cup pad material. The exercise protocol consisted of 30min sitting rest, three cycles of alternation between 5min walking (5km/h) and 10min jogging (7km/h), followed by a 5min walking (5km/h) and 30min sitting rest to recover. The skin temperature, rectal temperature (Tre), and heart rate (HR) were measured. The results are shown in Fig. 1.

As the exercise continuing, Tre of bra SW averaged among 5 subjects became obviously higher than that of bra CW, and the difference of Tre between two bras was up to 0.26ºC. The Tre rise of bra CW during the whole period was significantly lower than that of bra SW at the level of 0.05. Maybe because of the higher Tre of bra SW, Tsk of bra SW also kept higher than that of bra CW. During the second and the third cycles of jogging, HR of bra SW became obviously higher than that of bra CW. It confirmed that bra CW was superior in helping thermoregulation. It was concluded that the cup pad material is crucial to the thermal property of a sports bra.

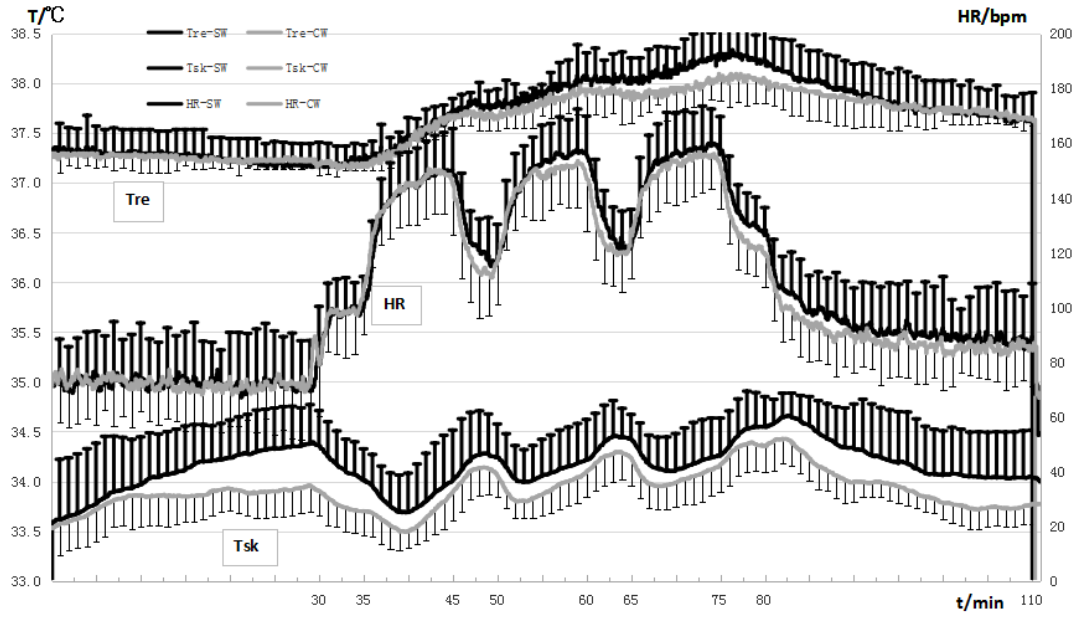

Figure 1: Change of Tsk, Tre and HR during the exercise

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Validation of body-mapping sports shirts designs on thermal physiological responses and comfort in warm and humid environment

Li-Yen Lin[1], Chuansi Gao[2], Amitava Halder[2], Kalev Kuklane[2], Gwo-Tsuen Jou[1]

[1]TTRI (Taiwan Textile Research Institute), New Taipei City, Taiwan, [2]Lund University, Lund, Sweden

It is thermally stressful to performance work and exercise in a warm and humid environment. Previous study discussed physical properties of selected fabrics by using a sweating torso and a thermo-physiological human simulator, the design and effect of clothing fit on local heat exchange of body-mapping shirts was examined using a thermal manikin. Furthermore, few studies documented moisture management, thermal physiological and comfort benefits for human subjects in simulated outdoor conditions. The objective of this study was to validate the design and explore whether body-mapping sportswear provide reasonable moisture management, thermal physiological and thermal comfort benefits during exercise in 28℃ and 80%RH. Eight healthy young males participated in the study. The tests were carried out in a climatic chamber. In addition to the controlled air temperature and relative humidity, 1.0 m/s wind was particularly applied to simulate walking and running outdoors while facing the wind. Each test consisted of the following periods: 1) seated rest (10 min), 2) warming up by walking at 4 km/h on the treadmill (10 min), 3) jogging at 8 km/h (15 min), 4) running at 10 km/h (15 min), and 5) seated recovery (15 min). Each subject participated in three tests with three types of T-shirts, which consisted of T-shirts with different materials and design (S1: non body-mapping t-shirt, solid structure with modified hydrophilic nylon; WM: the designed body-mapping t-shirt, with porous structure mesh fabric in partial parts; B: body mapping design, a commercial sample was chosen as the control sample). The measurements include rectal temperature, microclimate temperature and humidity, skin temperatures, sweat production, evaporation and accumulation in clothing, perceived thermal sensation, thermal comfort, and skin wetness, VO2 uptake and heart rate. Results showed that, the sweat is difficult to evaporate despite of the body mapping design in such a warm and humid environment. Nevertheless, the microclimate water vapor pressure of WM did show lowest values from around 40 min to the end of the test, indicating the best moisture management capacity. The microclimate partial water vapour pressure showed significant difference ($P<0.05$) among three t-shirts at the third activity phase and recovery phase. The skin temperature under WM was the lowest from about 15th min to the end of seated recovery. Overall thermal sensation and thermal comfort during exercise period with W and WM revealed better benefit than B. Other parameters did not show significant difference among the three sets of sportswear. In conclusion, the tight-fitting body mapping sportswear with porous mesh design improved the microclimate in terms of moisture management capacity, skin temperature and perceived thermal sensation in the warm and humid environment.

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Thermophysiological responses of exercising in body mapping T-shirts in a warm and humid environment: subject test and predicted heat strain

Chuansi Gao[1], Li-Yen Lin[2], Amitava Halder[1], Kalev Kuklane[1], Gwo-Tsuen Jou[2]

[1]Thermal Environment Lab, Lund University, Lund, Sweden, [2]Department of Testing and Certification, Taiwan Textile Research Institute, New Taipei, Taiwan

The capacity of sweat evaporation is limited in warm and humid environments. Body mapping T-shirts are designed to fit to sweat rates at various body regions to facilitate evaporative cooling during sport, exercise and at work. The objective of this study was to compare the thermophysiological responses of three tight-fitting sports T-shirts tested by subjects exercising in a warm and humid climate and estimated by Predicted Heat Strain (PHS) model.

Two body mapping T-shirts (B, WM) and one non-body mapping T-shirt (W) were tested in combination with the same shorts, briefs, socks and sports shoes on three different days in a climatic chamber (T_a=T_r=28 °C, RH=80%, v_a= 1 m/s, 180 degree front wind). The basic thermal insulation (I_{cl}) and moisture permeability index (i_m) of the ensembles were estimated based on ISO 9920: B (I_{cl} = 0.42 clo, i_m = 0.40), WM (I_{cl} = 0.39 clo, i_m = 0.46), W (I_{cl} = 0.40 clo, i_m = 0.42). Eight healthy male subjects (29.9±3.3 years old, 72.6±6.4 kg, 1.76±0.04 m, BMI 23.5±2.0) participated in three tests. The test protocol started with seated rest and walking (4 km/h) for 10 min each, followed by jogging (8 km/h), running (10 km/h) and recovery for 15 min each. The total duration was 65 min. Time-weighted metabolic rate (Watt) was used for PHS simulation (B: 427.7; WM: 432.5; W: 430.4). Time-weighted walking speed V_w was1.32(m/s) for all three tests.

The results of the PHS simulation showed that the rectal temperature increased 0.7 °C (from 37.2 to 37.9 °C), which was the same among the three T-shirts conditions. Likewise, the rectal temperature of the subjects with B, WM and W increased 0.8, 0.7 and 0.7 °C (from 37.4 °C in three initial conditions to 38.2, 38.1 and 38.1 °C) respectively. The different final rectal temperatures from subject tests and PHS prediction were likely caused by the initial rectal temperature input limit (36.6 - 37.2 °C) in the PHS simulation. The total sweat production at the end of 65 min exercise was 443, 434 and 437 g for B, WM and W T-shirts in the PHS model. However, the total sweat production measured in the subject tests was 606.6, 561.6 and 630.0 g for B, WM and W T-shirts, which was greater than that estimated by the PHS model. This difference could partly be attributed to respiratory water loss.

As PHS model is limited to constant activities with metabolic rate between 80-450 Watts and initial rectal temperature between 36.6-37.2 °C, the improvement of current PHS model is needed to accommodate incremental, intermittent and high intensity activities.

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T-shirt sweat absorption mapping

Margherita Raccuglia[1], Christian Heyde[2], Alex Lloyd[1], Simon Hodder[1], George Havenith[1]

[1]Environmental Ergonomics Research Centre, Loughborough Design School, Loughborough University, Loughborough, UK, [2]adidas FUTURE Sport Science, Herzogenaurach, Germany

Sweat evaporation from the skin is the greatest avenue of body heat loss in the heat and during exercise. Clothing sweat management is critical for clothing insulation, cooling efficiency and thermal comfort. Detailed body maps representing inter-regional variation in sweat rate across males and females exist. However, there are no quantitative data available on sweat transfer from the skin to the garment. This study provides a detailed analysis of sweat accumulation across the T-shirt, induced by 50 mins of running exercise. Eight western European male runners participated in the study. The participants performed, in a counterbalanced order, 10 running trials at 70% of their VO_{2max}, in a climatic room at 27 °C, 50 % rH and 1.5 $m \cdot s^{-1}$ air flow. The duration of the runs varied from 5 to 50 mins, to allow measurements of T-shirt sweat absorption at 5 min intervals. In each run participants donned a cotton T-shirt with a standard fit. The sweat absorption of 21 T-shirt regions was investigated (Fig 1). Local sweat absorption was calculated by cutting the T-shirts into the 21 pre-marked regions and weighing these before and after drying [regional-sweat-absorption ($g \cdot m^{-2}$) = WET_weight – DRY_weigh/Surface_Area]. During the exercise core temperature (T_{core}) was measured with rectal probe, heart rate (HR) with wrist-based monitor and post-exercise gross sweat loss (GSL) was estimated from PRE and POST body mass. After 50 mins, T_{core} rose from 37 ± 0.2 °C to 38.6 ± 0.3 °C, HR increased from 69 ± 15 bpm to 163 ± 12 bpm ($p < 0.001$) and GSL was 586 ± 86 $g \cdot m^{-2}$. On completion of 50 mins run, sweat production caused sweat to accumulate within the T-shirt and as result T-shirt WET_weight increase by 77 % compared to the DRY_weight. FRONT sweat accumulation started at 10 mins; the medial-chest showed the highest value, followed by lateral-chest, medial-abdomen, shoulders and sleeves, whereas lateral-abdomen and lower-end stayed dryer; Also for BACK, clear differences appear after 10 mins, with the medial-mid-back showing the highest value, followed by upper-back, lateral-mid-back, shoulders, medial-lower-back and sleeves; lateral-lower-back and lower-end stayed substantially dryer. These patterns were maintained until the end of 50 mins and compared to the FRONT the BACK showed higher sweat absorption values. Large variation in T-shirt regional sweat absorption was observed; the pattern was similar to the regional variation in sweat rate, although in absolute terms substantially lower, likely due to the skin-clothing air gap, ventilation and body movement. These data can aid the apparel industry in the development of sport and personal protective clothing with adequate comfort and performance, provide guidelines for material testing and implement the existing knowledge on thermophysiological modelling.

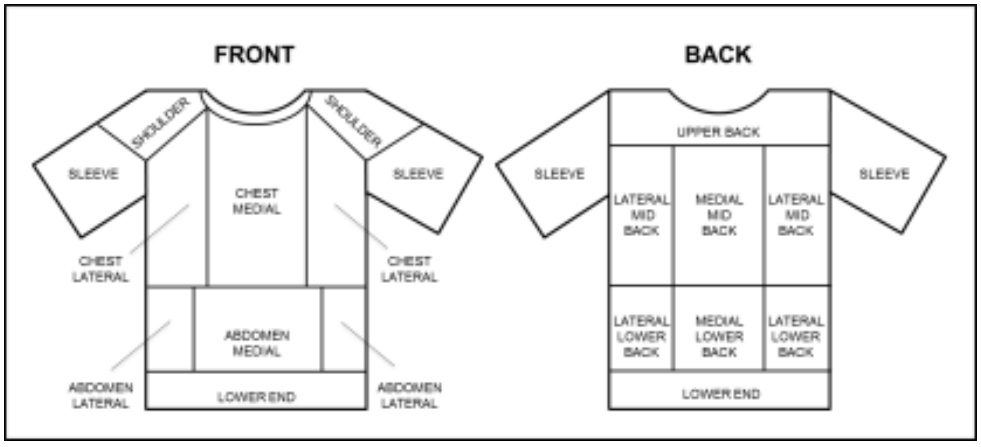

Figure 1 FRONT and BACK T-shirt regions.

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Time-motion analyses as a novel approach for evaluating the impact of environmental heat exposure on labor loss in agriculture workers

Leonidas G. Ioannou[1], Lydia Tsoutsoubi[1], George Samoutis[2], Lucka Kajfez Bogataj[3], Glen P. Kenny[4], Lars Nybo[5], Tord Kjellstrom[6], Andreas D. Flouris[1,4]

[1]FAME Laboratory, School of Exercise Science, University of Thessaly, Trikala, Thessaly, Greece, [2]Medical School, University of Nicosia, Nicosia, Cyprus, [3]Biotehnical Faculty, University of Ljubljana, Ljubljana, Slovenia, [4]Human and Environmental Physiology Research Unit, School of Human Kinetics, University of Ottawa, Ottawa, ON, Canada, [5]Department of Nutrition, Exercise and Sports, August Krogh Building, University of Copenhagen, Copenhagen, Denmark, [6]Centre for Technology Research and Innovation (CETRI), Limassol, Cyprus

In this study we (i) introduced time-motion analysis for assessing the impact of workplace heat on the work shift time spent doing labor (WTL) of grape-picking workers, (ii) examined if seasonal environmental differences can influence their WTL, and (iii) investigated whether their WTL can be assessed by monitoring productivity or the vineyard manager's estimate of WTL. This study has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 668786. Seven grape-picking workers were assessed during the summer and/or autumn via video throughout four work shifts. Air temperature (26.8±4.8°C), wet bulb globe temperature (WBGT; 25.2±4.1°C), universal thermal climate index (UTCI; 35.2±6.7°C), and solar radiation (719.1±187.5 W/m2) were associated with changes in mean skin temperature (1.7±1.8°C) ($p<0.05$). Time-motion analysis showed that 12.4% (summer 15.3% vs. autumn 10.0%; $p<0.001$) of total work shift time was spent on irregular breaks (WTB). There was a 0.8%, 0.8%, 0.6%, and 2.1% increase in hourly WTB for every degree Celsius increase in temperature, WBGT, UTCI, and mean skin temperature, respectively ($p<0.01$). Seasonal changes in UTCI explained 64.0% of the seasonal changes in WTL ($p=0.017$). Productivity explained 36.6% of the variance in WTL ($p<0.001$), while the vineyard manager's WTL estimate was too optimistic ($p<0.001$) and explained only 2.8% of the variance in the true WTL ($p=0.456$). Time-motion analysis accurately assesses WTL, evaluating every second spent by each worker during every work shift. The studied grape-picking workers experienced increased workplace heat, leading to significant labor loss. Monitoring productivity or the vineyard manager's estimate of each worker's WTL did not completely reflect the true WTL in these grape-picking workers.

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How much could a mist fan decrease WBGT values at an extreme hot outdoor worksite in summer ?

Hiroyuki Saito, Shin-ichi Sawada

National Institute of Occupational Safety and Health, Kawasaki, Kanagawa, Japan

Mist Fan is on the market as one of the products for preventive measures against heat disorders, but the effectiveness for reducing heat stress at workplace is not clear. Therefore, we experimentally examined how much a mist fan could decrease the WBGT values at an outdoor construction worksite in mid-summer. As environmental heat stress monitor, we used two natural wet bulb type WBGT measuring instruments (3M-Quest, QT-36). One WBGT instrument (No.1) was placed 1.5 m from the mist fan to examine the effectiveness of mist fan, and the other WBGT instrument (No.2) as a control was placed 2 m away from the WBGT instrument (No.1) to monitor the heat stress without any influence of mist fan at the same work site. We conducted successively 4 cycles of WBGT monitoring experiments. Each cycle consisted of the following three procedures in this order: [Proc.1] turning off both fan and mist (30 min), [Proc.2] turning on fan and off mist (30 min), [Proc.3] turning on both fan and mist (30 min). Compared with the control (almost comparable to the WBGT values with Proc.1), the WBGT value decreased about 1 to 2 °C with Proc.2, and decreased about 4 to 6 °C with Proc.3 The globe temperature (Tg) decreased by 5 – 10 °C with Proc.2, and decreased by 15 – 20 °C with Proc.3. The dry-bulb temperature (Ta) decreased by 0.5 – 1 °C with Proc.2, and decreased by about 4 °C with Proc.3. The natural wet bulb temperature (Tnw) decreased by 1 – 1.5 °C with Proc.2 and Proc.3. These drastic decreases in the variables of WBGT are thought to be caused by the combined effect of convective and evaporative heat dissipation. Our study confirmed that mist fan is very effective to decrease WBGT values in an extreme hot outdoor workplace. This provides one of the bases for utilizing mist fan as a measure to reduce environmental heat stress for prevention of heat disorders in outdoor workplaces.

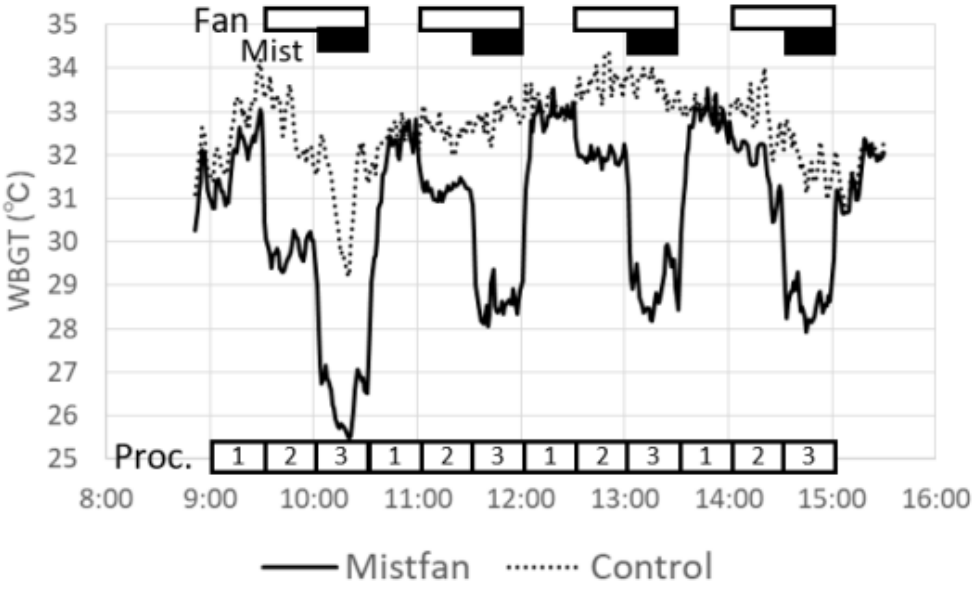

Figure 1: WBGT values with mist fan on and off.

Consideration of air-conditioning operating method which can save the energy consumption and awakening of occupants

Aya Yokoe, Motoi Yamaha

Chubu University, Kasugai, Aichi, Japan

Not only aim for comfort but also occupants awakening state will improve the learning environment of the student (intellectual production). This study aims to consider air-conditioning operation method which raises occupants' workspace productivity with awakening state. Energy saving by an air-conditioning operating method is being also considered.

A subjective experiment was made targeted for the college student of men and women. We experimented three conditions; continuously cooling at the 27degree setting of air-conditioning system and on-off control were done every fixed time period (10 minutes or 15 minutes). The distribution of laboratory temperature under each condition, the physiological and psychological state of the subject, the awakening situation and workspace productivity were measured.

When air conditioning was turned off, the temperature of the 1.0m height on the laboratory floor rose even about 29 degrees in about 10 minutes. When an air-conditioning was turned on again, it returned to the setting temperature in about 5-or 10 minutes. At this time, the skin temperature of the subject was following the room temperature. Many subjects declared psychologically 'comfort' when an air-conditioning system was turned on. The awakening state was estimated using R-R interval. Results of the Lorentz plot showed that on-off control of air-conditioning system simulates the subjects' awakening in this experiments(Fig.1). Workspace productivity was estimated using "Kraepelin test", but there are no differences during the conditions.

We investigated the difference in the energy consumption by on-off control of an air-conditioning system. The midsummer heat load of each condition in the lecture room at the Chubu University was calculated. As a result, it was showed that the heat load which should be eliminated falls approximately 50% at the on-off control of air-conditioning system from continuous operation.

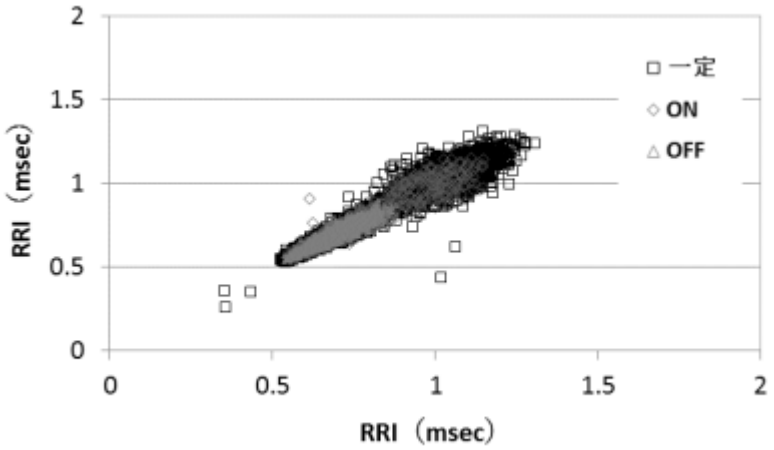

Figure1: Results of the Lorentz plot

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Can human biologically adapt to the forthcoming climate change? From the viewpoint of workable hours under thermal stresses

Jun'ya Takakura[1], Shinichiro Fujimori[1,2], Kiyoshi Takahashi[1], Yasushi Honda[3], Tomoko Hasegawa[1,2], Yasuaki Hijioka[1], Toshihiko Masui[1]

[1]National Institute for Environmental Studies, Tsukuba, Japan, [2]International Institute for Applied Systems Analysis, Laxenburg, Austria, [3]University of Tsukuba, Tsukuba, Japan

Anthropogenic greenhouse gas emissions will lead a climate change and global temperature rise. Thermal stresses, which will increase as a result of the climate change, will limit the workable hours particularly in outdoor worksites. International organization for standardization (ISO) and several governmental agencies recommends heat-stress-exposure-limit (HSEL) curves depending on the thermal environment and the intensity of the physical activity (metabolic heat). This recommendation is established based on the human's ability to deal with heat stresses. If this recommendation is followed, workable hours will decrease as the climate change progresses. On the other hand, it may be possible that human's ability to deal with heat stresses will be enhanced as the result of the climate change (i.e., autonomous biological adaptation). In this study, we investigated whether human biological adaptation can offset the worktime reduction due to the climate change. For this purpose, we quantified required shift of the HSEL curves to keep current-level workable hours under the situation in which severe climate change occurs with the increase in the climate radiative forcing of 8.5W/m^2. Current and future meteorological data is adopted from the result of general circulation models (GCMs), which physically simulate global climates. Based on the simulated meteorological data, we estimated hourly wet bulb glove temperature (WBGT) globally with the spatial resolution of 0.5×0.5 degree in latitude and longitude. Then the WBGT was translated to workable hours based on the HSEL, and it was aggregated for each region weighted by estimated spatial future population distribution. Firstly, annual average workable hours were calculated for each region. Secondly, we quantified required shift of the HSEL curves to keep current-level (2000s) workable hours in 2090s for each region. Estimated global total workable hours in 2090s reduced by 34% compared to current-level workable hours. In order to avoid this reduction in workable hours, the HSEL curve need to be shifted upward by more than 5 °C (Figure 1). However, maintaining human core body temperature under the shifted HSEL curve is physically and biologically unrealistic in terms of heat equilibrium. If severe climate change occurs, human will not be able to adapt to that environment biologically. Under such situations, cultural and behavioural adaptation will play major roles to maintain current-level social activities.

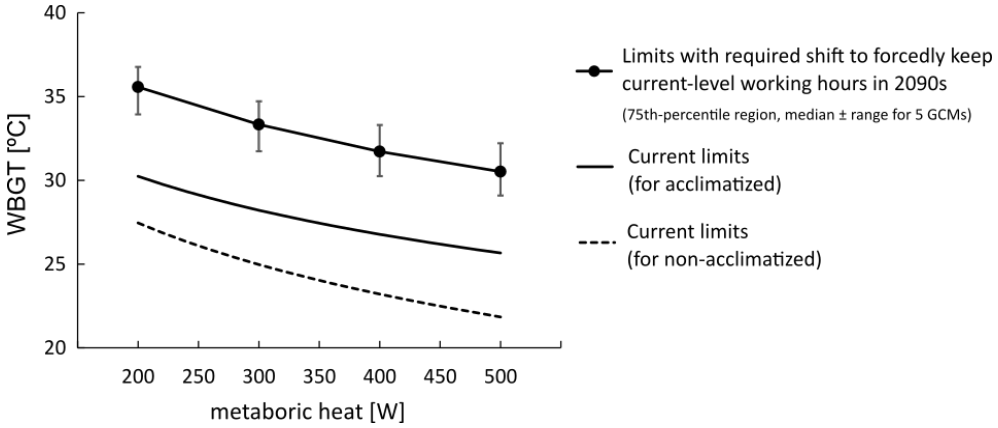

Figure 1: Currently-used and hypothetically-revised heat-stress-exposure-limit curves which determine continuous (without taking breaks) engage in physical activities.

Regional and age related incidences of heat disorder across Japan

Satoru Ueno

Japan Organization of Occupational Health and Safety, National Institute of Occupational Safety and Health, Kawasaki, Kanagawa, Japan

Previous research showed that the number of days whose maximum temperature is over 30°C or lowest temperature is below 25°C and so on influence heat disorder incidence. In the current heat stroke standards, the hot environment and work intensity are taken into consideration, but individual factors such as age and regional differences are not considered. In Japan, there exists cold climate, temperate climate, and subtropical climate from the northern part of Hokkaido to the southern part of Okinawa. The aim of this study is to investigate the regional and age difference of heat disorder incidence (HDI) by prefecture for one day. The database of emergency transport for heat disorders by prefecture from 2010 to 2015 in June to September was used for the index of HDI. The database includes the number of heat disorder by day, which was divided by age category (newborn, infant, 7-18yr, 19-64yr, over 65yr). HDI was calculated by use of the number of inhabitants by age by prefecture from the census data of 2010 and 2015. The daily maximum temperature (DMT) measured by meteorological observatory located at the prefectural office's site except for Hikone and daily maximum WBGT (DMW) predicted by Ministry of Environment were linked with HDI. By prefecture, HDI for 7-18yr, 19-64yr and over 65yr age category was plotted against DMT and DMW, which fitted well with an exponential regression line. To estimate the heat tolerance of the residents in each prefecture, the temperature (T_{100k}) and WBGT (W_{100k}) of the intersection of the regression line of HDI and HDI of one per 100,000 people were calculated for three age category. T_{100k} means the daily highest temperature when one per 100,000 persons call an ambulance due to heat disorders. The average T_{100k} of adult age in 47 prefectures was 36.3°C, the highest was 39.4°C, and the lowest was 34.0°C. T_{100k} over 65yr was lower than the other age group, which means older persons were prone to suffer heat disorders. The average W_{100k} of adult age was 32.2°C, the highest was 34.3°C, and the lowest was 29.2°C. The correlation between average daily maximum temperature in August and T_{100k} or W_{100k} suggested that higher level of heat stress in summer strengthened the heat tolerance of inhabitants. This study showed that the regional difference of heat disorder incidents existed and the average daily maximum temperature in summer influences the heat tolerance of the inhabitants. Lower T_{100k} and W_{100k} in older age showed decreased heat tolerance.

189 POSER SESSION 5

Whole body and skin thermal sensation are not improved with regular exercise in elderly men

Ryosuke Takeda[1], Daiki Imai[1,2], Akemi Ota[2], Eriko Kawai[2], Genta Hanno[2], Nooshin Naghavi[2], Emiko Morita[2], Yuta Suzuki[1,2], Hisayo Yokoyama[1,2], Kazunobu Okazaki[1,2]

[1]Research Center for Urban Health and Sports, Osaka City University, Osaka, Japan, [2]Department of Environmental Physiology for Exercise, Osaka City University Graduate School of Medicine, Osaka, Japan

Normal aging is associated with deteriorated autonomic heat dissipative responses and with blunted thermal sensations. We recently found that whole body thermal sensation and skin warm perception but not skin cold perception are more sensitive in trained (> 3 days of exercise/week) than untrained young men. In this study, we assessed whether blunted thermal sensation in the elderly was improved with regular exercise.

Eight elderly (72±2.4 yrs) healthy men underwent 3-month regular exercise (brisk walking more than 60 min/week or daily walking more than 10,000 steps/day). Pre and post 3-month regular exercise, subjects underwent measurements of the cold and warmth detection thresholds (±0.1°C/s) of their chest and forearm skin by using a thermode (6.25 cm^2) and whole-body thermal sensation (VAS) under normothermia (NT; esophageal temperature, Tes, 36.4±0.3 ˚C) and mild-hyperthermia with lower legs immersion in 42 ˚C water (HT; Tes, 37.2±0.3 ˚C) conditions. Peak oxygen uptake (VO2peak; step-up maximal walking test) and total hemoglobin mass (THb, CO-rebreathing method) were also assessed before and after exercise intervention.

VO2peak increased but no significantly (pre: 26.6±1.5 mL/kg/min, post: 28.0±1.7 mL/kg/min) and THb increased significantly ($P < 0.05$) after 3-month regular exercise. Skin warm and cold detection thresholds at both sites, and whole-body thermal sensation remained unchanged under both NT and HT after 3-month regular exercise.

3-month regular exercise did not improve whole body and skin thermal sensation although it increased aerobic capacity with increased THb in elderly men.

190 POSER SESSION 5

Car cabin thermal comfort measurement under real traffic conditions

Jan Fišer, Jan Pokorný, Miloš Fojtlín, Róbert Toma

Brno University of Technology, Brno, Czech Republic

Human thermal comfort in vehicular cabins has been broadly discussed in various contents. The most actual topics relate to efficient energy utilisation and enhancement of thermal comfort experience – especially in electric passenger vehicles. In fact, these two factors are contradictory at present; therefore, new concepts of HVAC management are being investigated. The presented study shows progress in systems based on equivalent temperature and real-time evaluation of thermal sensation of a driver and passengers. The aim of such systems are real-time evaluation of thermal conditions in the cabin using compact equivalent temperature sensors and prediction of thermal sensation based on comfort zone diagram. The system primary tests were done in car cabin under climatic chamber environment and group of test subjects was used. However the test subjects reported that the environment of the test is too artificial and they missing any interesting activity between questionnaires (taken with 5min period). This conditions probably led to very strong focusing on thermal feelings and hypersensitivity on cabin environment. Hence the measurement system was install to the cabin of four different middle-class passenger cars to test the system under real traffic conditions. The study was done from January to April 2017, mainly under weather conditions of middle Europe winter and spring. 43 journeys were measured, which could be split into three main groups - a) everyday short commuting inside the city (up to 20min duration), b) longer travels around city (up to 60 min duration) c) long distance journeys (more the 2 hours duration). The HVAC unit was set by the driver to reach the thermal comfort and all possible setting was allowed (temperatures, directions of outlets, speed of the fan etc.). Three types of calculation of overall thermal sensation based on local predictions is mentioned and their correlation with reported thermal sensation of test driver is presented.

191 POSER SESSION 5

Relevance between thermal comfort limit by metabolism in Japanese young female and male

Takako Fukazawa, En-gyo Qui

Kyoto University of Education, Kyoto-shi, Kyoto, Japan

Human thermal discomfort sensation depends upon metabolic rate due to his/her activity level. An estimation equation has been reported to express its relation as the thermal comfort limit by means of the skin wettedness. In the present study, therefore, validity of the estimation equation for Japanese has been examined experimentally through a series of subjective measurement using Japanese young females (Female) and males (Male). Each of female and male participants in the study was 5. In the study, 5 activity levels have been employed for the measurement as the metabolic rates, those of which were rest condition and 2, 3, 4, and 5 Mets. Each desired activity level except the rest condition has been realised by walking on a treadmill.

The resulted thermal comfort limits expressed by the skin wettedness for Male were rest: 0.34 ± 0.27 (-), 2 Mets: 0.52 ± 0.23 (-), 3 Mets: 0.62 ± 0.23 (-), 4 Mets: 0.43 ± 0.09 (-), and 5 Mets: 0.60 ± 0.21 (-); the ones for Female were rest: 0.16 ± 0.10 (-), 2 Mets: 0.22 ± 0.11 (-), 3 Mets: 0.24 ± 0.14 (-), 4 Mets: 0.23 ± 0.16 (-), and 5 Mets: 0.24 ± 0.14 (-). Although there was significant difference in the thermal comfort limit in each activity between Female and Male, the thermal comfort limit increased indeed with the increasing metabolic rate in both Female and Male groups. A strong tendency of high correlation between the metabolic rate and the comfort limit was seen in each group with significances of $p= 0.06$ for Female and $p= 0.08$ for Male. For Male, change in the comfort limit as a function of metabolism was similar to the one given by the estimation equation, while the comfort limit in each metabolic rate was slightly larger than that by the estimation equation. On the other hand, for Female, the obtained comfort limit indicated an obviously smaller value compared to the one estimated value by the equation.

Diurnal variation in the core interthreshold zone and its relation to cutaneous sensation threshold zone

Naoshi Kakitsuba, Igor Mekjavic

Meijo University, Nagoya-city, Japan

The core interthreshold zone (CIZ) is defined as the range between temperatures at the onset of shivering and sweating. Its circadian or diurnal variation has not been extensively studied. The present study examined whether the CIZ is subject to a diurnal rhythm. In addition, according to the previous finding that the CIZ was proportionally correlated with peripheral interthreshold zone (PIZ), it was also examined whether cutaneous sensation threshold zone (CSZ) is correlated with the CIZ. The CIZ and the CSZ were measured in 10 Japanese men who underwent three experiments in a single day on the morning, afternoon, and evening in the 2014 experiment, and six Japanese men underwent the same experiments on the morning of day 1, the afternoon of day 2, and the evening of day 3 in the 2015 experiment. Air temperature was controlled at 20-24 °C. Each subject wore a suit perfused with 25 °C water at a rate of 600 cc/min, and exercised on an ergometer at 50 % of their maximum work rate for 10-15 min until their rate of sweating increased. They then remained seated without exercising until their oxygen uptake increased. Rectal temperature, skin temperatures at seven sites, the sweating rate at the forehead, and oxygen uptake were continuously monitored throughout experiment. Cutaneous warm and cold sensation thresholds at three sites were measured using 1-cm2 and 2-cm2 probes. The results from the 2014 experiment demonstrated small change in the CIZ and core temperature prior to exercise (Tc-init) whereas those from the 2015 experiment demonstrated continuous increase in the CIZ and Tc-init. The CSZ measured with a 1-cm2 probe was inversely proportional to the average skin temperature at three sites prior to measurement. The results suggested that the CIZ may be not dependent on time of a day but Tc-init per se, and may not be associated with the CSZ.

193 POSER SESSION 5

Estimation of thermal sensation based on human´s physiological parameters in indoor environment

Róbert Toma, Jan Fišer, Miroslav Jícha

Brno University of Technology, Brno, Czech Republic

Research in thermal comfort field is nowadays driven by imperfection in HVAC (Heating, ventilation and air conditioning) systems regulation, which results in inefficient energy utilization of these systems. Therefore, more precise and energy efficient regulation system for HVAC is needed. The biggest issue in the regulation is the insufficient information about humans´ thermal state. Thermal sensation estimation from humans´ physiological parameters is a current trend as prediction models based on environmental parameters (e.g. PMV model, Nilsson model) recently showed their limitations. Our ongoing research, which is a foundation for my dissertation thesis, is focused on prediction of thermal sensation based on peripheral skin temperatures. The main goal is to construct an empirical model which will be able to predict person´s thermal sensation from his/her peripheral skin temperatures and its gradient on multiple spots on the face and wrists separately or by using combinations of these temperatures. Three stages of experiments will be examined -stationary conditions (construction of the model), non – stationary conditions (validation) and testing in real conditions (validation). The scope of the model covers sedentary position with metabolic rate of 1.2 met, which simulates classic office work. Skin temperatures on the face will be obtained by post-processing of pictures from an infrared camera Flir on several spots – forehead, nose, left cheek, right cheek and chin. Wearable devices (e.g. E4 wristband, Microsoft Band2) will be utilized for measuring skin temperatures on each wrist. Wireless technologies for data transfer will be used during our experiments as we are aiming to implement our method into real situations in the future, where “smart” devices are intended to be used as an input for HVAC control systems. In our pre-tests, we found good relationship between subjective thermal vote from volunteers obtained during experiments and skin temperature on their faces. The Pearson´s correlation coefficient was particularly good when air temperature changed from 20°C to 26°C during test and reached values: 0.971 on nose; 0.939 left cheek; 0.921 right cheek; 0.937 on whole face – using average of all five temperatures. However, the values of Pearson´s coefficient were significantly lower when air temperature changed from 26°C to 20°C during test, reaching values of around 0.600 on same parts. We are expecting to find better correlation using multiple regression analyses on the gradient of these peripheral temperatures. Comparison between our innovative approach and more convective models, as PMV or MTV, will be also conducted in the final stage of this research.

194 POSER SESSION 5

Cutaneous thermal thresholds in elderly people with lifestyle-related disease

Nobuko Hashiguchi[1], Mami Miyazono[1], Akiko Chishaki[1], Yutaka Tochihara[2]

[1]Department of Health Science, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan, [2]Department of Human Science, Fuculty of Design, Kyushu University, Fukuoka, Japan

We investigated that cutaneous warm sensation thresholds in healthy elderly males and young males, and found that the elderly people tended to be less sensitive in detecting warmth in lower legs (Tochihara et al. 2011). However the participants of this previous study were good health and had never suffered from lifestyle-related diseases, such as diabetes (DM) and hypertension (HT). Because, in generally, lifestyle-related disease induce nervous disorder and circulatory deficit, cutaneous thermal sensations in the elderly people with lifestyle-related diseases might differ from those in healthy ones. Hence, we investigated the cutaneous thermal sensation thresholds in elderly people including patients with lifestyle-related diseases.

This study participants were 58 elderly men, including 11 subjects with diabetes (DM) and 20 with hypertension (HT), 7 with cardiac disease. The remaining 20 subjects were in good health and had never suffered from lifestyle-related diseases, such as DM and HT.We measured peripheral warm and cool thresholds in five body regions (cheek, abdomen, hand, calf, and foot) using a thermal simulator controlled by a Peltier element and push-button switch (Intercross-210, Intercross Co., Japan). The measurements took place in a climatic chamber maintained at an air temperature of 25°C with 50% relative humidity and with the subjects wearing shorts and a T-shirt. Prior to measurements, the subjects lay supine on a bed in the climatic chamber for 30 minutes. All threshold measurements were repeated three times, and we took the average of those measurements. All the subjects underwent practice in making the thermal threshold discriminations: they learned to press the switch as soon as they perceived the feeling of slight warmth or slight coolness from their thermal neutral state. Moreover, we diagnosed the presence of sensitive to cold or heat by questionnaire.

The cutaneous warm thresholds on the abdomen, hand, and calf were significantly greater in subjects with DM than in those with HT or in healthy subjects ($p<0.05$), though no significant differences were found with the cool thresholds. There was no significant relationship between cutaneous thermal thresholds and life style, such as diet, exercise, and sleep, and usage situation of cooling and heating system. The cutaneous cold thresholds on hand were significantly greater in subjects who were sensitive to cold compared to subjects were not.

This study found the difference of cutaneous thermal thresholds between the elderly with lifestyle-related disease and healthy ones, and the elderly with DM were less sensitive to warm compared to elderly without DM.

Tochihara Y, et al. (2011) Journal of Thermal Biology 36(2):105-111

Individual variations in perceived thermal sensation and skin temperature of fingers at different work intensities during cold exposure

Øystein Wiggen[1], Trine Seeberg[2], Hanne Opsahl Austad[2], Hilde Færevik[1]

[1]SINTEF Technology and Society, Trondheim, Norway, [2]SINTEF Digital, Oslo, Norway

Low finger skin temperature (T_{finger}) is likely to occur during work in cold environments, and can lead to reduced manual performance, comfort, and increase risk of human errors. Individuals perceived thermal sensation (PTS) is the most common decision tool for when to abort work due to cold stress. The aim of this study was to investigate the variation between reported PTS compared to T_{finger} during different work intensities. Six healthy males, dressed in winter clothing, where exposed to a wind chill temperature of -25 C while performing three adjacent work periods; 1) 30 minutes of moderate intensity, 2) 30 minutes of hard intensity and, 3) 0-60 minutes of low intensity. T_{finger} was measured continuously and PTS measured each 15th minute throughout the experiment. The experiment was stopped when the subject reached a T_{finger} lower than 8 C. Results are presented in Figure 1. Large individual differences was demonstrated, with more than 15C differences in T_{finger} at the same PTS (slightly cool). Neutral or slightly cool PST would not make an individual stop working, demonstrating that in some individuals manual performance is likely to occur due to low T_{finger} despite only a neutral to slightly cool PST. It is therefore a necessity for other objective decision support tool when working in cold environments

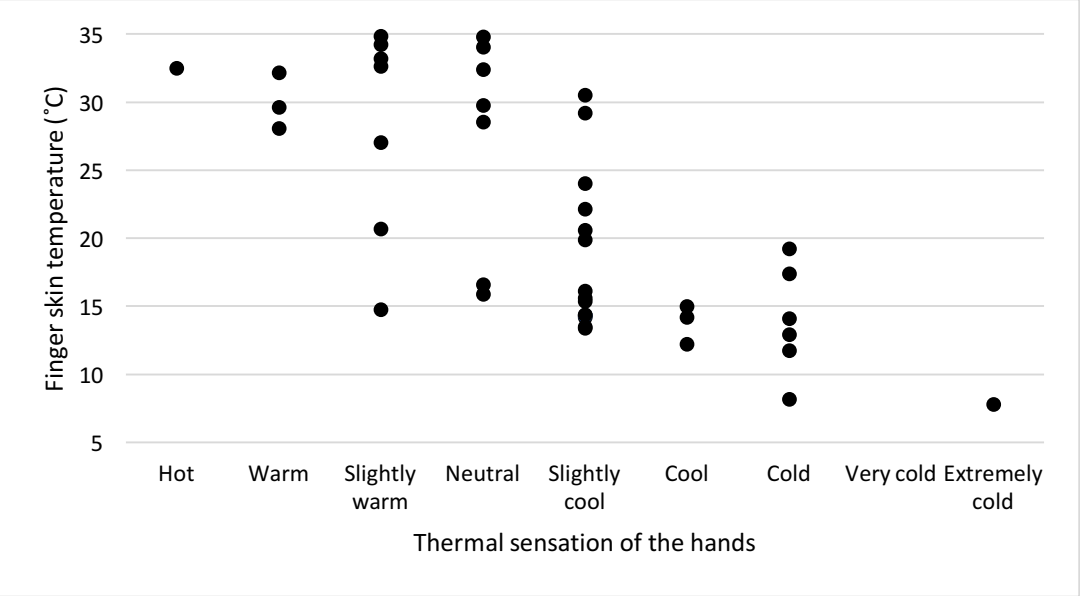

Figure 1: Thermal sensation of the hands and the corresponding finger skin temperature (n=6)

Reliability and face validity of a protocol for defining the inflection point in deep body temperature during cycling exercise in a high and low humidity

Ella F. Walker[1,2], Jo Corbett[2], James R. House[2], Michael J. Tipton[2]

[1]University of Chichester, West Sussex, UK, [2]University of Portsmouth, Hampshire, UK

Reliability is an essential criteria if a test is to be considered valid. However, the reliability of critical environmental limits, have not been established. These limits are defined as where an ambient thermal burden is progressively incremented causing a point where deep body temperature increases without returning to stability, indicating that the conditions for thermal balance are no longer satisfied because of excessive dry heat gain or insufficient evaporative heat loss. Two studies were conducted to: i) determine the reliability of the deep body temperature (T_{re}) inflection point under conditions of low- and high-humidity (LH and HH); ii) to establish whether the T_{re} inflection point determined with an continuous type protocol provides a valid index of the transition from a compensable (CO) to uncompensable (UN) thermal environment.

Study 1 method: n=8 healthy males completed two tests commencing at 34 °C, 20 % RH (LH) and two commencing at 28 °C, 80 % RH (HH) at 60 W. There were two phases in each trial: a) CO phase - 60 minutes at 60 W; b) UN phase – immediately following the CO phase, ambient temperature (T_{db}) was increased by 1 °C every 5 minutes, UN was confirmed by an inflection in T_{re} (T_{reinfl}). Study 2 method: n=9 healthy males completed two visits at 34 °C, 20 % RH at 60 W. Visit 1) protocol: as above in Study 1 and Visit 2) protocol: T_{db} was raised as per Study 1, but then held at a T_{db} just beyond the T_{reinfl} point in Visit 1).

Study 1 showed that T_{reinfl} was identified successfully using the Dmax method (used by previous authors) with low CV (<10%), had good face validity, and was less subjective than a purely visual approach. Study 2 showed that when T_{db} was clamped in Visit 2, T_{re} continued to increase for a further 40-60 minutes.

Thus, it appears that the protocol is reliable in causing a T_{reinfl} (Study 1) and that participants had achieved an uncompensable thermal state when the T_{reinfl} occurred (Study 2). Therefore, previous authors were correct to conclude that their protocols provide insight into thermal and non-thermal factors which affect the point of uncompensability in adults and children.

197 POSER SESSION 5

Neuromuscular function during knee extension exercise following cool-water immersion

Hitoshi Wakabayashi[1], Titis Wijayanto[2], Yutaka Tochihara[3]

[1]Hokkaido University, Sapporo, Japan, [2]Gadjah Mada University, Yogyakarta, Indonesia, [3]Kyushu University, Fukuoka, Japan

Impairment of exercise performance in cold water would be a factor for drowning on accidental immersion. This study investigated the effect of cold water immersion on the exercise performance and neuromuscular function during maximal and submaximal isometric knee extension. Nine healthy males participated in this study. They performed maximal and submaximal (20, 40 and 60% maximal load) isometric knee extension pre and post immersion in 23, 26 and 34°C water to their chest level for 60 minutes, on separate days. The muscle activity of the rectus femoris (RF) and vastus lateralis (VL) was measured using surface electromyography (EMG). The percentages of the maximum voluntary contraction (%MVC) and mean power frequency (MPF) of EMG data were analyzed. The post-immersion maximal force was significantly lower in 23°C than in 26 and 34°C conditions ($P<0.05$). The post-immersion %MVC of RF was significantly higher than pre-immersion during 60% maximal exercise in 23 and 26°C conditions ($P<0.05$). In the VL, the post-immersion %MVC was significantly higher than pre-immersion in 23 and 26°C conditions during 20% maximal exercise and in 26°C at 40 and 60% maximal intensities ($P<0.05$). The post-immersion %MVC of VL was significantly higher in 26°C than in 34°C at 20 and 60% maximal load ($P<0.05$). The post-immersion MPF of RF during 20% maximal intensity was significantly lower in 23°C than in 26 and 34°C conditions ($P<0.05$), and significantly different between three water temperature conditions at 40 and 60% maximal intensities ($P<0.05$). The post-immersion MPF of VL during three submaximal trials were significantly lower in 23 and 26°C than in 34°C conditions ($P<0.05$). The lower shift of EMG frequency after cold immersion would be connected with the decrease in the nerve and muscle fibers conduction velocity [1]. The greater EMG amplitude in cold would be due to the more muscle fibers recruitment to compensate for the impairment of each muscle fibers function. In general, the slow twitch fibers were more sensitive to cold, and faster muscle fibers were recruited at relatively lower velocity than in the thermoneutral condition [1]. Additionally, we previously reported that the skeletal muscle metabolism during isometric hand grip was gradually supressed as a function of the muscle temperature reduction [2]. This result would indicate a greater anaerobic contribution in the hypothermic skeletal muscle. Thus, the greater amplitude of EMG after the cold water immersion might be due to the recruitment of more muscle fibers, especially the fast twitch fibers.

[1] Wakabayashi H, Oksa J, Tipton MJ. (2015) J Phys Fitness Sports Med 4: 177-85.

[2] Wakabayashi et al. (2017) Int J Biometeorol 61: 1261-7.

198 ORAL 19: Heat Exposure 2

Thermal strain during prolonged low intensity exercise wearing an immersion protection aircrew equipment assembly (AEA) in air temperatures of 10, 20 and 30 °C

AS Weller, JWR Boyd

QinetiQ, Farnborough, UK

Aircrew wear immersion protection when overflying cold water to aid survival in the event of ditching, which comprises an immersion protection garment (IPG) and underlying insulation. Aircrew often report significant discomfort during routine flight wearing immersion protection, and therefore this study quantified the thermal strain imposed by an in-service immersion protection AEA across representative air temperatures (T_A) to better understand the burden vs protection trade-off and support work defining AEA thermal performance requirements. Eleven men undertook a 120-min treadmill walking protocol (representative of aircrew workload) in a thermal laboratory on three occasions (T_A; 10, 20 & 30 °C). Measurements included: rectal temperature (T_{RE}), mean skin temperature (T_{SK}), total mass loss rate (M_{TOT}), and ratings of thermal sensation (TS), thermal comfort (TC) and perceived exertion (RPE). Data were analysed by ANOVA and paired t-tests (physiological parameters) and Wilcoxon's signed-rank tests (subjective). $\alpha = 0.05$. Measures obtained at the end of the tests and statistical differences are given in the table. Thermal sensation/comfort was optimal at 10 °C, with modest physiological/subjective strain at 20 °C. As expected, physiological thermal strain was greater at 30 °C compared with 20 °C, but remained within occupational limits, and subjective ratings were not different in the two environments. It is concluded that wearing an immersion protection AEA during prolonged low intensity exercise in a warm environment (20 to 30 °C) will impose a level of thermal strain comparable with wearing non-immersion AEA at a higher T_A, but is unlikely to cause unacceptable physiological strain.

T_A (°C)	T_{RE} (°C)	T_{SK} (°C)	M_{TOT} ($g \cdot h^{-1}$)	TS [-4 to +4]	TC [0 to 4]	RPE [6 to 20]
10	37.3 ± 0.3	32.2 ± 0.6	100.1 ± 32.6	-0.3 ± 0.6	0.2 ± 0.4	9.8 ± 1.6
20	37.4 ± 0.3	34.4 ± 0.7¥	201.6 ± 68.9¥	+1.7 ± 1.0¥	1.2 ± 0.8¥	10.5 ± 1.5
30	37.6 ± 0.3¶$	36.3 ± 0.4¶$	309.6 ± 99.9¶$	+2.4 ± 0.7¶	1.7 ± 0.6¶	11.3 ± 1.8¶
Differences between conditions: ¥ 10 vs 20 °C; ¶ 10 vs 30 °C & $ 20 vs 30 °C.						

199 ORAL 19: Heat Exposure 2

Heat disorder risk evaluation by a new effective wet bulb globe temperature index

Tomonori Sakoi[1], Tohru Mochida[2], Yoshihito Kurazumi[3]

[1]Shinshu University, Ueda, Japan, [2]Hokkaido University, Sapporo, Japan, [3]Sugiyama Jogakuen University, Nagoya, Japan

The wet bulb globe temperature (WBGT) is an effective measure for risk screening to prevent heat disorders. However, heat risk evaluation by WBGT requires adjustments depending on the clothing. In this study, we proposed a new effective WBGT (WBGTeff*) for general vapor permeable clothing ensembles and vapor impermeable protective clothing. WBGTeff* is a transformation of the heat balance equation for the human body with skin wettedness at 0.45 and can be interpreted as the environmental potential to increase skin temperature rather than the heat storage rate of a human body. WBGTeff* enables the conversion of heat stress into the scale experienced by the occupant dressed in the basic clothing ensemble (work clothes). We confirmed that WBGTeff* was effective for expressing the critical thermal environments for the prescriptive zones for occupants wearing vapor impermeable protective clothing.

The weighting coefficients for natural wet bulb, globe, and air temperatures and the intercept of WBGTeff* changed depending on clothing properties and the surrounding environmental factors. The weight of environmental temperatures (globe and air temperatures) for vapor impermeable protective clothing increased compared with that for general vapor permeable clothing, whereas that of natural wet bulb temperature decreased. For WBGTeff* for outdoor conditions with solar load, the weighting ratio of globe temperature increased and that of air temperature decreased with air velocity. Approximation equations of WBGTeff* were proposed for both general vapor permeable clothing ensembles and for vapor impermeable protective clothing.

200 ORAL 19: Heat Exposure 2

Revisiting the occupational exposure limit based on wet bulb globe temperature

Thomas Bernard, Ximena Garzón, Yougui Wu, Candi Ashley

University of South Florida, Tampa, FL, USA

The wet bulb globe temperature (WBGT) has been used for over 60 years to limit exposures to heat stress with the goal of avoiding diminished capacity. Sustainable exposures are heat stress levels at which thermal equilibrium can be achieved, and Unsustainable exposures occur when there is a steady increase in core temperature. This paper addresses the ability of WBGT-based occupational exposure limits to differentiate between Sustainable and Unsustainable heat exposures over a range of environments, metabolic rates and clothing ensembles.

Two progressive heat stress studies provided data on 480 trials with 1440 pairs of Sustainable and Unsustainable exposures over three levels of relative humidity (20, 50 and 70% relative humidity), three levels of metabolic rate (115, 180, and 254 W/m^2) and four clothing fabrics (woven clothing, particle barrier, water barrier and vapor barrier coveralls) using 29 participants. The progressive heat stress protocol was used to identify a critical condition at the upper limit of the ability to maintain thermal equilibrium. Sustainable observations were 15 min prior to the critical condition and when the critical condition met criteria for steady-state core temperature; and Unsustainable observations were 15 min after the critical condition and critical conditions that were preceded by a rise in core temperature of 0.1 °C in the preceding 20 min. The exposure metric was the difference between the observed WBGT and the ACGIH® Threshold Limit Value® (TLV®) adjusted for metabolic rate. Conditional logistic regression models provided information on odds ratios. Logistic regressions were used to model the dose-response curve, estimate offsets from woven clothing, and determine Receiver Operating Characteristic (ROC) curves with area under the curve (AUC).

The odds ratios for Unsustainable were about 2.5 per 1 °C-WBGT for woven clothing, particle barrier and water barrier and for vapor barrier at 50% relative humidity. When using the published Clothing Adjustment Values or the offsets that included different values for vapor barrier based on relative humidity, the AUC for all clothing was 0.86. When the fixed CAVs of the TLV, which excluded water barrier, were used, the AUC was 0.81.

Overall, the risk profiles for nonwoven clothing worn as coveralls were similar in the rate of change of risk (odds ratio of about 2.5 / °C-WBGT). Further, the use of Clothing Adjustment Values (CAVs) provided a robust way to account for the risk of nonwoven clothing on the transition from Sustainable to Unsustainable. The robust nature extended to the exclusion of different adjustments for vapor barrier by relative humidity. The interaction between evaporative resistance and humidity required further exploration.

201 ORAL 20: Body Morphology

Body morphology appears not to influence thermoeffector function during uncompensable heat adaptation

Sean Notley[1], Elizabeth Taylor[1], Norikazu Ohnishi[2], Nigel Taylor[1]

[1]University of Wollongong, Wollongong, NSW 2522, Australia, [2]Mie Prefectural College of Nursing, Mie, 514-0116, Japan

Cutaneous vasomotor and sudomotor function can be enhanced during heat acclimation, yet the inter-individual variation in the extent of those adaptations is extensive. This may be related to individual differences in the ratio between body surface area and mass (specific surface area), which is a key determinant of passive heat exchange and storage, and a significant predictor of acute cutaneous vasomotor and sudomotor activity. Accordingly, this study was designed to determine whether or not individual differences in specific surface area may also assist in explaining variations in thermoeffector adaptation. Cutaneous vasomotor function (forearm plethysmography), as well as local (ventilated capsules; four regions) and whole-body (mass change) sudomotor responses, were examined in ten smaller and ten larger males with wide differences in specific surface area (273 ±8 $cm^2.kg^{-1}$ and 244 ±10 $cm^2.kg^{-1}$, respectively; $P<0.05$). Heat stress tests were performed before (day 1) and after (day 10) eight consecutive days of heat acclimation (days 2-9). All exposures were in hot-dry conditions (40.0°C, 37% relative humidity). Heat acclimation consisted of intermittent cycle exercise (90 min.day-1) to clamp deep-body temperature (38.5°C). Heat stress tests involved seated rest (30 min) followed by steady-state cycling (45 min), eliciting two matched and clamped deep-body temperatures (mild hyperthermia: 37.5°C, moderate hyperthermia: 38.5°C). Thermoeffector responses were determined within the final 5 min of exercise. Deep-body temperature during both stages of the pre- and post-acclimation heat stress tests were similar between groups ($P>0.05$), and did not differ within each group following acclimation ($P>0.05$). Forearm blood flow during mild and moderate hyperthermia increased following acclimation in both the smaller (22% and 30%, respectively; $P<0.05$) and larger groups (26% and 19%; $P<0.05$). The four local, as well as whole-body, sweat rates also increased following acclimation, with those increments ranging from 17% to 41% in the smaller group, and from 23% to 47% in the larger group ($P<0.05$). However, those thermoeffector adaptations did not differ significantly between groups ($P>0.05$). These outcomes indicate that, when assessed during uncompensable exercise following short-term acclimation, neither vasomotor nor sudomotor adaptations appear to be morphologically related.

202 ORAL 20: Body Morphology

Hand rewarming following exercise in cold air is dependent on body fatness

Damien Fournet[1], Thomas Voelcker[1], George Havenith[2]

[1]DECATHLON SPORTSLAB, Villeneuve d'Ascq, France, [2]LOUGHBOROUGH UNIVERSITY, Loughborough, UK

Marked inter-individual differences in rewarming have been highlighted in human hands when exposed to cold air or water immersion. Following exercise in 0 and 10°C, Hellström et al. (1970) observed that finger rewarming was not related to individual differences in $VO_{2,max}$. The influence of body fatness on hand skin temperature (T_{sk}) has rarely been explored. Savastano et al. (2008) found that obese adults had significantly higher finger T_{sk} and lower abdominal T_{sk} compared to normal weight adults, in a thermoneutral environment at rest. Our study aimed at investigating hand T_{sk} dynamics and distribution of males with varying body fat during cold air exposure.

Twenty semi-nude males sat for 60 minutes on a stool with limited motion. The resting phase was followed by a 30-min exercising phase at 100W on a cycle ergometer. Both phases were performed in a 10°C, 50% RH climatic chamber. Three distinct categories of body fat percentage (%BF calculated from 7 skinfold locations), but similar fitness level, were arbitrarily created (Low Fat (LF): 5-10%, Medium Fat (MF): 10-15% and High Fat (HF): 15+) with a total range varying from 7 to 40 %BF. Hand T_{sk} and mean T_{sk} were measured by infrared (IR) thermography at different stages of the protocol together with oxygen uptake (VO_2) by the Douglas bag method, allowing an estimation of heat production (ISO8996). Rectal temperature (T_{re}), finger T_{sk} (thermocouple) fingertip blood flow (Laser Doppler flowmetry) and heart rate were monitored throughout the whole protocol. Thermal sensation and comfort were evaluated for 11 different body regions including the hands.

Following exercise, T_{re} was significantly higher in HF compared to LF and MF (37.8±0.1°C vs 37.2±0.5°C and 37.3±0.2°C) whilst mean T_{sk} was significantly lower in HF (23.3±1.3°C) compared MF (25.5±0.8°C), and in turn to LF (26.8.±0.6°C). Heat production was similar between groups at all stages. The most important finding was that %BF was positively correlated with finger rewarming (post-pre-exercise T_{sk})($r = 0.82$, $p<0.05$). T_{sk} rise during exercise was preceded (5-min delay) by a 10-fold rise in tissue perfusion in HF leading to an overall 16°C increase in finger T_{sk}. Exercise-induced vasodilation (in HF) occured at the fingertip with arteriovenous anastomosis opening, as clearly shown on the first-ever produced average hand IR mapping. Lastly, participants in HF reported warmer thermal sensation and lower discomfort in the hands after exercise compared to LF and MF, in line with the large differences in post-exercise finger T_{sk} (29.1±2.6°C in HF vs 14.5±4.5°C in LF and 14.5±5.3°C in MF).

Our results indicated that individuals with larger %BF favoured heat dissipation through a region with low adiposity (the hands) during exercise. Though this was not sufficient to offset total heat storage, this had positive psychological and protective (e.g frostbite) impacts.

203 ORAL 20: Body Morphology

Individualising the exposure of −110°C whole body cryotherapy: The effects of sex and body composition

Saul Cuttell[1], Lucy Hammond[2], Dominic Langdon[3], Joseph Costello[4]

[1]University of Northampton, Northampton, UK, [2]University of Warwick, Coventry, UK, [3]Moulton College, Northampton, UK, [4]University of Portsmouth, Portsmouth, UK

Whole body cryotherapy involves exposing individuals to extremely cold dry air, which means below -100°C, for two to four minutes in a specialised cabin or chamber. The purpose of this study was to investigate the effects of whole body cryotherapy (WBC) on a range of thermoregulatory measures. A convenience sample of 18 healthy participants (10 males and 8 females) (27±6 yr) volunteered for this study. Temperature (rectal, tympanic, skin and mean body), heart rate, blood pressure, and thermal comfort and sensation were recorded pre- and post- (immediately and every 5 min until 35 min post) exposure to a single bout of WBC (30 s at −60 °C, 150 s at 110 °C). Anthropometric data (height, weight, body surface area, body mass index, fat mass and fat free mass measure using bioelectrical impedance) were also recorded. No significant differences in temperature (core, tympanic, skin and mean body), heart rate, blood pressure, or thermal comfort / sensation were observed between male and females at baseline. Immediately post WBC mean body (male: 31.9±0.8 °C; female: 31.0±0.9 °C; Δ mean body temperature: 0.9±0.1 °C higher in males; P≤0.05, d=0.64) and mean skin (male: 22.1±2.2 °C; female: 19.6±2.8 °C; Δ mean skin temperature: −2.5±0.6 °C; d=0.99, P≤0.05) temperature was significantly different between sexes. Sex differences were also observed in regional skin temperature (male thigh, 20.8±1.1 °C; female thigh, 16.7±1.1 °C, d=3.72; male calf, 20.5±1.1 °C; female calf, 18.2±1 °C, d=3.61; male arm, 21.7±1 °C; female arm, 19±0.4 °C, d=3.54; all P≤0.05). Mean arterial pressure was significantly different over time (P≤0.001) and between sexes (male 0 mins: 94±10 mmHg; female 0 mins: 85±7 mmHg; male 35 mins: 88±7 mmHg; female 35 mins: 80±6 mmHg; P≤0.05). Combined data set indicated a strong negative relationship between skin temperature and body fat percentage 35 min' post WBC (r=−0.749, P≤0.001) and for core temperature and body mass index in males only (r=0.726, P≤0.05) immediately after WBC. There were no significant differences between sexes in any other variables (heart rate, tympanic and perceptual variables). We observed sex differences in mean skin and mean body temperature following exposure to whole body cryotherapy. In an attempt to optimise treatment, these differences should be taken into account if whole body cryotherapy is prescribed.

204 SYMPOSIUM: Early Career Researchers: Adaptations

Adaptations Introduction

Tatsuro Amano[1], Naoto Fujii[2], Nicola Gerrett[3]

[1]Niigata University, Niigata, Japan, [2]Tsukuba University, Tsukuba, Japan, [3]Kobe University, Kobe, Japan

The Early Career Researcher symposium has been identified as an integral part of the ICEE program. The committee hope to bridge the gap between the students and well-established researchers by highlighting those individuals in the early stages of their research career. Postdoctoral research fellows, assistant or associate professors just starting out on their independent research career have been selected to showcase their research on topics associated with adaptations.

Humans live and are exposed to various environments/stressors and have the capability of adapting to them. The adaptive ability in humans provides many benefits including improving health and exercise performance as well as reducing risks in the work place. This symposium focuses on human adaptive responses to hot and cold environments as well as exercise training, all of which are important topics in ICEE. The first presentation will provide important insights into our knowledge of the cold shock response associated with psychological status. The second presentation focuses on human heat adaptation (via heat therapy) and its benefit to health. Finally, human thermoregulatory adaptation to habitual exercise training, especially focusing on sweating response, will be introduced. Hopefully this symposium will encourage our understandings in human adaptation and will help early career researchers develop their future research topics.

205 SYMPOSIUM: Early Career Researchers: Adaptations

Habituation of the cold shock response: novel drivers of the habituation process in an integrated model of cold shock

Martin Barwood[1], Mike Tipton[2], Jo Corbett[2], Heather Massey[2], Christopher Wagstaff[1], Terry McMorris[3]

[1]Leeds Trinity University, Leeds, UK, [2]University of Portsmouth, Portsmouth, UK, [3]Northumbria University, Northumbria, UK

Habituation is defined as a diminished response to a stimulus of the same magnitude but is transient and may not result in adaptation. Habituation of the cold shock response (CSR), a life-threatening response if accidentally immersed, can be achieved by as few as four separate short immersions and is retained for 11 to 14-months. Hence, inducing an habituation of the CSR may be practical for those at daily risk of accidental cold water immersion (CWI) to reduce the risk of drowning. Yet the CSR remains variable both before and after habituation suggesting novel drivers of the habituation process require consideration. We have undertaken four studies where the primary variable was the role that acute anxiety prior to and during CWI plays in the extent of the CSR in unhabituated and habituated participants. Forty-eight participants (34 male, 14 female; mean [SD] age 20.3 [1.7] years, height 1.75 [0.1] m, mass 76.2 [16.7] kg) were recruited across these ethically approved studies in order to test the hypotheses that: study 1) acute anxiety could magnify the CSR in unhabituated participants; study 2) acute anxiety after habituation could reverse the habituation of the CSR; study 3) habituation includes a significant perceptual component and study 4) repeated anxiety would prevent CSR habituation. For CWIs, participants were immersed for 7-minutes using a standardised technique to the same depth in 15 °C water. When required, anxiety levels were manipulated by deception about water temperature (they were instructed it would be 1°C colder than previous; studies 1,2 & 4) and a punitive maths task where incorrect responses extended immersion to a maximum of 7-minutes (study 4 only). Where CWI habituation was studied (i.e. studies 2 & 4) a total of seven CWIs were completed. In study 3, five thermoneutral water (35 °C) immersions were undertaken between two CWIs to establish the resultant effect of familiarisation (i.e. a change in threat perception) on the CSR. Acute anxiety (20 cm visual analogue scale) was measured prior and after 1,3,5 and 7 minutes of immersion. The cardiorespiratory responses (cardiac frequency [f_C], respiratory frequency [f_R], tidal volume [V_T], minute ventilation [$\dot{V}_E$]) were measured by ECG and spirometry. We found: study 1) acute anxiety magnifies the CSR in unhabituated participants; study 2) acute anxiety reverses habituation of the cardiac component of the CSR after habituation has occurred; study 3) habituation includes a significant perceptual component; study 4) habituation is delayed or prevented by repeatedly high(er) levels of anxiety when present throughout habituation immersions. We offer a new integrated model to explain the role anxiety plays in habituation of the CSR considering the neuroanatomical, perceptual and attentional components contributing to the CSR from the perspective of magnifying compared to reducing acute anxiety levels.

206 SYMPOSIUM: Early Career Researchers: Adaptations

Thermal Therapy in the management and treatment of chronic disease

Steve Faulkner

Nottingham Trent University, Nottingham, UK

The use of passive heating or thermal therapy as a means of replicating some of the beneficial effects of exercise has experienced a recent resurgence. Many researchers acknowledge that thermal therapy may offer an effective opportunity for those who are unable or unwilling to exercise, to achieve some of the health benefits attributed to exercise. These include cardiovascular and metabolic improvements as well as alterations to body composition.

Animal models have provided the basis for which thermal therapy may exert its effect to improve metabolic function, having considerable implications for the treatment and management of many chronic diseases including obesity and type 2 diabetes (T2DM). The seminal work of Chung et al., (2008) showed how regular expose to thermal therapy improved insulin sensitivity and glycaemic control in a murine model of diet and obesity induced hyperglycaemia. Importantly they showed that heat shock proteins (HSPs) likely play an important role in the adaptive response to thermal therapy in models of metabolic disease. Furthermore, they also demonstrated that humans with obesity and insulin resistance have a reduced level of intracellular HSP72 (iHSP72). Subsequently, others have investigated the effects of a reduction in iHSP72 on the stress kinases that contribute to the development of insulin resistance and T2DM. These data suggest that thermal therapy increases the expression of intracellular HSPs, which may maintain insulin signalling and glucose uptake.

Recently, we have demonstrated that an acute bout of thermal therapy has beneficial effects on lowering peak glucose excursions compared to exercise following a standardised meal. In addition it was revealed that thermal therapy resulted in a similar acute inflammatory response as is evident following exercise. Such an inflammatory response could promote an anti-inflammatory profile, and thus reduce the systemic inflammation associated with many forms of chronic disease.

Epidemiological and experimental data offer support for the role of thermal therapy in improving cardiovascular function. For example, Laukkanen et al (2015) report an association between increased sauna frequency and a reduction in cardiovascular disease and all-cause mortality. Experimentally, beneficial effects on vascular function have been reported following both acute and chronic thermal therapy, with HSPs being suggested to have an important role in the adaptive process following heat exposure.

Although in its infancy of application to chronic disease, thermal therapy appears to have a beneficial impact on health. It is the aim of this presentation to summarise the research related to thermal therapy as a potential intervention for the treatment and management of chronic disease.

207 SYMPOSIUM: Early Career Researchers: Adaptations

Characteristics of sweating response in habitually trained individuals and its potential mechanisms

Tatsuro Amano[1], Narihiko Kondo[2]

[1]Niigata University, Niigata, Japan, [2]Kobe University, Kobe, Japan

Sweat is produced in sweat glands and appears on the skin surface. Sweat evaporation is an essential heat loss pathway during heat stress and therefore understanding its adaptation to exercise training is an important issue. It has been implicated that a longer period of exercise training for several years such as typically performed in habitually trained athletes may induce greater sweat production relative to a shorter period of training for weeks or months. Thus in this presentation I will mostly focus on the sweating response in habitually trained individuals relative to their untrained counterparts. There are two driving factors to induce sweating during exercise: thermal and non-thermal factors. Thermal factors indicate core and skin temperatures while non-thermal factors indicate central command, muscle metabo- and mechano-receptors, etc. It has been shown that endurance trained athletes show enhanced sweating responses to both thermal and non-thermal stimulations relative to their untrained counterparts. However, underpinning mechanism(s) for the enhanced sweating responses in trained athletes has not been extensively studied. Recent studies demonstrated that nitric oxide synthase and cyclooxygenase play important roles for sweat production and thus we have investigated whether these key enzymes contribute to the higher sweat production in trained athletes. Furthermore, we also investigated whether and how β-adrenergic mechanisms contribute to the greater sweat production in habitually trained athletes relative to their untrained counterparts. In this presentation I will firstly outline the characteristics of sweating response to thermal and non-thermal factors in habitually trained athletes and thereafter discuss its underpinning mechanisms.

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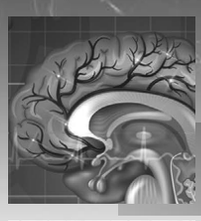

Measurement parameters

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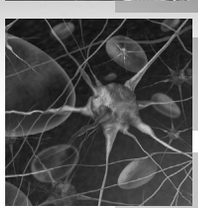
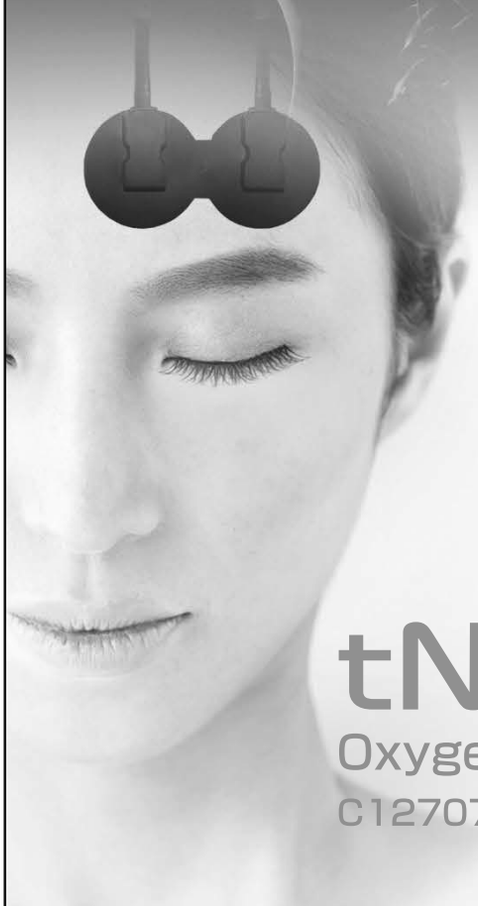


HHb Deoxygenated Hemoglobin Concentration

tHb Total Hemoglobin Concentration

StO_2 Oxygen Saturation of Hemoglobin



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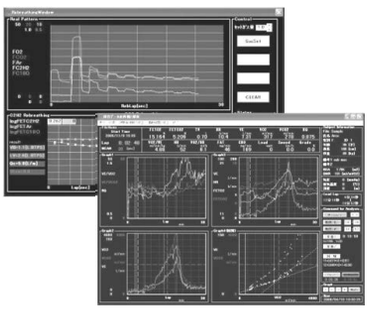

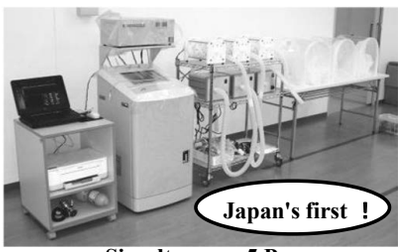

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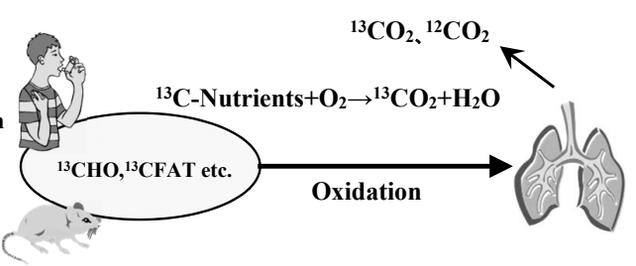

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有限会社アルコシステム

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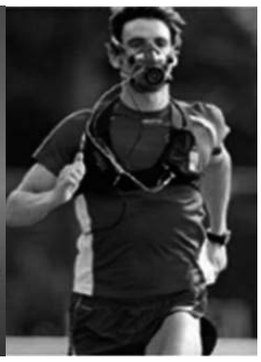

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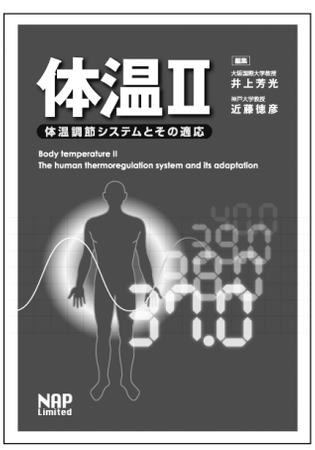

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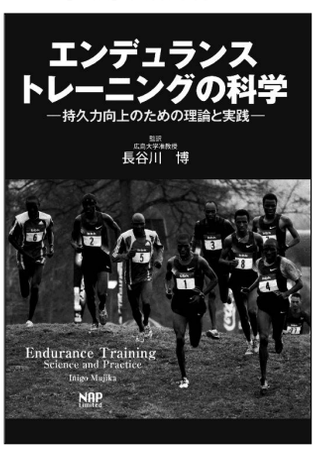

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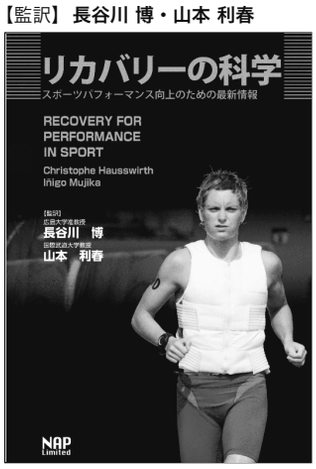

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It has been used widely in research areas such as physiology or medicine physical strength.
LCG of Med-Eng reduces the physical stress of heat in various environments by cooling water.
Portable cooling unit that is proprietary, it does not interfere with the freedom of movement,
even if you installed a lightweight / compact design.

On the other hand,
you can circulate hot water by using a pump and constant temperature water tank.

SIZE	HEIGHT (FT)	WEIGHT (LBS)	HEIGHT (CM)	WEIGHT (KG)
Small	4'11" - 5'9"	110 - 150	150 - 175	50 - 68
Medium-Small	5'7" - 6'0"	154 – 185	170 - 183	70 - 84
Medium	5'9" - 6'4"	187- 220	175 - 193	85 - 100
Large	6'2" - 6'6"	210 - 250	188 - 198	95 - 113

The LCG tube suit consists of a 3 pieces(hood and jacket and pants) by connecting the tube hose.

CoreTemp Core Body Temperature Monitoring

The CorTemp Data Recorder receives the signal from the CorTemp Core Body Temperature Pill Sensor.
And it is converted the signal frequency into digital temperature data.
This temperature data is displayed on the LCD screen with a resolution of 0.01 degree.
The temperature is sampled at a user programmable interval and
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This recorder operates on one standard 9-Volt alkaline battery,
which will provide approximately 110 hours of continuos recording at 10 second intervals.
Battery power can last up to 336 hours(114 days),
depending on the sampling interval programmed into this recorder.

The Pill Sensor size is 22.6mm x 10.7mm.
It needs within 60cm between the recorder and pill sensor for readings.

If you are interested in these products,
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Otsuka

体が知ってる大切な水と電解質

脱水状態に。経口補水液 OS-1 オーエスワン®シリーズ

消費者庁許可 個別評価型 病者用食品

ゼリータイプ

オーエスワンゼリー
内容量:200g
メーカー希望小売価格 190円(税抜)

オーエスワンPETボトル
内容量:280mL
メーカー希望小売価格 133円(税抜)

オーエスワンPETボトル
内容量:500mL
メーカー希望小売価格 190円(税抜)

POINT1
消費者庁から許可された特別用途食品
個別評価型病者用食品です。

POINT2
下痢・嘔吐・発熱、経口摂取不足、過度の
発汗による脱水状態等に適しています。

POINT3
乳幼児から高齢者の軽度から
中等度までの脱水状態時にお勧めします。

POINT4
オーエスワンゼリーは、そしゃく・えん下困難な場合にも
用いることができますが、医師とご相談の上、ご使用下さい。

〈オーエスワンが許可を受けた表示内容〉
オーエスワンは、電解質と糖質の配合バランスを考慮した経口補水液です。軽度から中等度の脱水状態の方の水・電解質を補給・維持するのに適した病者用食品です。感染性腸炎、感冒による下痢・嘔吐・発熱を伴う脱水状態、高齢者の経口摂取不足による脱水状態、過度の発汗による脱水状態等に適しています。

〈オーエスワンゼリーが許可を受けた表示内容〉
オーエスワンゼリーは、電解質と糖質の配合バランスを考慮した経口補水液です。軽度から中等度の脱水状態の方の水・電解質を補給・維持するのに適した病者用食品です。感染性腸炎、感冒による下痢・嘔吐・発熱を伴う脱水状態、高齢者の経口摂取不足による脱水状態、過度の発汗による脱水状態等に適しています。そしゃく・えん下困難な場合にも用いることができますが、医師とご相談の上、ご使用下さい。

〈摂取上の注意〉
下記の1日当たり目安量を参考に、脱水状態に合わせて適宜増減してお飲み下さい。

学童～成人(高齢者を含む)		500～1000mL(g)/日
幼児		300～600mL(g)/日
乳児	体重1kg当たり	30～50mL(g)/日

※gは、オーエスワンゼリーのみに適用する。
医師から脱水状態時の食事療法として指示された場合に限り飲み下さい。医師、薬剤師、看護師、管理栄養士の指導に従ってお飲み下さい。食事療法の素材として適するものであって、多く飲用することによって原疾患が治癒するものではありません。

個別評価型病者用食品とは、特別用途食品のうちで特定の疾病のための食事療法上の期待できる効果の根拠が医学的、栄養学的に明らかにされている食品として消費者庁が許可した食品です。

詳しい商品情報 OS-1 検索

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2017年3月作成 OSA8117B01

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