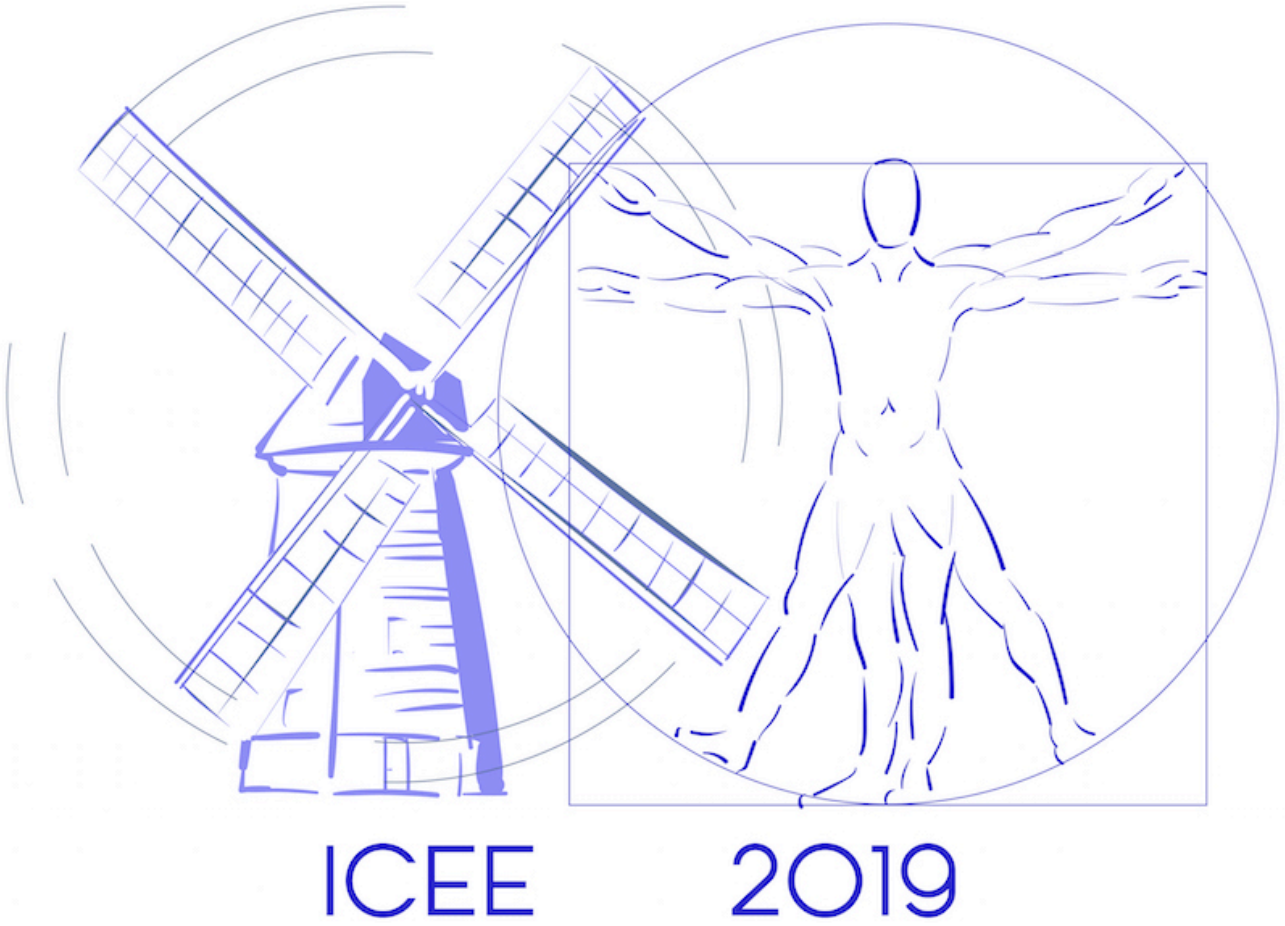
The 18th International Conference on Environmental Ergonomics ICEE2019



BOOK OF ABSTRACTS

July 7 – 12, 2019
Amsterdam, The Netherlands

Environmental Ergonomics XVIII / editors Local Organising Committee. International Society for Environmental Ergonomics.

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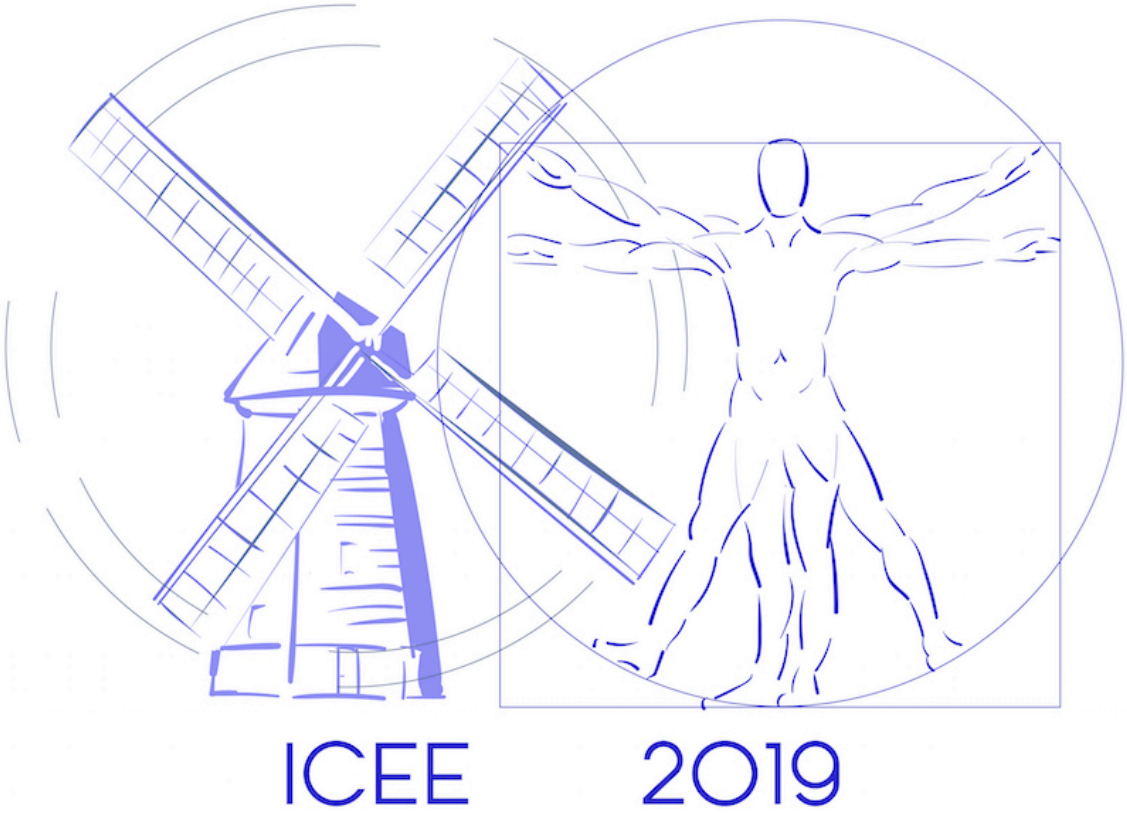
Book of Abstracts



XVIII International Conference on Environmental Ergonomics

7-12th July 2019, Amsterdam, The Netherlands

WELCOME

ICEE is back in The Netherlands! In 1992 Wouter Lotens and George Havenith selected Maastricht as the conference venue; a city in the south of The Netherlands in which life is enjoyed in a Burgundian life style. Now, 27 years later it is Amsterdam's turn. With world-class museums, quirky festivals, theatre, live music, laid-back bars and delightful restaurants, there's never a shortage of things to do in Amsterdam. The ICEE conference is held in the Royal Tropical Institute of the Tropics, a stylish building opened by Queen Wilhelmina the 9th of October 1926.

We received 246 submissions with authors coming from 31 countries! The topic of environmental ergonomics is alive and kicking with a strong focus on the effect of heat on human performance. 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.

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 ICEE2019.

We wish you a successful meeting and an enjoyable time in Amsterdam!

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ICEE2019 conference website:
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An introduction to the history of the International Conference on Environmental Ergonomics: http://www.environmental-ergonomics.org/

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ICEE 2019 Week Schedule

Date/Time	Sunday 7th July
18:00-20:00	Registration & Welcome reception (Vrjie Universiteit Amsterdam)

Date/Time	Monday 8th July
08:00-08:30	Registration
08:30-08:45	Welcoming address: Prof Daanen
08:45-10:00	Symposium: **Cryotherapy for recovery: time for the cold shoulder or a warm welcome?**
10:00-10:30	Coffee break & Posters 1
10:30-12:00	Oral presentation 1: **Sports performance**
12:00-13:00	Lunch & Posters
13:00-14:30	Symposium: **The ins and outs of heat stroke: examining novel risk factors of susceptibility**
14:30-15:00	Poster presentations 1
15:00-15:30	Coffee break & Posters 1
15:30-17:15	Oral presentation 2: **Thermoeffector control**
17:15-17:30	Meeting adjourned for the day. Announcements.

Date/Time	Tuesday 9th July
08:00-08:30	Registration
08:30-10:00	Symposium: **Heat acclimation for special populations**
10:00-10:30	Coffee break & Posters 2
10:30-12:00	Oral presentation 3: **Heat acclimation**
12:00-13:00	Lunch & Posters
13:00-14:30	Symposium: **Impact of cold exposure on individuals with clinical disease**
14:30-15:00	Poster presentations 2
15:00-15:30	Coffee break & Posters 2
15:30-17:20	Oral presentation 4: **Vulnerable populations**
17:20-18:00	Meeting adjourned for the day. Announcements & group photo
18:00-late	Student party

Date/Time	Wednesday 10th July
08:00-08:30	Registration
08:30-10:30	Symposium: **Occupational heat strain in a warming world**
10:30-11:00	Coffee break
11:00-12:30	Oral presentation 5: **Heat exposure**
12:30-13:30	Lunch
13:30-15:00	Social activity: Boat tour
Date/Time	**Thursday 11th July**
08:00-08:30	Registration
08:30-10:00	Symposium: **The application of menthol in sport, exercise and occupational settings: to apply, ingest or discard?**
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10:30-12:00	Oral presentation 6: **Physiology**
12:00-13:00	Lunch & Posters
13:00-14:30	Symposium: **Thermal modeling and soldier load**
14:30-15:00	Poster presentations 3
15:00-15:30	Coffee break & Posters 3
15:30-17:15	Oral presentation 7: **Manikin and modelling**
17:15-17:30	Meeting adjourned for the day. Announcements
18:00-late	Conference dinner
Date/Time	**Friday 12th July**
08:00-08:30	Registration
08:30-10:00	Symposium: **Drowning**
10:00-10:30	Coffee break & Posters 4
10:30-12:15	Oral presentation 8: **Cold and hypoxia**
12:15-13:00	Lunch & Posters
13:00-14:30	Oral presentation 9**: Perception**
14:30-15:00	Poster presentations 4
15:00-15:30	Coffee break & Poster 4
15:30-16:15	Closing ceremony & awards

ICEE2019 Abstracts

First/Presenting author	Title	Abstract page #	Board #
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Vascular effects of cryotherapy

David Low

Research Institute of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK

The accumulated stresses of training and/or competition may temporarily cause impairments in physiological and/or muscular function leading to suboptimal performance. Recovery strategies during training/competition are therefore critical interventions to maximize athletic performance and/or training adaptations. The application of cryotherapy to previously exercised limbs has become a widely used recovery method in acute and chronic settings and is typically used in the immediate treatment and management of soft tissue injuries. Acute and repeated exposure to cryotherapy causes a range of physiological and psychological adjustments, including, vascular, metabolic and perceptual alterations that have important implications for exercise performance recovery and training adaptations. The proposed vascular benefits of acute cryotherapy exposure, which are often the most overt, are related to reductions in body/local temperatures, microvascular blood flow and oedema that may influence the inflammation response and/or performance recovery. Whilst initial studies have assessed the thermal and vascular responses to acute bouts of cryotherapy after exercise the specific effects of variations in the severity and duration of the cryotherapy bout as well as the effect on muscle blood flow are less clear. The aim of this talk is to critically examine the current state of knowledge pertaining to the vascular and thermoregulatory responses of cryotherapy for sport and exercise performance.

Cryotherapy and performance

Chris Abiss

School of Medical and Health Sciences, Edith Cowan University, Joondalup, Western Australia, Australia

Progressive increases in training stimuli are critical to facilitate optimal beneficial physiological and performance adaptations. The accumulated stresses of training and/or competition may temporarily cause impairments in physiological and/or muscular function leading to suboptimal performance though, particularly if inadequate recovery periods are provided. A balance therefore exists between training/competition and recovery to maximize athletic performance. Recovery modalities are therefore commonplace in training regimens to abrogate training/competition-induced physiological and functional deficits and speed up the recovery process. Cryotherapy, applied using cold water immersion (CWI) or other methods such as whole-body cryotherapy (WBC), is a popular and widely used recovery method. CWI consists of immersing the limb(s) or body into water of a reduced temperature, typically 10-15ºC for 5-10 min. WBC involves the participant standing in a chamber that fills with a safe, but extremely cold gas, maintained at −110–190°C for 2-5 minutes. Although there is evidence for the use of cryotherapy in maintaining/preserving within and between day performance, findings are not always positive, however, which is likely a result of variations in the type of exercise model, the index of exercise performance, the 'dose' of cryotherapy, the level of athlete and the duration of recovery examined. The proposed mechanisms of the benefits of cryotherapy exposure are numerous and include, reductions in body/local temperatures, microvascular blood flow, oedema, exercise-induced muscle damage, cardiovascular strain, as well as alterations to the autonomic and central nervous systems and reducing perceived soreness. Further research is needed to elucidate the mechanisms by which cryotherapy enhances recovery to enable a more guided practice with regards to periodization of recovery alongside longer term goals for training- induced adaptations, especially due to cryotherapy-induced enhancements in muscle oxidative adaptations to endurance training but impaired hypertrophic/strength adaptations derived from resistance training. The aim of this lecture is to critically examine the efficacy of cryotherapy for sport and exercise performance.

Thermal state response following different dosages of whole-body cryotherapy

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Introduction: The use of whole-body cryotherapy (WBC) in medicine, health and sports domains is increasing. While different studies (Lombardi et al. 2017, Rose et al. 2017) are focussing on the physiological mechanisms and its efficacy, hardly any studies are looking into the used WBC protocol. It is unclear how different dosages of WBC affect the thermal state, which is surprising as this thermal state is regarded as the proxy for the resultant effects. This study aimed to assess the effects of different WBC dosages on the thermal state response.

Methods: 10 healthy volunteers, 4 female and 6 male (33±7,9 years, 172±9,0cm and 76,3±13,4kg) participated and were exposed to two different protocols; protocol A= 4 minutes at -90°C (30s pre-exposure to -60°C) and protocol B= 3 minutes at -125°C (30s pre-exposure to -90°C). The thermal state was monitored by measuring core- and skin temperature, thermal sensation and thermal comfort prior (15 minutes), during and after exposure (45 minutes).

Results: Thermal state was reduced after both protocols. Protocol B resulted in a significantly ($p<0.05$) lower skin temperature, thermal sensation, and comfort compared to protocol A, while core temperature was not significantly affected. Big intra-individual differences in both protocols were identified. In 3 out of 10 participants the local shin temperature directly after exposure following protocol B was lower than 8°C, which is generally accepted as the critical barrier concerning shins problems.

Conclusions: The thermal state response is significantly affected by a difference in WBC dosage. To provide effective as well as safe WBC exposures it is pivotal to acknowledge treatment temperature as the more critical factor. Customization of the WBC treatment protocols is warranted to prevent safety-related issues.

Cryotherapy and Adaptation

Dr Robert Allan

University of Central Lancashire, Preston, UK

Historically cold application (cryotherapy) was used in the treatment of soft tissue injury, however more recently its popularity stems from an ability to reduce perceptions of delayed onset muscle soreness (DOMS) often associated with intense exercise, with the added potential to induce acute subsequent performance benefits (Leeder et al., 2012). Whilst the acute recovery period is vital for restoration of energy stores and recovery from exercise induced damage, it is also the window for mediating adaptation to the exercise stimulus via cell signalling and remodelling.

In recent years many labs have been able to show post-exercise cooling can enhance the gene expression of the so called "master regulator" of mitochondrial biogenesis, PGC-1α, above the exercise response alone (Slivka et al., 2013; Ihsan et al., 2014; Joo et al., 2016; Allan et al., 2017). In doing so it could be suggested this might lead to enhanced endurance adaptations via improved mitochondrial biogenesis. Indeed, regular cooling following training sessions has been shown to enhance PGC-1α protein content (Ihsan et al., 2015), some markers of cellular stress response and signaling molecules related to mitochondria biogenesis (Aguiar et al., 2016).

However, research seems to show a paradoxical response between adaptation towards a more endurance or resistance phenotype. Acute post-exercise cold water immersion is suggested to dampen gene transcription associated with ribosome biogenesis (Figueiredo et al., 2016) whilst attenuating acute changes in satellite cell numbers and activity of kinases that regulate muscle hypertrophy (Roberts et al., 2015). Interestingly this is associated with further implications when post-exercise CWI is regularly used, such as dampened gains in muscle mass and strength following 12 weeks of strength training (Roberts et al., 2015).

Therefore, the aim of the presentation is to critically discuss the contrasting research and suggest correct application of these methods moving forwards.

Are inter-individual responses to post exercise cryotherapy responsible for inconsistent findings?

Joseph Costello

University of Portsmouth, UK

The available literature details the physiological, perceptual, and performance effects of cryotherapy with some equivocal results. The use of a one-size-fits-all approach to post-exercise recovery, in addition to use of varying exercise modalities, populations and environmental conditions are likely to contribute to the contrasting reports of the efficacy of cold-water immersion and whole-body cryotherapy. Moreover, whilst there is limited consistency between studies when the effects of post exercise cryotherapy are viewed at the cohort level; where individual data are presented, even greater heterogeneity is evident. The aim of this presentation is to critically discuss these inconsistent results and attempt to establish if the basis for these findings is the inter-individual responses to cold exposure.

Integrating post-exercise sauna bathing into the training program of middle-distance runners improves tolerance to exercise heat stress

Nathalie V Kirby [a]; Samuel J E Lucas [a]; Oliver Armstrong [b]; Samuel R Weaver [a]; Gabrielle Vickers [b]; James Gibbon [a]; Rebekah A I Lucas [a]

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Introduction: For athletes, passive heating immediately following exercise offers a pragmatic alternative to active heat acclimation (Zurawlew et al., 2018). Post-exercise sauna bathing for ~3 weeks improves exercise performance in the heat (e.g. VO2max, total work in a time trial) although hallmark heat acclimation adaptations were not examined (Tyka et al., 2008). We hypothesised that post-exercise sauna bathing interspersed across 3 weeks of endurance training would induce hallmark heat acclimation adaptations (i.e., reduced rectal [Trec] and skin [Tsk] temperatures, heart rate [HR], and perceived exertion [RPE] and thermal tolerance) when exercising at a standardised workload.

Method: Seventeen trained middle-distance runners (11 female; age 20±2 years, BMI 21±1, VO2max 56.0±9.1 ml·kg·min^{-1}) performed a running heat tolerance test (30- minutes, 9 kph/2% gradient, 40°C/40%RH; RHTT) before (PRE) and after (POST) 3- weeks normal training (CON; *n*=6) or normal training with 30-minutes post-exercise sauna bathing (101-108°C) 3±1 times per week (SAUNA; *n*=11).

Results: SAUNA accumulated 10±1 post-exercise sauna sessions, totalling 290±48 minutes of exposure over 3 weeks. During RHTTPOST, SAUNA exhibited reduced peak Trec (-0.3±0.3 °C; $p<0.01$), peak Tsk (-0.2±0.3 °C; $p=0.01$), peak HR (-11±11 bpm; $p<0.01$), peak RPE (12±2 vs 10±2; $p=0.01$), peak thermal sensation (10±1 ["Hot"] vs 9±1 ["Warm"]; $p=0.02$), and peak thermal comfort (5±2 ["Uncomfortable"] vs 4±2 [between "Slightly Uncomfortable" and "Uncomfortable"]; $p=0.01$). Total body sweat loss did not change ($p=0.57$). CON exhibited no changes in these physiological and psychophysical variables (all $p>0.05$), except for a reduced sweat loss (-0.2±0.2 kg; $p=0.04$).

Conclusions: These data support our hypothesis that 3 weeks post-exercise sauna bathing reduces cardiovascular strain, core and skin temperatures, and improves perceived tolerance during exercise heat stress. Therefore, post-exercise sauna bathing is an effective and pragmatic method of heat acclimation.

An assessment of courtside thermal conditions measured at the 2019 Australian Tennis Open

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Introduction: Heat stress risk assessments for large participation elite sport events are often calculated using environmental parameters provided by independent local weather stations. However, the application of these values to actual on-site conditions is questionable.

Method: Hourly air temperature (Tair), black globe temperature (Tglobe), relative humidity (RH) and wind speeds were measured with custom-made environmental measurement units (EMU) courtside at a stadium and outer tennis court throughout Australian Tennis Open in Melbourne, Australia (January 2019). Values for Tair, RH and wind speed were compared to those simultaneously issued by the nearest Australian Bureau of Meteorology (BOM) weather station (Melbourne Olympic Park).

Results: Daily maximum values from BOM underestimated on-court Tair on all days for stadium (-2.6˚C; 95%CI [-0.6 to -4.5˚C]) and outer (-2.2˚C; [-2.3 to -2.1˚C]) courts. Simultaneous RH values from BOM were subsequently overestimated for stadium (+4.8%; [+3.1 to +11.9%]) and outer (+3.2%; [+1.6 to +4.8%]) courts, but absolute humidity values were similar. Wind speed values from BOM overestimated court-side values for the outer court (+2.6 m/s; [+1.9 to +3.0 m/s]), and stadium court (+2.2 m/s; [+1.7 to +2.7 m/s]). On the hottest tournament day, peak Tair values from BOM underestimated highest values measured on-site by 3.8˚C (outer court: 43.8˚C). While not reported by BOM, peak Tglobe on this day was 55.6ºC (stadium) and 54.7˚C (outer court).

Conclusions: Environmental data issued by BOM underestimates Tair and overestimates RH and wind speeds for both stadium and outer courts. These data highlight the importance of monitoring courtside environment conditions for the accurate assessment of local thermal conditions that can be subsequently used for the optimal implementation of an extreme heat policy.

Sex-based Differences in Core Temperature during Repeat Exercise in the Heat

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Introduction: When working in extreme heat, the Australian Army refer to work tables that assume body core temperatures will on average peak at 38.5°C at the end of work. We examined the sex-based differences in peak body core temperature following four work and recovery cycles in the heat.

Method: Fourteen males (M: 32 ± 8.21yr; 179.78 ± 4.82cm; 76.5 ± 6.4kg, 54.39 ± 8.68ml/kg/min) and thirteen females (F: 31.2 ± 7.25yr; 166 ± 6.73cm; 58.06 ± 6.09kg, 51.73 ± 7.18ml/kg/min) performed four successive bouts of treadmill walking in 32.5°C Wet Bulb Globe Temperature (WBGT) at a constant work rate, alternating between 35 minutes (~600W) and 55 minutes (~400W), each separated by 30-min seated rest at 28°C WBGT as per current work tables. Participants wore standardised military clothing including body armour and a helmet. Women were tested on days 5-8 of their menstrual cycle. Peak heart rate (HR), rectal (Tc) and 4-site mean skin temperature (Ts) were compared across exercise periods. Statistical analyses were conducted using repeated measures ANOVA.

Results: Peaks in Tc were significantly different between the exercise bouts (E1-4) (M: E1 38.20 ±0.31°C, E2 38.36 ±0.34°C, E3 38.49 ±0.42°C, E4 38.32 ±0.41°C / FE1 38.05 ±0.40°C, E2 38.09 ±0.37°C, E3 38.33 ±0.38°C, E4 38.15 ±0.35°C) (*P=<0.001*), but not between males and females (*P=0.163*). Five males and four females reached 38.5°C by the conclusion of the fourth work. There was no difference in peak HR (*P=0.522*) or peak Ts (*P=0.336*) between males or females, nor between exercise bouts (HR: *P=0.194*) (Ts: *P=0.586*).

Conclusions: Participants on average did not meet the assumed body core temperature of 38.5°C within four work and recovery cycles. These findings indicate the current work tables can apply to both males and females across four work bouts.

The effect of acute caffeine ingestion on thermoregulatory responses to exercise in the heat – a double blind, placebo-controlled, randomised trial

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Introduction: In most thermoregulatory research, participants are asked to abstain from consuming caffeine, prior to participation, due to an assumed confounding effect on core temperature, skin blood flow and/or sweating responses. Yet, evidence supporting this notion appears inconclusive. Our aim was to assess the impact of acute caffeine ingestion on thermoregulatory responses to exercise in moderate heat.

Method: 14 moderately fit (VO2MAX: 42.3±10.1 $ml \cdot kg^{-1} \cdot min^{-1}$) individuals (9 men and 5 women) cycled at a fixed metabolic heat production of 7 $W \cdot kg^{-1}$ for 60 minutes on two separate occasions, 60 minutes after ingesting either a 5 $mg \cdot kg^{-1}$ caffeine (CAF) or a 5 $mg \cdot kg^{-1}$ maltodextrin placebo (PLA) pill, in a counter-balanced order. Environmental conditions of 30.6±0.9°C, 31±1% RH were chosen to ensure compensable heat stress conditions.

Results: The rise in Teso from baseline (ΔTeso) was greater in CAF 0.93±0.39°C relative to PLA 0.76±0.40°C ($P<0.001$). Cutaneous vascular conductance on the forearm was attenuated in CAF (39.1 ± 11.5 %CVCmax) versus PLA (49.9 ± 21.6 %CVCmax) ($P=0.034$), there were no differences observed on the upper back ($P=0.55$). No differences between conditions were observed for end-exercise whole body sweat loss (CAF:0.68±0.14 kg, PLA:0.65±0.14 kg; $P=0.20$), or local sweat rate on the forearm (CAF: 0.89±0.28 $mg \cdot cm^{-2} \cdot min^{-1}$, PLA: 0.78±0.27 $mg \cdot cm^{-2} \cdot min^{-1}$; $P=0.19$) and upper back (CAF: 0.96±0.35 $mg \cdot cm^{-2} \cdot min^{-1}$, PLA 0.88±0.30 $mg \cdot cm^{-2} \cdot min^{-1}$; $P=0.12$). Rating of perceived exertion ($P=0.80$) and thermal comfort ($P=0.76$) were also similar between conditions.

Conclusions: CAF significantly attenuated skin blood flow on the forearm compared to PLA and led to a greater ΔTeso after 60 minutes of exercise in the moderate heat. These findings may support the current practice in which research participants abstain from all sources of caffeine prior to their participation in studies that involve thermoregulatory measures. Any potential interaction between caffeine-habituation state and an acute dose of caffeine on thermoregulatory responses, however, remains unclear and warrants further investigation.

Head and neck cooling does not improve maximal voluntary torque or rate or torque development during brief maximal voluntary contractions in the heat

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Introduction: Maximal voluntary torque (MVT) is impaired when hyperthermic due to a reduction in the central nervous system's capacity to voluntarily drive the available force capacity of muscle. Rate of torque development (RTD) is considered more functionally relevant than MVT in some situations and neural drive is a key determinant of RTD. Head and neck cooling can improve endurance performance when hyperthermic, but its effects on neural drive are unclear. The purpose of this study was to investigate head and neck cooling on thermal perception during whole-body hyperthermia on MVT, RTD, neural drive and the contractile properties of the muscle.

Method: 9 participants completed two trials in HOT conditions (50°C, 40% RH), involving light exercise before passive heating to a rectal temperature (Tre) of 39.5°C. During one trial, the head and neck was continuously cooled (HOTcool) using a towel soaked in ice water. At Tre=39.5°C neuromuscular measurements were completed to assess MVT, voluntary activation and EMG at MVT normalised to maximal M-wave. Voluntary RTD and normalised EMG were measured over 0-50, 0-100, 0-150 and 0-200 ms. Involuntary RTD at 0-50 ms was measured during evoked octets at 300 Hz. Thermoregulatory and perceptual variables were measured throughout.

Results: MVT and RTD, and their neuromuscular determinants were unaffected by cooling ($P > 0.05$). Neck (-20%) and head (-12%) temperature were lower in HOTcool, as were thermal sensation of the head (-36%) and body (-12%) and thermal comfort (body) (-23%). Time to target Tre was increased (71%) in HOTcool, and not all participants were able to reach 39.5°C. Tre (-0.3%) and skin temperature (-6%) were lower in HOTcool ($P < 0.05$), but heart rate was similar ($P > 0.05$).

Conclusions: Head and neck cooling did not affect MVT, RTD, or the neuromuscular determinants of these functional variables despite improving perceptions of thermal strain.

Exploring the 'training effect' myth: A 10-day moderate-intensity exercise protocol does not elicit aerobic performance gains in trained males

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Introduction: Exercise training sessions are included into heat-acclimation programmes to potentiate increases in core temperature. Consequently, a training effect may contribute to aerobic gains in individuals of a sub-elite fitness level after participating in such protocols. We investigated whether 10 moderate-intensity exercise sessions can independently enhance aerobic performance in both trained and untrained individuals.

Method: We recruited trained (57.9 ± 6.2 mL·kg^{-1}·min-1, n=10) and untrained (41.7 ± 5.0 mL·kg^{-1}·min^{-1}, n=10) young males to exercise daily for 60min at 50% peak power output (W_{peak}) for 10 days. Pre- and post-training, the participants were tested on a cycle ergometer in normoxic (23°C, 50% RH, 20.9% F_iO_2; NOR), hypoxic (23°C, 50% RH, 13.5% F_iO_2; HYP) and hot (35°C, 50% RH, 20.9% F_iO_2; HE) conditions in a randomized and counterbalanced order. The exercise tests consisted of two stages; a 30-min steady-state exercise followed by incremental exercise to exhaustion. The steady-state exercise was performed at 40% NOR W_{peak} to evaluate thermoregulatory function and gross mechanical efficiency (GME).

Results: Following the training protocol, $\dot{V}O_{2max}$ increased by 9.2 ± 8.5% ($p = 0.024$) and 10.2 ± 15.4% ($p = 0.037$) only in the untrained group in NOR and HE, respectively. W_{peak} increases were largely correlated with baseline values in NOR ($r = -0.58$, $p = 0.010$) and HYP ($r = -0.52$, $p = 0.018$). GME improved only in HYP in the trained individuals while the anaerobic threshold remained unaffected. Peak sweat rate increased for both groups in HE whereas the forehead sweating response was activated at a lower rectal temperature post-training only in the trained group across environments.

Conclusions: We demonstrate that a 10-day exercise training protocol might elicit a training effect in the untrained but not in the trained males. Accordingly, heat-acclimation protocol-associated performance benefits in the trained individuals are most likely not modulated by the exercise stimulus *per se*.

Inter-sensor agreement and reliability of contact skin temperature sensors during rest and exercise

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Introduction: Data about skin temperature (Tsk) has been found to be important, amongst others, for understanding thermoregulatory and cardiovascular responses, for the evaluation of thermal strain, for estimating mean body temperature or for understanding perceptual responses. As different types of contact sensors are used for the measurement of Tsk in scientific studies, knowledge about the inter-sensor agreement and reliability is needed for a better understanding and comparability between studies. The aim of this work was to assess the inter-sensor agreement and reliability among three types of contact Tsk during rest and physical activity.

Method: Three types of Tsk sensors (custom thermistor consisting of a glass- encapsulated NTC thermistor set inside a small volume of silicone elastomer encapsulant, Grant thermistors, and iButtons) were applied on fourteen adult males; each completed one experimental session (~24°C, ~46% relative humidity; RH) involving 40min baseline seated rest, 45min exercise (cycle ergometer) and 40min recovery rest. Tsk was measured at four body sites using each sensor type and weighted-mean Tsk was calculated. Finally, sensor data was corrected according to a conventional calibration procedure. Absolute mean difference (AMD) for Tsk from different sensors was compared at different time points.

Results: A good agreement between sensors was found during baseline rest and before sweating during exercise (AMD < 0.12°C). After onset of sweating during exercise through to 20min following exercise, the range for AMD increased to [0.17 0.31]°C and returned to [0.03 0.08]°C at the end of recovery rest.

Conclusions: The systematic inter-sensor differences and variation following the onset of sweating during exercise indicate the application of Tsk data during heat stress cannot be assumed as independent of the sensor-attachment system. In order to ensure comparability between sensor systems, new calibration procedures for a detailed characterization of the sensor-skin interaction (particularly for sweating conditions) have to be considered.

Prior Viral Illness as a Risk Factor for Heat Stroke

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Introduction: This talk will provide experimental data that confirms recent epidemiological findings that prior illness is a significant risk factor for heat stroke.

Methods: To study this risk factor, we examined retrospective cases of heat stroke through clinical records and employed an experimental mouse model of heat stroke.

Results: The experimental data demonstrate that even in the absence of overt clinical symptoms of illness, mice with previous viral illness experienced more severe heat stroke compared to naïve animals that never experienced a prior illness. Importantly, heat stroke severity was increased despite no effect on the thermoregulatory response to heat exposure, but was related to dysfunction of inflammatory and coagulation pathways. Human exertional heat stroke patients that suffer from recent illness present with elevated core temperatures and pulse rates, although this did not affect the biomarker profile at the time of presentation.

Conclusion: The aim of this presentation is to demonstrate the impact of prior illness on heat stroke severity, and how physiological and immunological pathways can interact to mediate the systemic inflammatory response to these stressors.

Modeling blood factor signatures to identify mechanisms for increased heat stroke risk with prior illness

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Introduction: Heat stroke results in central nervous system dysfunction, organ failure, and death. While core body temperature over 40 °C has been used for diagnosis, no definitive test exists to measure severity or predict outcome. Heat stroke induces similar inflammatory responses to infection, and prior infection exacerbates pathology. Immune involvement in heat stroke pathology provides an opening for quantification of severity and prognostic timecourse.

Method: Mice were implanted with radiotelemetry devices and injected with poly I:C, LPS, or saline. After 48 or 72 hours, mice were exposed to heat (T=39.5 °C) until reaching a maximum core body temperature Tc,max=42.4 °C. Radiotelemetry recording of Tc was performed until mice were sacrificed at one of three time points: Tc,max, 1 day, or 7 days. A complete blood count was performed, and concentrations of plasma coagulation factors and liver granzyme-B were assessed by ELISA. Partial least squares modeling identified a signature of blood factors correlating with heat stroke pathology as measured by Tc and granzyme-B concentration.

Results: Complete blood count results predict circadian change in Tc, an indication of heat stroke severity, and separate subjects based on heat stroke timecourse. Heat stroke decimates immune cell populations, but levels return after removal from heat. Low platelet levels correlate with heat stroke severity, and their large size and broad size distribution indicate new, active platelets. This signature strengthens at later time points. Increased levels of soluble thrombomodulin and D-dimer indicate coagulopathy, with lower D-dimer levels in the most severe cases suggesting fibrinolytic resistance.

Conclusions: Severe heat stroke cases present with high levels of factors indicating coagulopathy. Despite thrombocytopenia, platelets are large with a broad size distribution. Levels of clotting factors increase in more severe heat stroke, with potential fibrinolytic resistance in the most severe cases, resulting in elevated organ damage pathology.

What do we learn from burn survivors regarding factors that alter heat stroke risk?

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Thermoregulatory responses can be compromised in severely burned individuals. Surgical treatment of deep burns involves the excision of damaged tissue (often inclusive of sweat glands) and the subsequent transplantation of grafts from non- injured donor sites onto wounded areas. Removal of skin grafts disrupts the innervation and structural integrity of sweat glands within a graft, culminating in a suppressed sweating response within grafted sites. The ensuing reduction in evaporative heat loss potential results in exacerbated elevations in core temperature during exercise-heat stress, the magnitude of which is strongly associated with the surface area of remaining non-grafted skin that can participate in evaporative heat dissipation. It follows that for burn survivors undertaking exercise training, competing in athletics, or performing work in occupational heat stress, combinations of physical activity and environmental heat will heighten the risk of heat-related illness/injury compared to non-injured individuals. This presentation will highlight recent research on the thermoregulatory consequences of burn injuries/skin grafting, with emphasis on: (i) modelling the thermoregulatory effects of burn injuries/skin grafting based on the interplay between various physiological and physical properties known to influence heat balance and heat illness risk; (ii) recent data from our laboratory examining the interactive effects of burn injuries and various biophysical factors; and potential strategies to minimize the risk of heat illness/injury among burn survivors exposure to heat stress. Attendees will gain a better understanding of the thermoregulatory impairments that accompany burn injuries, and the implications for heat illness/injury risk of such individuals in occupational settings.

Heat acclimation as a protective mechanism against heat stroke during exercise: is it enough under all conditions?

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Exertional heat illnesses represent a continuum of medical conditions with potentially severe consequences that can affect physically active individuals in both hot and cool environments. The severity of exertional heat illnesses can escalate from heat exhaustion, to heat injury, and on to heat stroke, which is characterized by high body temperatures (>40ºC), profound central nervous system dysfunction, organ and tissue damage, and can lead to death. However, when repeatedly exposed to conditions that are sufficiently stressful to elicit profuse sweating and elevate skin and core temperature (i.e. heat acclimation), adaptations develop that can that reduce the risk of exertional heat stroke. The adaptations include plasma volume expansion, better maintenance of fluid balance, enhanced sweating and cutaneous blood flow responses, as well as acquired thermal tolerance through the heat shock response. Notwithstanding these adaptations, exercise in certain contexts (e.g. environmental heat stress, competitive setting) may lead to, or increase the likelihood of experiencing exertional heat stroke. This is in response to exercise in the heat being associated with various internal (e.g. heat production, illness) and external (e.g. thermal environment) factors that may diminish the benefits conferred by heat acclimation. Contextualising heat acclimation as a protective mechanism and its efficacy as a strategy to protect against heat stroke during exercise therefore requires to be evaluated.

Acute effects of cooling therapy on functional ability and quality of life in patients with multiple sclerosis

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Introduction: Multiple sclerosis (MS) patients are characterized by thermoregulatory failure, known as Uthoff's phenomenon. Precisely, of the MS patients present adverse clinical symptoms when their body temperature is increased. Thus, the development of treatment strategies to overcome the thermoregulatory problem in these patients is crucial. Given that cooling has been proposed as an effective method, the aim of this study is to examine whether the application of head cooling therapy during an exercise training session is capable to prevent the core temperature increase and to improve the patient's functional ability and quality of life.

Method: 10 MS patients (aged 25-50 years) with Expanded Disability Status Scale between 2 to 6.5 have agreed to participate in this study. Each participant will complete two different experimental conditions separated by one week. The first will include an exercise training session involving head cooling and neck wraps while the second session will be performed without cooling. The exercise training session will consist of 40 min continuous cycling where the participants will perform an incremental submaximal exercise protocol beginning at 45 W, increasing 10 W every 10 min for a total of four stages on a semirecumbent cycle ergometer in a 20°C room. Before and after the completion of both conditions each participant will perform a variety of functional ability tests. The evaluation of the core temperature and the assessment of the patient's quality of life will also be performed.

Results: This is an on-going study and the results will be presented at the conference. However, at the literature there is only one study where body cooling was applied and observed improvements in the participants' functional ability.

Conclusions: Based on our pilot trial results head cooling will be proved to be an effective strategy that could help patients with MS to overcome the thermoregulatory problems during physical working.

Older middle-aged men with type 2 diabetes have impaired cardiac autonomic activity during exercise in the heat

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Introduction: Exercise has long been considered a cornerstone in the treatment regimen for patients with type 2 diabetes mellitus (T2D). However, T2D tends to place individuals at greater risk for heat-related illness during physical activity due to an impaired capacity to dissipate heat, which may be exacerbated by cardiovascular complications. This study aimed to detect potential differences in heart rate variability (HRV) in older middle-aged men with well-controlled T2D compared to age-matched controls during and following exercise under heat.

Method: Twenty-four habitually active older middle-aged men with well-controlled (n=12, 59.1±6.0 years) and without T2D (n=12, 60.5±3.4 years) performed three successive 30-min bouts of semi-recumbent cycling at increasingly greater fixed rates of metabolic heat production, at exercise intensities of 150 (Low), 200 (Moderate) and 250 (Vigorous) W/m2 (equivalent to ~37, ~50, and ~62% of their pre-determined VO2peak) each separated by a 15-min recovery in a hot-dry environment (40˚C, ~20% relative humidity). Eleven HRV indices (e.g. low and high frequency power, Shannon Entropy, and others) characterizing common domains of variability and complexity of heart rate were computed and assessed at baseline resting, end of exercise and recovery.

Results: During exercise a significant time*group interaction on low-frequency power was observed (p=0.05), as the T2D group demonstrated decreased levels through time. During recovery, significant group differences (i.e., main effects of group) were observed in Shannon Entropy (p=0.03), as the T2D group showed reduced levels at each successive recovery periods indicating decreased parasympathetic activity.

Conclusions: We show habitually active older middle-aged men with well-controlled T2D had weaker cardiac autonomic control during exercise and recovery in the heat placing them at a greater risk for cardiovascular complications. This study supports the importance of developing effective strategies to safeguard the health and well-being of older middle-aged adults with T2D who are engaged in physical activity.

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Caffeine and Carbohydrate Ice Slurry ingestion has nominal effect on repeated sprint cycling in the heat

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Introduction: The benefits of ice and caffeine individually on performance is well established. However, to date little is known on the combination and application to repeated sprint performance in the heat.

Method: Twelve male team-sport athletes (age 29 ± 6 y, mass 82.0 ± 6.3 kg, height 180.4 ± 6.5 cm) completed eight randomly assigned trials, ingesting either water (w) at 25°C or ice slurry (i) at -1°C as follows; placebo (PLAw and PLAi), caffeine (5 $mg \cdot kg^{-1}$; CAFw, CAFi), carbohydrate (6%, 0.41 $g \cdot kg^{-1}$ CHOw, CHOi), caffeine and carbohydrate (5 $mg \cdot kg^{-1}$ and 6%, 0.41 $g \cdot kg^{-1}$; C+Cw, C+Ci) 40 min prior to completing 18 × 4-s maximal sprints in the heat (37.0 ± 1.1°C, RH 38.0 ± 1.9%). Rate of perceived exertion (RPE), thermal sensation and thermal comfort were sought 30 sec prior to start of each sprint.

Results: There was a significant reduction in rectal temperature (Tre) in ice slurry compared with corresponding water trials (Delta values of Tre between 1.3-1.6°C ; PLAw p=0.002, CAFw p=0.007, CHOw p=0.001, C+Cw p=0.008). CAFi had the highest mean power of 1008±235 W, yet whilst not significantly different to any other condition CAFi did show a meaningful difference (>36W) between PLAi (962 ± 202 W) and CHOi (957 ± 210 W). CAFw also produced high power outputs (mean 999 ± 197 W) compared with the ice conditions (PLAi 962±202 W, p=0.04, 95%CI 1.7,91.0 and CHOi 957±210 W, p=0.04, 95%CI 3.5,127.9). Although importantly, CAFw showed greater decrement in performance than CAFi.

Conclusions: In hot conditions the ingestion of caffeinated beverage (CAFw) or caffeinated ice slurry (CAFi) consumed 40 min pre-exercise produced higher mean power repeated sprint outputs than non-caffeinated alternatives. These findings would be of benefit within intermittent team sports where repeated high power efforts are required but should be applied conservatively to minimise the negative decrement effects, and reduced early performance associated with ice slurry ingestion.

The Impact of Hip Angle and Time Trial Position on Heat Production During Cycling

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Introduction: Cycling time trials are characterised by riders adopting aerodynamic positions to minimise drag. Adopting aerodynamic positions may have an effect on heat strain, due to modifications in muscle recruitment, metabolic heat production (Hprod) and heat loss due to airflow changes. The aim of this study was to determine whether cycling in an aerodynamic position impacts upon Hprod. It was hypothesised that a change in hip angle would result in alterations to Hprod.

Methods: Eleven trained male cyclists (Height 1.9±0.1 m; age 33±9 yrs; $\dot{V}O_2 max$ 57.5±7.6 mL·kg·min^{-1}) visited the laboratory on five occasions to complete a graded exercise test. Hip angle was set at 12◎, 16◎, 20◎◎24◎◎and the rider's self-selected position. Blood lactate (Bla) and gastrointestinal temperature (Tgi) were recorded throughout, with metabolic rate (M) and Hprod calculated via indirect calorimetry. For each condition, power output, M and Hprod corresponding to a Bla value of 4 mmol·L^{-1} weredetermined.

Results: Neither Tgi (P=0.096), nor power output (P=0.222) were different at 4 mmol·L^{-1} between hip angles. An effect of condition was evident for M and Hprod (both P<0.05). M was higher in control (1222±167 W) vs 12˚ (1150±166 W; P<0.05), and in 24˚ (1264±212 W) vs 12˚ (P<0.05). Consequently, Hprod was higher in 24˚ (983±168 W) compared to 12˚ (880 ± 125), with a positive relationship between hip angle and Hprod (R^2=0.414, P<0.05). The Δ power output at 4mmol·L^{-1} compared to control reduced as hip angle increased (R^2=0.844, P<0.01).

Conclusions: These data show that Hprod is sensitive to changes in hip angle, possibly due to an increase in muscle recruitment and consequently metabolic rate. Based on Tgi data, there may be increased heat loss associated with greater hip angle, which is likely due to increased airflow over the body as a consequence of increased frontal area. This requires further clarification.

Undertaking Extreme Endurance Events: A case study on the Colorado Trail Mountain Bike Race

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Introduction: The Colorado trail race (CTR) is an extreme endurance mountain bike (MTB) race requiring participants to complete 500-miles (800km) of racing between Denver and Durango in the Rocky Mountains. The race is unsupported and includes 70,000 feet (21,336m) of cumulative ascent with a peak altitude of 13,200 ft (4,023m) at which there is acute mountain sickness risk. Here we describe a case-study of an entrant to the 2018 CTR.

Method: Participant characteristics were: 47-year-old male, height 1.73m, 61kg, BMI, 20.3kg.m^2. The participant completed incremental lactate threshold (LT) tests to establish training intensities and training progression; final LT was used to estimate the decrement to sustainable power output at altitude; he also completed dietary and hydration assessment. At baseline and during the CTR the participant reported sleep quality and mood disturbances (10-point Likert scale), rating of perceived exertion (RPE) and recorded race pace and elevation using GPS. He supplemented with iron to facilitate haematological acclimatisation.

Results: The participant's LT at sea-level was 225 to 250 Watts (W) with a peak power output of 356W. We extrapolated a range of possible decrements to PPO at 4000m (4.5, 6.3 and 7.5%) in line with published literature potentially reducing PPO to 250, 225 and 225W; assuming no acclimatisation. We suggested that he should "sleep low, ride high" to maximise resting race recovery. He finished 6th overall in 5 days 6 hours, averaging 4.1mph with 2.5 hours of sleep per night. He reported depression (5) and anxiety (9) peaks (day 4), fatigue (10) and RPE peaks (20) on day 5 and that heat load and dehydration were significant problems.

Conclusions: The CTR is a significant endurance challenge that takes place in a high-altitude, hot environment with limited access to support provisions. Completion of the CTR results in profound cumulative fatigue and mood disturbance.

Regional variations in nitric oxide synthase- dependent cutaneous vasodilatation during cholinergic stimulation

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Introduction: The majority of studies examining the mechanisms of cholinergic vasodilatation in the skin have been performed on the forearm. While regional variations in such responses exist across different body areas, the underlying mechanisms behind this effect remain poorly understood. Nitric oxide (NO) synthase (NOS) is a well-established mediator of cholinergic vasodilatation due its modulating effects on NO bioavailability. However, the relative contribution of this enzyme across different body regions has yet to be examined. Therefore, the purpose of this study was to evaluate the NOS contribution to cutaneous vasodilatation across different body regions during cholinergic stimulation.

Method: In eleven young men (24±3 years) cutaneous vascular conductance (CVC, assessed via laser-Doppler flowmetry) was measured at six skin sites. On each of the Forearm, Chest and Back, two sites were continuously perfused with either 1) lactated Ringer's (Control) or 2) 10 mM N◎-Nitro- L-arginine (L-NNA, non-selective NOS inhibitor) via intradermal microdialysis. All six sites were continuously co-infused with five incremental doses of the acetylcholine mimetic, methacholine (1, 10, 100, 1000, 2000 mM; 25 min each), followed by infusion of 50 mM sodium nitroprusside to achieve maximum cutaneous vasodilatation.

Results: Forearm CVC was significantly attenuated by L-NNA from 1 to 100 mM methacholine (all $P<0.05$), which was associated with a 20% reduction overall. Back CVC was attenuated by L-NNA from 10 to 100 mM methacholine (both $P<0.05$), associated with an 11% reduction overall. Chest CVC, however, was not influenced by L-NNA at any methacholine dose (all $P>0.05$; 8% reduction overall).

Conclusions: Our preliminary data indicate that regional variations exist in the NOS component of cholinergic vasodilatation. Further exploration of the mechanisms influencing regional variations in cutaneous vasodilatation may help identify optimal sites for representing whole-body responses under various experimental conditions.

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The effects of head and neck cooling during breaks in play in simulated American Football on cognitive function in the heat

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Introduction: Exercise performance can be compromised in hot environments. The effects on cognitive performance are less well-known but thermal strain may impair complex cognitive function. Localised head cooling can alleviate thermal strain and improve exercise performance but data regarding the effectiveness of such cooling on cognitive performance is equivocal.

Methods: Participants (n=10) completed two 165 min American Football simulations in the heat (36 °C; 50% RH) wearing full American football uniforms throughout. Each protocol had four quarters (Q1 – Q4) consisting of sprints and plyometric push-ups separated by representative breaks. During one session (COOL), participants removed the helmet and donned a cooling hood (covering the cheeks, forehead, head, and neck) during breaks longer than two minutes. Thermoregulatory and perceptual variables were measured throughout. Executive function and visuospatial learning were assessed using Spatial Working Memory (SWM) and Paired Association Learning (PAL) tests conducted before, midway ("half time" (HT)), and after exercise (FT). Cognitive performance data were analysed as changes from baseline due to intra-trial variability at this time-point.

Results: In COOL, participants had lower head skin temperatures (-5.8 – -0.2°C) during all three testing windows and lower core (-0.4°C) and skin (-0.6°C) temperatures post-exercise. Participants felt cooler and more comfortable when wearing the cooling hood. More correct choices were made at the 1st attempt in COOL (+1) at HT and FT (+2) whereas fewer were made without cooling (-2 & - 1). In the same test (PAL), fewer incorrect choices were made in COOL at HT (-2) and FT (-1) but more were made in CON at FT (+5). Fewer strategic errors were made without cooling at HT (-1) and with cooling at FT (-1) compared to baseline.

Conclusion: Wearing a cooling hood reduced the physiological and perceptual thermoregulatory strain and improved visuospatial learning and aspects of executive function compared to CON.

Hot water immersion acutely increases glucose area under the curve in response to a glucose challenge

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Introduction: Hot water immersion (HWI) therapy confers chronic health benefits, including reductions in fasting blood glucose concentration. The mechanisms behind this are unclear, and glucose metabolism directly following an acute HWI session is poorly explored. Therefore, the aim of this study was to investigate glycaemic control directly following HWI.

Method: Ten participants (age: 25±6 years, body mass: 84±14 kg, height 1.85±0.09 m) were immersed in water to the neck (60 min at 39°C, HWI) or sat at room temperature (CON). One hour following this intervention, they performed a two-hour oral glucose tolerance test (OGTT), with blood collected before and after HWI/CON and during the OGTT. Plasma protein concentrations were quantified using enzyme-linked immunosorbent assays, and incremental areas under the curve (iAUC) determined for glucose and insulin.

Results: Glucose iAUC during the OGTT was greater in HWI (HWI 233±88, CON 156±79 mmol·L^{-1}·2h, P=0.02) whilst insulin iAUC was similar between conditions (HWI 4309±3660, CON 3893±3031 mU·L^{-1}·2h, P=0.32). Body temperature increased to 38.6±0.2°C during HWI; during the OGTT body temperature did not differ between conditions (HWI 37.0±0.2, CON 36.9±0.4°C, P=0.34). Directly following HWI, plasma adrenaline and growth hormone concentrations increased 2.7 and 10.7-fold, respectively (P<0.001). No differences between conditions were found for the plasma concentrations of the gut hormones glucagon like protein-1, peptide YY, or acylated ghrelin (P>0.11) during the OGTT.

Conclusions: HWI increased postprandial glucose concentration to an OGTT, despite no difference in body temperature or insulin during the OGTT between conditions. This change in glycaemic control might be explained by the residual effect of the HWI- induced stress hormones, which may act on hepatic glucose output or intestinal glucose uptake. Gut hormone kinetics during the OGTT were unaffected by HWI, therefore unlikely to explain the difference in the observed glucose response between conditions.

The accuracy of the Physiological Heat Strain Index to identify individuals at risk of heat induced fatigue.

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The physiological heat strain index (PSI) was developed to assess individuals' heat strain within various settings, yet evidence supporting its use to accurately identify individuals at potential risk is limited. The aim of this study was to assess whether PSI can identify individuals at risk of heat induced fatigue (HIF). Fifteen females (24.2 ± 5.7 years; 1.69 ± 0.09 m^2) and 21 males (26.9 ± 4.7 years; 1.95 ± 0.13 m^2) completed nine trials, each consisting of two 40-60 mins of treadmill walking separated by ~20-mins rest, wearing permeable or impermeable clothing, either in 25 °C, 50% relative humidity (rh), 35 °C, 35% rh , or 40 °C, 25% rh, with or without solar radiation (~530 W m^{-2}). Heart rate (HR), skin temperature (Tsk), rectal temperature (Tre), temperature sensation (TS) and thermal comfort (TC) were measured throughout. PSI was calculated using the equation by Moran (1998) with inital Tre and HR set at 37.0 °C and 70 bpm. End of trial PSI, HR, Tre, Tsk, rate of change (ROC) in Tsk and Tre and TS and TC were compared between the trials completed (C, 117 trials) and those terminated prematurley (HIF, 35 trials) using independent t-tests. End PSI did not significantly differ between HIF (6.98 ± 1.67) and C (6.71 ± 1.56). However, there was a significant difference between HIF and C in Tre-Tsk (0.9 ± 0.86 °C vs 1.29 ± 0.86 °C, respectively, $P = 0.009$) and in TS (18.03 ± 2.22 vs 15.70 ± 4.33, respectively, $P = 0.008$). In HIF, 42.24% of the cases had a PSI > 7.5 (considered 'at risk' from HIF). These results suggest PSI alone does not distinguish between individuals at risk of HIF, however, using additional measures of Tsk and TS may provide a better prediction of heat tolerance.

Fluid maintenance augments cardiac vagal autonomic activity during prolonged exercise in hot, dry conditions

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Introduction: Progressive sweat-induced fluid loss without fluid replacement during prolonged exercise-heat stress (≥60 min) compromises cardiovascular and thermoregulatory function, although its effects on cardiac autonomic activity remain unclear. We examined heart rate variability (HRV), as a surrogate of cardiac autonomic activity, during prolonged exercise in the heat with and without fluid replacement.

Methods: Ten young and healthy men performed 90-min of semi-recumbent cycling in dry- heat (40 °C; 20% relative humidity) at a fixed rate of metabolic heat production (600 W; ~46% $\dot{V}O_{2peak}$) without fluid replacement (No-FR; ~3.4% reduction in body mass). On a separate day, participants completed the same protocol with fluid replacement (FR) to offset sweat losses as determined in No-FR. Esophageal temperature and electrocardiogram were recorded throughout, with temperature and HRV averaged over the final 10-min of each 30- min interval during exercise.

Results: Esophageal temperature and heart rate was elevated in No-FR compared to FR (all $P \leq 0.02$). Compared to baseline (No-FR, -1.32 [0.22]; FR, -1.37 [0.23]), cardiac vagal index (CVI = log10[16 x SD1 x SD2]) was attenuated during exercise, with the magnitude of this reduction being greater in No-FR (90-min, -3.27 [0.20]) relative to FR (90-min, -2.84 [0.45]; all $P < 0.05$). Likewise, lnRMSSD was attenuated throughout exercise in both conditions (all $P < 0.01$), with a greater reduction in No-FR (all $P \leq 0.043$). Finally, sample entropy was reduced at 90-min relative to baseline in both No- FR and FR (both $P < 0.01$), but was lower throughout exercise during the former (all $P \leq 0.03$).

Conclusions: Prolonged exercise in the heat was associated with reduced activity of HRV indices reflecting vagal tone, indicative of increased cardiac autonomic stress. Those alterations were blunted, however, when fluid was provided to offset progressive sweat losses, highlighting the importance of fluid maintenance during exercise in the heat.

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Determining sweating efficiency during exercise using a human heat balance approach

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Introduction: Sweating efficiency (Eeff) is the fraction of secreted sweat that evaporates from the skin, and has been traditionally estimated using an oil-pan method. Our study explored the notion of estimating Eeff during exercise using a heat balance method.

Method: Nine participants walked on a treadmill for 75 minutes (5 km/h with a 2% (low heat production (Hprod); n=6) or 6% (high Hprod; n=3) gradient) in: 1) a high efficiency (34.0±0.1°C, 24.9±0.8% RH, 2.0 m/s air velocity), and 2) a low efficiency (34.7±0.5°C, 60.3±1.9% RH, no wind) trial. Both trials were conducted twice to assess repeatability. Hprod and body temperatures were measured continuously, and nude mass assessed after 0, 45 and 75 minutes. After 45-min (steady-state), we assumed Hprod, corrected for dry and respiratory heat loss, was equal to evaporative heat loss (Eloss). Body mass loss (45-75-min), corrected for respiratory and metabolic mass losses, was used to estimate evaporative potential (Epot). The percentage of Eloss relative to Epot equalled Eeff.

Results: With low Hprod, Eloss was 335±44 and 344±42 W in the high and low efficiency trials, respectively, whereas Epot was 375±65 and 388±81 W. With high Hprod, Eloss was 416±16 and 452±29 W in the high and low efficiency trials, respectively, whereas Epot was 499±24 and 695±102 W. Estimated Eeff values were 90±7% and 88±11% in the high and low efficiency trials with a low Hprod, but 84±6% and 58±13% in the high and low efficiency trials with a higher Hprod. Repeatability of the Eeff, measured as coefficient of variation, was 12.4%.

Conclusions: Differences in Eeff were detectable in the high Hprod condition, but not in the low Hprod condition. Accurate measurements of weight loss, Hprod, body temperatures and ambient conditions are essential, and present significant challenges to making this method viable. Work on refining this method is ongoing.

TRPV4 channels do not contribute to cutaneous vasodilatation and sweating during passive heating in young adults

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Introduction: Transient receptor potential vanilloid 4 (TRPV4) channels play an important role in the activity of sensory receptors including osmo-, mechano-, and thermo-receptors, and others. While these channels exist on vascular endothelial cells and eccrine sweat gland secretory cells in human skin, it remains unclear if they are functionally involved in the activation of cutaneous vasodilatation and sweating during a passive heat stress.

Method: Twelve young adults (6 men, 6 women) were exposed to a moderate heat stress induced by increasing esophageal temperature of ~1.0ºC above resting levels using water-perfusion suits. Prior to and during heating, cutaneous vascular conductance and sweat rate were simultaneously measured at four intradermal microdialysis sites on the dorsal forearm continuously perfused with either 1) lactated Ringer (Control), 2) 5 % dimethyl sulfoxide (organic solvent) only, or one of the two following TRPV4 channel antagonists dissolved in 5 % dimethyl sulfoxide solution: 3) 200 μM HC 067047, or 4) 125 μM GSK 2193874. Following whole-body heating, 100 μM GSK1016790A, a TRPV4 channel agonist, was administered to the Control and both TRPV4 channel antagonist treated skin sites.

Results: The administration of a TRPV4 channel antagonists did not modulate cutaneous vascular conductance and sweat rate during resting under a non-heat stress condition (pre-heating period). Similarly, no effect of the TRPV4 channel blockade was measured during whole-body heating. Furthermore, the administration of 5 % dimethyl sulfoxide alone had no effect throughout. Administration of TRPV4 channel agonist did not affect sweat rate, but it increased cutaneous vascular conductance at the Control site. This elevation in cutaneous vascular conductance was partly attenuated by both TRPV4 channel antagonists.

Conclusions: We show that TRPV4 channels do not contribute to the heat loss responses of cutaneous vasodilatation and sweating during a whole-body moderate passive heat stress in young adults.

Investigation on the effectiveness of human rapid-reaction ability under heat stress condition

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Introduction: Human core temperature is one of the most important parameters that indicating human heat stress situation, and the accumulation of heat strain may lead to heat related illnesses, as well as functional and cognitive decline. In this study, the effect of hot environment on human physiological response and rapid-reaction ability was investigated.

Method: Eight healthy male subjects voluntarily participated in this study. They were physically healthy and had no history of heat related illnesses. Prior to the test, nude subject was weighed on a weighing scale, and then was dressed with clothing, measurement equipment (e.g., half face mask, chest strap, core temperature monitor, oxygen saturation monitor), also visual retention and choice reaction time tests were carried out. After the preparation, subjects came into the climatic chamber (40±0.5 °C, 40±5%RH), and were asked to perform the exercise consisted of four activity phases, i.e., warm up (walking at 5.0 km/h treadmill at level 5 until the core temperature reached 38 °C), visual retention and choice reaction time tests, treadmill walking at 5.0 km/h and level 5 to maintain the core temperature between 38 °C and 38.5 °C for 20 min, and a final visual retention and choice reaction time test. Heart rate, oxygen saturation, core temperature, skin temperature were recorded throughout the tests.

Results: It was found that the mean skin temperature increased from 32±0.5 °C to 37±0.5°C within 20 min and maintained until the end of the test. No mistake was discovered in both visual retention and choice reaction time tests. In addition, no statistic significant different was detected between the results measured at different test periods.

Electric fans and physical work capacity during heat stress: Impact of air temperature, humidity, and clothing

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Background: Self-paced physical work in the heat is largely characterised by a stable working heart rate, integrating the stress of the physical work and the climate. At present, major public health agencies (WHO, CDC, NHS) advise against forced convection (e.g., electric fans) at air temperatures above 35°C, however without empirical basis. In this study, we provide the empirical evidence to evaluate these advisories by comprehensively re- examining the critical environmental limits for benefits of fans to physical work capacity (PWC) above the advised 35°C.

Method: A heterogeneous sample of 14 young adult males (8 semi-nude, 6 wearing protective coveralls) performed 242 experimental trials consisting of 1-hour treadmill walking at a fixed heart rate of 130 b·min^{-1}. After a reference trial without heat stress (15°C, 50% rh), remaining trials were conducted across a wide range of air temperatures (35 to 50°C) and humidity (20 to 80% rh, 1.1 to 5.9 kPa water vapour pressure), each with and without wind at 4.0 m·s^{-1}.

Results: The effect of wind was dependent upon air temperature, humidity and protective clothing insulation. In minimal clothing, wind was beneficial up to 45°C, but only above 2.0 and below 4.7 kPa vapour pressure. For coveralls, wind was beneficial up to 40°C, above 2.0 and below 3.5 kPa. Fans typically impaired PWC beyond these critical environmental limits.

Conclusions: Contrary to current advice, fans can increase PWC at air temperatures above 35°C, allowing more work to be performed for the same cardiovascular strain. However, new guidelines for their safe use must incorporate air temperature, relative humidity, and whether protective clothing is required. In hot dry environments, exogenous skin wetting may be a safe addition or alternative to electric fan use.

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Blunted autophagy and heat shock responses in the elderly during extreme day-long heat exposure

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Introduction: Humans have evolved several cellular stress-response pathways including autophagy and the heat shock response to ensure survival under changing environmental conditions. Autophagy is a cytoprotective mechanism that plays a major role in cellular homeostasis and stress resistance, while the heat shock response suppresses protein toxicity and aggregation under environmental stressors such as increased ambient temperature. Elderly individuals are at greater risk for heat-related illness, which may be associated with dysfunction in these two major stress response pathways. The purpose of this study was to examine autophagy and the heat shock response in young and elderly adults during a day-long exposure to extreme heat.

Method: Peripheral blood mononuclear cells (PBMCs) were harvested from five young (22±2 years; one woman) and six elderly participants (70±3 years; two women) at 4.5-h and 9-h of resting exposure to extreme heat conditions (40°C, 10% relative humidity). Genes associated with autophagy (MAP1LC3B and p62/SQSTM1) and the heat shock response (HSPA1A) were analyzed via qRT-PCR. All values are reported as fold change relative to their respective baseline measurement.

Results: After 4.5-h of heat exposure, MAP1LC3B, p62/SQSTM1, and HSPA1A gene expression increased in young (1.70±2.09, 1.19±0.90, and 1.60±1.77, respectively) and elderly adults (1.39±0.38, 1.35±0.58, and 1.50±0.28, respectively). However, at 9-h there was a further increase in expression of measured genes in the young (2.57±3.78, 2.27±3.02, and 2.88±4.29, respectively), but not in the elderly adults (1.41±1.53, 1.44±1.35, and 1.58±1.64, respectively), despite a larger increase in rectal temperature in the elderly adults (0.97 vs. 0.52°C).

Conclusions: These preliminary findings indicate that older individuals experience blunting in both the autophagy and heat shock response pathways during a day-long extreme heat exposure, which may contribute to greater rates of heat-related illness in this population during extreme heat events.

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Sweat rate analysis in the heat tolerance test (HTT)

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Introduction: The current analysis of the Heat Tolerance Test (HTT), which allows the evaluation of the body's response to an exercise-heat stress is based on the dynamics of rectal temperature and heart rate. Sweat rate, which reflects the potential ability to dissipate heat and thus may serve as an adjuvant parameter to determine tolerance to heat has never been analyzed. The purpose of this study is to investigate the correlation between a subject's sweat rate and a diagnosis of heat intolerance.

Method: Data related to male subjects who had suffered from heat stroke and participated in a HTT were analyzed retrospectively. This database consisted of the results of 873 HTTs from the Institute of Military Physiology, the Israel Defense Forces. Sweat rates were examined in correlation with a diagnosis of heat intolerance.

Results: From the examined cohort 311 tests were considered as negative, reflecting a state of tolerance to heat (HT) and 67 were found to be positive, reflecting a state of heat intolerance (HI). The average sweat rate of the 378 HTTs was 781±240 g/hr (in the range of 200-1200 g/hr). When sub-divided into the HT and the HI groups, the average sweat rate in the HT group was significantly ($p=0.05$) higher than the HI group (792± 223 g/hr, and 730±291 g/hr, respectively).

Conclusions: Subjects who failed the test and were defined as HI had a lower sweat rate than those with a normal physiological response. Furthermore, subjects with a sweat rate in the first quartile have a 2.2 times greater risk of being diagnosed as HI. Decreased sweat rates may be part of the pathophysiology leading to HI and consequently to higher risk of exertional heat stroke.

Heat transfer during newborn brain cooling process – measurements and numerical analysis

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Introduction: The purpose of this work is to present the preliminary experimental re- sults and computational analysis of the newborn's brain cooling process. Hypothermal therapy is considered as an effective method of treatment hypoxic- ischemic encephalopathy. Although neonatologists agree that this should be standardized and improved, there is still a lot of opened questions. How long should therapy last? How to manage the rewarming process? Should the head be cooled selectively? Therefore, the interdisciplinary team was built to research the heat transfer and thermoregulation processes in the human body.

Method: Heat flux delivered to the cooling medium as well as the intensity of external heat sources are being recorded on-line during the cooling process at University Clini- cal Hospital in Opole. The measurements and medical data from patients undergoing brain cooling therapy are analysed and utilized to formulate the boundary conditions of the heat transfer calculations. In the current stage of research, the simplified numeri- cal model is being built by means of ANSYS Fluent code. It includes the water flowing inside the plastic pipes being in contact with the tissues: an outer skin, inner skin, fat, bone, and brain. The basic thermoregulation model of metabolic heat generation and blood perfusion were implemented. The preliminary model is aimed at verification of adopted assumptions and to test its sensitivity to the model input parameters.

Results: Based on the sensitivity analysis, the blood temperature, contact resistance and conductivity of plastic pipes material were identified to have crucial input on sim- ulation results.

Conclusions: Results show the importance of the accurate determination of indicated values to tune a complete numerical model of the heat transfer in the neonatal body during a selective brain cooling process.

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Heat intolerance test – its strength in preventing exertional heat stroke

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Introduction: The heat tolerance test (HTT) is designed as a surrogate clinical tool to examine the ability of soldiers/athletes who have been succumbed to exertional heat stroke (EHS) to return to duty/practice under conditions that might put them in risk to a recurrent episode. Over the years it has become clear that the test applies not only to those who have already been affected by EHS but also as a clinical diagnostic tool in preventing potential heat injuries. The following case reflects the validity of the test in in this regard.

Methods: A 20 years old soldier, healthy except for Familial Mediterranean Fever and no history of any heat injury. He was referred for a HTT by the military base physician after casually mentioning that he did not sweat since childhood. On questioning he told of headaches and palpitations after short walks in the sun and of cooling himself frequently with tap water when trying to participate in popular sports activities.

Results: The test lasted 40 min. and was stopped because the soldier felt exhausted. Rectal temperature had risen steeply; last measurements of rectal temperature and heart rate were: 38.5°C and 160 bpm, respectively with no tendency to plateau. The probability of heat tolerance (PHT) was lower than 0.5. Sweat rate was 75 g/hr. According to all parameters the soldier was diagnosed as heat intolerant.

Conclusions: The HTT is a standardized test to evaluate the ability to sustain an exercise-heat stress with the ability to differentiate between heat tolerant and heat intolerant individuals. The test enabled to substantiate the diagnosis of hypohidrosis, reducing the risk of EHS. It follows that in any case of a thermoregulatory malfunction the HTT results may be used as a clinical indication in the prevention of potential heat stroke.

Thermoregulation in the heat following a thoracic sympathectomy: A case study

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Introduction: One treatment for primary hyperhidrosis, excessive sweating of plantar, palmar and/or axillary surfaces, is an endoscopic thoracic sympathectomy (ETS), a surgical procedure in which sympathetic ganglia are cut or excised to disrupt the innervation of sweat glands, ultimately reducing the skin surface area capable of sweat secretion. The purpose of this case study was to characterise the thermoregulatory responses of a 37-year-old male following an ETS (T2-T4). Specifically, we assessed the impact of this reduced effective surface area on maximum skin wettedness (ωmax) and evaluated whether disproportionately higher sweat rates are observed in areas that remain innervated.

Method: Thermoregulatory responses were separately measured during a 70-min steady-state compensable heat stress exercise bout in 35°C/42% relative humidity (RH); and during a humidity ramp protocol at a fixed ambient temperature of 35°C with increasing RH (23-64%). Thermoregulatory measures included rectal (Tre), oesophageal (Toes), and 8-site mean skin (Tsk) temperatures, heart rate (HR), local sweat rate (LSR), skin blood flow (SkBF) and sweat gland density. In addition, technical absorbents assessed regional sweat rates (RSR) during the steady-state bout.

Results: The reduction in innervated skin surface area resulted in a ωmax of 0.64 that falls outside previously reported ωmax range (95% CIs) of [0.66 to 0.78], [0.76 to 0.92] and [0.90 to 1.00] for untrained and unacclimated, trained and unacclimated, and trained and heat-acclimated individuals, respectively (Ravanelli et al., 2018). Evidence of disproportionately higher sweat rates in innervated areas was supported by higher normalised median RSR on the thigh (1.32 vs 1.09) and lower back (1.77 vs 1.29) compared to existing sweat mapping data (Smith & Havenith, 2011).

Conclusions: Despite evidence of a compensatory increase in sudomotor output in skin areas with intact sudomotor apparatus, a lower ωmax following ETS persists, potentially reducing the upper environmental limits for safe exercise/work in the heat.

Effects of warming or cooling stimulation of the forearm and/or palm on brachial artery shear rate profiles during lower cycling exercise

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Introduction: Recent human studies have reported modulated profile of brachial artery shear stress (BA-SS) during lower limb exercise, which may be a key factor contributing to endothelial adaptations of the inactive upper limbs. During exercise, the BA primarily supplies the skin BF (SBF) to the glabrous (G; palm) and non-glabrous (NG; dorsal and forearm) regions; however, it remains unclear which between these is most responsible for upstream BA-SS profile. Therefore, the purpose of this study was to elucidate the effects of G and/or NG cutaneous vascular conductance (CVC), which were modulated by warming or cooling stimulation, on BA-shear rate (SR: an estimate of SS) during cycling exercise.

Methods: Seven healthy young subjects performed 60-min cycling exercise, which corresponded to a heart rate of approximately 120 bpm. Between 20 and 50 min of the exercise, the NG+G or G skin regions of the right arm were warmed to 43°C or cooled to 15°C using a water bath. Each subject underwent four trials in a random order. Throughout the protocol, the diameter and blood velocity of the BA were simultaneously recorded using Doppler ultrasonography to calculate antegrade, retrograde and mean SRs. SBFs in the forearm (f) and palm (p) were also measured to calculate the CVC (SBF divided by mean arterial blood pressure).

Results: At 20 min of the exercise, f-CVC and mean BA-SR significantly increased compared with resting baseline values in all trials. Subsequently, during NG+G warming stimulation, dramatic increases in f-CVC and concomitant BA-SR (primarily characterized by increased antegrade SR and decreased retrograde SR) were observed. By contrast, when the skin regions either G or NG+G were cooled, both CVCs and mean BA-SR were slightly but significantly decreased.

Conclusions: NG CVC response possibly plays a major role in the modulation of BA- SS profile during lower limb exercise. [JSPS-KAKENHI (#17K01616)]

Acute physiological responses to different modes of heat exposure

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Introduction: Heat is a common stressor and drives many adaptations. Three practical modes of heating are exercise in hot conditions, spa bathing, and sauna. These may differentially affect vascular pressures, shear stress, neuroendocrine responses, and thermal distributions - but their relative effects appear unreported. We compared three common modes of heat stress for their thermal and cardiovascular impacts during heating and for up to 24 h afterward.

Method: Thirteen, healthy, active participants (5 women), completed four regimes of 5 daily 60-min exposures: Spa (40ºC); Sauna (55ºC, 55% rh); Exercise in humid heat (40ºC, 50% rh; ExHeat); and a Thermoneutral bath (36ºC; Control). Regimes were in randomised order, 6-wk apart. Differences ($p<0.05$) reported below are from Linear Mixed Models analyses performed in R, for acute data pooled across days within each mode.

Results: Heating: Sauna was poorly tolerated (42 ± 10 min) despite lower peak rectal temperature than ExH (38.5 vs 38.9 ºC) and no additional hypotension. Thus, thermal impulse in Sauna was only 71% of that in Spa and ExH, despite higher sweat rates (~18%) and skin temperature (peak: 40.2ºC). Average heart rate during Spa didn't exceed Control and was 23 bpm below Sauna, which was 37 bpm below ExH (145 bpm). Plasma volume rose ~7% during immersion, regardless of heating. Aldosterone concentration rose 1.4 and 0.6 fold in ExH and Sauna, while ANP responses were variable. Recovery (from first exposure only): ExH elicited the only clear postexercise hypotension (-8 mm Hg at 0.75 h) and rebound plasma volume expansion (+5.7% at 24 h). Arterial pressure was unchanged at 24 h, irrespective of prior heating mode.

Conclusions: Combined exercise and heat stress, and the augmented metabolic and cardiovascular strain not evident with passive heating, may be required to elicit short- term cardiovascular benefits in healthy adults.

Development and Evaluation of Layered Nomex Honeycomb Fabric Protective Clothing for Firefighters under Extreme Heat

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Introduction: Current three layered firefighter protective clothing (FPC) can prevent 2nd degree burns from several seconds of heat and flame exposure at 84 $kW \cdot m^{-2}$. However, structural fires, due to their various building materials, occasionally reach over 84 $kW \cdot m^{-2}$. Lately, it is developing an FPC capable of withstanding exposure to higher heat, such as 125 $kW \cdot m^{-2}$, while maintaining comfort has been an issue. Increasing protective functions may cause excessive heat strain of firefighters. This study evaluated the protective and comfort functions of a newly-developed FPC with layered Nomex honeycomb fabric (HPC).

Method: We developed a new FPC using Nomex honeycomb fabric (as the middle layer of the FPC (HPC)) and examined its flame protection using a flame manikin and its heat- resistance using a thermal manikin. A maximum oxygen consumption test (VO_2max) was carried out with firefighters. Through a simulated firefighting task protocol with firefighters, performance and mobility were evaluated. All the tests and trials were compared to the current FPC.

Results: The estimated surface area for a 2nd degree burn was lower for HPC than for the current FPC. HPC had 0.21 higher clo than the current FPC. VO_2max was reduced to 14% (current FPC) and 12% (HPC) compared with wearing light sportswear, but no significant difference in VO_2max between the current FPC and HPC was found. Completion time to accomplish the simulated firefighters' task was 14 min (FPC) and 13 min (HPC). There were not a remarkable differences between FPC and HPC in thermal sensation, thermal comfort, and sweat sensation.

Conclusions: These results indicate that the newly developed Nomex honeycomb FPC can 1)minimize skin burns when facing sudden high risk situations, and 2)not impair firefighters' maximal performance or subjective perceptions when compared to the current FPC. Further studies with longer wear trials (over hours) are needed to evaluate the impact of the 0.21 clo increased on thermal strain.

Heat strain assessment of firefighters by smart technology and a model

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Introduction: Firefighting is physiologically a very demanding occupation. The combined effects of a hot working environment, protective clothing and heavy physical tasks may lead to cardiovascular and thermoregulatory strain. The aim of this study was to develop a smart technology-based assessment system to identify firefighter's heat strain and to prevent heat-related illness.

Method: Firstly, interviews of requirements were performed in five rescue departments. Secondly, human measurements were performed in laboratory conditions and at the Emergency Service College during their training program. Movesense sensor (Suunto, Finland) was used to measure individual heart rate, activity and temperature. Data transfer and route methods were developed for the sensor. Core temperature (Tc), skin temperatures (Ts) and heart rate (HR) were measured. Subjects' physical characteristics and HRmax were measured or previously measured VO2max was used. In addition, thermal insulation and water vapour resistance of the firefighter clothing were measured.

Results: In the interviews several topics were raised eg., location of the partner, ambient temperature, volume of the compressed air, heat and physical strain. Assessment of heat strain was chosen for this study because of its importance of their health and well-being. Simplified version (HTM_D) of the VTT Human Thermal Model (HTM) was developed. Parameters for the HTM_D were HR, Ts and thermal insulation of the clothing. Measured and calculated (by the model) Tc differed by 0.2 °C. HR and calculated Tc were then used to estimate the physiological strain index (PSI) according to Moran et al. (1993).

Conclusions: HTM_D can be used to assess PSI of a firefighter in real time. HTM_D together with smart Movesense technology is a useful tool for fire officers to monitor firefighters' health and safety during their demanding tasks. Saved database can be used to explore individual cumulative exposures to heat strain.

Clothing insulation and evaporative resistance values and heat strain predictions for sugarcane field workers

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Introduction: Industrial sugarcane workers perform difficult, strenuous work under hot environmental conditions. It is possible that clothing and protective gear further exacerbates worker's heat exposure as clothing has a strong thermal impact on humans. The aim of this study was to evaluate i) the thermal performance of clothing and protective gear used in sugarcane harvesting and chemical spraying tasks, and ii) workers' predicted heat strain (PHS).

Method: The thermal manikin Tore at Lund University was used to test the clothing insulation and the evaporative resistance of sugarcane harvester (SC) and chemical sprayer (CP) clothing sets. Tested clothing ensembles were acquired from Ingenio San Antonio, the largest sugar mill in Nicaragua, and are currently worn by field workers. Sugarcane field weather data, estimated activity levels and clothing parameters were entered into the PHS model (http://www.eat.lth.se/fileadmin/eat/Termisk_miljoe/PHS/ PHS.html). Exposure characteristics were calculated hour by hour for temperature (ta=18.6-36.4 °C, tg=20.5- 52.1 °C) and activity combinations. The curves of exposure limit were prepared based on core temperature and water loss.

Results: Parameters for both clothing sets were all within the limits of PHS requirements (Icl,SC=0.107 m2K/W, Icl,CP=0.177 m2K/W; Recl,SC=13.2 m2Pa/W, Recl,CP=74 m2Pa/W). Heat exposure in chemical protective clothing was strongly limited by increasing core temperature, while cane cutters' core temperature raised above 38 °C only at air temperatures above 34 °C, and for them dehydration was a stronger limitation: core temperature rise may trigger rest breaks, and during breaks people drink. Alternatively, dehydration is harder to notice subconsciously.

Conclusions: Insulation and evaporative resistance values (total, regional and local) of typical clothes used in sugarcane fields are available. Although, accuracy of PHS method can be questioned, these data provide estimations of exposure time, rest break frequency and recommendations for regular water intake. Thus, enabling 1) evaluation of work situation and 2) better organisation of work schedule.

Evaluation of firefighter protective clothing visibility obscured by smoke and fire damage

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Introduction: This study aimed at evaluating the visibility of new and damaged firefighter protective clothing (FPC) by smoke and light intensity conditions.

Method: Eight male firefighters sat at a distance of 12 m from a FPC wearer and evaluated the visibility of FPC within the range of 0% (not visible) to 100% (very visible). Main experiments consisted of eight conditions: 2 smoke (smoke, no-smoke) × 2 light intensity (day, night) × 2 FPC conditions (new, flame-damaged). Additional experiments using light emitting diode (LED) bands and flashlights were performed in order to find auxiliary ways of improving the FPC visibility.

Results: Under the day condition, the visibility scores of new and damaged FPC were 2.1 ± 0.7% and 1.8 ± 0.7%, respectively, under the smoke condition, while the visibility scores were 100.0 ± 0.0% and 66.3 ± 6.3% under the no-smoke condition. There were significant differences in the visibility scores between smoke and no-smoke conditions ($P < 0.001$), and between new and damaged FPC under the no-smoke condition ($P<0.05$). Under the night condition, the visibility scores were all 0% under the smoke condition, while the visibility scores were 10.1 ± 2.1% (new) and 5.4 ± 1.2% (damaged), under the no-smoke condition. Meanwhile, these visibility scores under the night-no smoke condition were improved up to 47.8% (new) and 45.3% (damaged) with the LED bands, and 45.0% (new) and 35.6% (damaged) with flashlights.

Conclusions: The visibility of FPC was degraded due to smoke obscuration and flame damage. This degradation was especially serious under the night-smoke condition, but it was confirmed to be able to improve when using LED bands and flashlights. Further studies in different smoke concentration levels and colours, and with various brightness, locations, sizes, and flashing patterns of different auxiliary tools are required for field application.

Thermal protection of the new born during carrying: an evaluation of parents' practices

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Introduction: Public health guidelines on how to ensure babies' thermal proception are available (e.g. dressing with 1 extra layer of clothing than the adult); yet little is known on the strategies that parents adopt to ensure their babies' thermal protection when these are carried in a sling (i.e. babywearing). The aim of this study was to survey parents' practices during babywearing with regards to baby dressing and thermal monitoring in the heat and cold.

Method: Participants undertook an anonymous online questionnaire aimed at establishing a) demographics; b) knowledge of guidelines for babies' safety (e.g. thermal protection and sleeping position); c) babywearing practices in the heat and cold (e.g. number of clothing layers placed on babies); d) thermal monitoring (e.g. parts of the babies' body used to determine their thermal state); e) subjective thermal responses (e.g. babies' body parts that become hotter during babywearing).

Results: 317 responders (98% females) completed the questionnaire. Most participants carried their baby outdoor (66%), more than once a week (67%), and between 30 min and 1 h (53%). Only 33% of participants were aware of guidelines on baby dressing, whereas 97% of responders had knowledge of safe sleeping guidelines. Most participants reported to dress babies in 1 layer less than if using a pram during both warm (52%) and cold (52%) days. They also reported they would touch their babies' skin to determine their temperature (90%), and that during both warm (87%) and cold days (95%), their babies' trunk becomes the warmest regions.

Conclusions: We show that knowledge of public health guidelines for babies' thermal protection during babywearing is comparatively low that of safe sleeping. Yet, we observed clear practices amongst parents for both baby dressing and thermal monitoring that consider the thermal impact of babywearing in both warm and cold ambient.

Impaired balancing ability due to physiological responses with the prolonged workload and heat exposure

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Introduction: Increased heat stress due to global warming has resulted in frequent accidents related to heat stroke. East Asia has areas prone to high temperatures and high relative humidity (RH) during the summer season, which leads to increases in the incidence of heat stroke among outdoor workers. It is well known that nausea, vomiting, and vertigo are initial symptoms of heat stroke. Heat stroke may increase human errors such as slips, trips, and falls, as distinct from heat stress. This study aimed to investigate the impaired balancing ability due to physiological responses with the prolonged workload and hot exposure.

Method: Eight healthy men participated in this experiment for measuring physiological responses and deterioration of balancing ability in response to a 4-h workload and heat exposure (34℃, 50%RH). The experiment protocol consists of four sets of the test (45 min of low-speed treadmill exercise and 15 min of recovery). The participants performed this test from morning to afternoon with 1h of lunchtime. Heart rate and body temperature were recorded during the test. Functional reach, 2 steps test, timed up and go, and Y-balance test was measured for a functional balance test. Also, body sway length and area were tested.

Results: This study indicates that impaired balancing ability was affected by prolonged workload and heat exposure. During the 4-h workload with heat exposure, the rectal temperature was increased 0.8℃. The mean body weight loss was 1.5% of participants body weight (0.9kg). Those physiological responses were significantly higher than without heat exposure condition ($p<0.05$). The sway length and area were shown no significant differences, however, the 'functional reach and 'timed up and go' were deteriorated due to the workload with heat exposure.

Conclusions: Accumulation of physiological fatigue from the prolonged workload and heat exposure seems to contribute to the impaired the functional balancing ability.

Heat shock protein 90 inhibition attenuates cutaneous vasodilatation in young women during rest, exercise, and recovery in the heat

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Introduction: Heat Shock Protein 90 (HSP90) enhances nitric oxide (NO) bioavailability by stabilizing the NO synthase (NOS) enzyme. In young men we previously showed that HSP90 inhibition attenuated cutaneous vascular conductance (CVC) during exercise, but not during rest or post-exercise recovery in the heat; an effect that was NOS-dependent. However, it remains to be determined if similar effects occur in young women. Therefore, the purpose of this study was to evaluate the effects of HSP90 inhibition on CVC in young women during rest, exercise, and recovery in the heat and to determine if this effect was NOS-dependent.

Method: In nine habitually active young women (23±3 years), CVC (assessed via laser Doppler flowmetry) was measured at four forearm skin sites receiving either: 1) lactated Ringer's (Control), 2) 178 μμM Geldanamycin (Gelda, HSP90 inhibitor), 3) 10 mM NG-nitro-L-arginine methyl ester (L-NAME, NOS inhibitor) or 4) combined 178 μμM Gelda + 10 mM L-NAME (G+L), via intradermal microdialysis. A 5% DMSO solution was used to fully dissolve Gelda, and was added to all sites for consistency. Participants rested in the heat (35°C) for 70 min, followed by 50 min of moderate-intensity exercise (~55% VO2peak) and 30 min of recovery. All testing was performed during the early follicular phase of the menstrual cycle.

Results: Inhibition of HSP90 attenuated CVC by ~10% between 30-50 min of exercise (all $P<0.05$), but not during rest or post-exercise recovery (all $P>0.05$). NOS inhibition attenuated CVC by ~20% during rest and ~37% throughout exercise and recovery (all $P<0.05$). However, combined HSP90 and NOS inhibition was not different from NOS inhibition alone (all $P>0.05$).

Conclusions: Consistent with our previous findings in young men, HSP90 inhibition attenuated CVC during exercise in the heat in young women in a NOS-dependent manner.

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Response characteristics of esophageal and gastrointestinal temperature in athletes with a spinal cord injury exercising in the heat

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Rationale: Athletes with a spinal cord injury (SCI) have impaired thermoregulation, therefore it is important to accurately assess their thermal status. Esophageal temperature (T_{es}) provides the best surrogate of circulating blood temperature, however is impractical outside a laboratory. In contrast, gastrointestinal temperature (T_{gi}) is regularly used in field settings, yet there is typically a temporal lag in T_{gi} for a given T_{es}. Differences between T_{gi} and T_{es} may also be impacted by impaired splanchnic blood flow secondary to SCI. This study compared T_{gi} and T_{es} during and post-exercise in the heat in athletes with different SCI levels.

Methods: 8 tetraplegic (TP; C5-C8), 7 high paraplegic (HP; T1-T5), 8 low paraplegic (LP; T6-L1) and 8 able-bodied (AB) exercised for 3x10-min with 3-min breaks, then rested for 30-min in 35°C and 50% RH while T_{gi} and T_{es} were measured. Estimated means and 95% confidence intervals are reported for within-group comparisons.

Results: Within each group, absolute T_{gi} and T_{es} changed similarly with time throughout the trial (TP: p=0.389, HP: p=0.532, LP: p=0.344, AB: p=0.085), with T_{gi} consistently greater than T_{es} (TP; p=0.012, HP; p<0.001, LP; p<0.001, AB; p<0.001). Changes from baseline revealed no interaction of time and site for HP or LP, however ΔT_{es} was higher than ΔT_{gi} for TP after 20 and 30-min of exercise (ΔT_{es}: 1.86°C [1.70, 2.02], ΔT_{gi}: 1.32°C [1.16, 1.47], p=0.001), and for AB after 10-min (ΔT_{es}: 0.33°C [0.24, 0.42], ΔT_{gi}: 0.10°C [0.00, 0.19], p=0.001). Furthermore mean ΔT_{es} was greater than ΔT_{gi} throughout the trial for TP (p<0.01).

Conclusion: Mean T_{gi} was higher than T_{es} during 30-min of exercise and passive-recovery, irrespective of SCI. However, due to the responsiveness of the two sites, ΔT_{es} was greater than ΔT_{gi} during exercise in TP. Peak T_{gi} may occur later than T_{es}, particularly in TP. Monitoring SCI individuals post-exercise until a reduction in T_{gi} is observed is recommended.

Thermophysiological Responses and Heat-Induced Labour Loss in Agriculture

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Introduction: Occupational heat stress is detrimental for human performance leading to significant labour loss. However, the magnitude of this problem remains unclear even in industries such as agriculture which are depended on manual labour conducted outdoors. Therefore, the aim of our study was to quantify the magnitude of heat-induced labour loss and examine the thermophysiological responses of agriculture workers during different seasons.

Methods: During the last three years, we evaluated >1000 work hours via time-motion analysis on a second-by-second basis collected from 165 workers (age: 41.9±13.0 years; BMI: 25.8±4.8 kg/m^2) while performing different agriculture jobs. Physiological data (core temperature, skin temperature, and heart rate) were collected from 30 individuals. Environmental data were recorded throughout the work shift using a portable weather station. The study has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant agreement no. 668786.

Results: Very strong relationships were identified between thermophysiological responses [core temperature (range: 36.7°C to 38.2°C): r=0.97; skin temperature (range: 27.5°C to 37.9°C): r=0.97; heart rate (range: 25.1% to 100% of HRmax): r=0.86], labor loss (r=0.95) and wet bulb globe temperature (WBGT) (all $p<0.001$). Precisely, labour loss escalates from 3.7%, during low occupational heat stress (12-18°C WBGT), to 15.0% during high occupational heat stress (25-30°C WBGT), increasing by 0.89% for every 1°C increase in workplace WBGT (R^2=0.90, $p<0.001$). On the other hand, we found a negative relationship between metabolic rate (r=-0.33) and WBGT ($p<0.001$).

Conclusions: Occupational heat stress affects the human thermophysiological responses leading to impaired capacity to perform work.

Reliability of tehchniques to assess gastrointestinal barrier integrity following a military exercise-heat stress intervention

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Introduction: Strenuous exercise-heat stress adversely distrupts GI barrier integrity and appears central in the development of exertional heat stroke (EHS). The development of assessment techniques to determine GI barrier integrity is consequently an important step in the prevention, diagnosis and treatment of EHS. This study investigated the reliability of the gold-standard dual-sugar absorption test (DSAT) in serum and several promising GI barrier integrity biomarkers in response to a military style exercise-heat stress intervention.

Method: Fourteen healthy males completed two separate exercise-heat stress interventions (EHSI). The EHSI consisted of two 40 minute-bouts of fixed-intensity (6 $km.h^{-1}$ on 7% gradient) treadmill walking in the heat (35°C/25% relative humidity) interspersed by a 20-minute recovery period. Venous blood samples were collected pre, post and 1-hour post exercise. The DSAT was determined in serum at 90- and 150- minutes post sugar probe ingestion using high-performance liquid chromatography. Intestinal Fatty-Acid Binding Protein (I-FABP) and Lipopolysaccharide Binding Protein (LBP) were determined pre-to-post exercise by ELISA. A battery of reliability statistical tests (e.g. Pearson's correlation (r), coefficient of variation (CV), limits of agreement (LoA) were utilised to compare between-trial responses.

Results: Whole-body thermoregulatory (peak rectal temperature 38.63 ± 0.28 vs. 38.46 ± 0.37°C) and cardiovascular (peak heart rate 164 ± 13 vs. 161 ± 16 $beats.min^{-1}$) responses were similar between trials. The DSAT offered acceptable reliability at both 1.5 (0.028 ± 0.012 vs. 0.025 ± 0.014; r= 0.90; CV= 11.5%; LoA= -0.003) and 2.5 hours (0.033 ± 0.015 vs. 0.034 ± 0.016; r= 0.94; CV= 12.2%; LoA= 0.001) following probe ingestion. I-FABP responses increased from pre-to-post EHSI's (p = 0.85), though reliability was poor-to- moderate (Δ 769 ± 453 vs. 790 ± 377 $pg.ml^{-1}$; r= 0.59; CV= 36.6%; LoA= -19 $pg.ml^{-1}$).

Conclusions: GI barrier integrity was reduced following a moderate-intensity military EHSI. The DSAT offered acceptable levels of reliability, though I-FABP concentrations showed greater between-trial variation.

What is the effect of changing female sex hormones on cerebral blood flow? A systematic review

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Introduction: Age-adjusted heat-related mortality indicates elderly women are more susceptible to extreme heat compared to men. Changing female sex hormones (e.g. oestrogen and progesterone) are thought to influence cerebral blood flow (CBF), with possible implications for heat-related mortality. Therefore, the aim of this study is to perform a systematic review of the current literature on changing female sex hormones and CBF.

Method: Three databases (EMBASE, MEDLINE and Web of Science) were searched and identified texts were screened by two independent reviewers (RD, BS). Inclusion criteria were articles from the earliest available date to December 2018 on adult CBF and female sex hormones. Articles were excluded if both themes were not addressed, were animal studies or involved adolescents under 18 years. Middle cerebral artery velocity (MCAv) data from included texts were collated and changes between a 'low hormone phase' and 'high hormone phase' (e.g. Low: non-pregnant vs. High: 3rd trimester pregnancy) were calculated.

Results: 48 studies met inclusion criteria. 27 reported measures of CBF with MCAv the most frequent measure (n=14). Overall, MCAv was 3.7% greater in low hormone phases when compared to phases of elevated female sex hormones (68.6±11.0 vs. 66.1±12.9cm/s). Within life-stages, pregnancy (n=6) had the greatest decrease in MCAv from a low to high hormone phase (- 9.5%; Low: 65.8±6.4 vs. High: 58.9±3.7 cm/s) and ovarian hyperstimulation (n=1) the greatest increase (6.2%; Low: 97±13 vs. High:103±14 cm/s). Changes in MCAv from low to high hormone levels across the menstrual cycle (n=3), with HRT use (n=2), and with menopause (n=2) were -0.5%, -2.3%, and -0.1%, respectively.

Conclusions: Lower levels of female sex hormones generally appear to cause an increase in CBF, with the exception of ovarian hyperstimulation. To fully elucidate how changing female sex hormones may influence heat-related mortality, other indices of cerebrovascular function (e.g. autoregulation) should be examined.

Muscle atrophy following bed rest

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ABSTRACT WITHDRAWN

Evaluation of elderly males' heat strain during light activities in hot and humid environments

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Introduction: A physiological strain index (PSI) based on the combination of core body temperature and heart rate has been applied to estimate heat strain (Moran et al. 1998). A non-invasive index using thermal perception (PeSI) has been proposed (Tikuisis et al. 2002). Most heat strain indexes are designed for young adults during heavy exercise under hot and dry environments. However, in 2018, about 60% of heat-related deaths in Korea were found in 65 years old or older people while daily walking or light activities in agricultural fields. This study evaluated heat strain of elderly males during light activities in hot and humid environments and suggested a non-invasive heat strain index for elderly people during heat waves.

Method: Ten older males (74.7±4.0 yr, 157.3±6.1 cm, 66.7±5.8 kg) and 11 young males (23.5±2.3 yr in age, 167.2±7.0 cm in height, 73.7±10.0 kg in body weight) participated in four experimental conditions: 60-min sitting and 60-min walking at an air temperature of 30°C with 70%RH (WBGT 27°C) and 35°C with 70%RH (WBGT 32°C). During all trials, rectal temperature (Tre), ear canal temperature (Tear), 11 skin temperatures (Tsk), energy expenditure, heart rate (HR), total sweat rate (TSR), thermal sensation (TS) and thermal comfort (TC) were recorded.

Results and conclusions: The results showed that the elderly's maximum exposure time at an air temperature of 35°C (70%RH) at rest were 167 min (Tre 38.5°C) and 193 min (Tre 39.0°C) as an alarm and a danger criterion, respectively, and during daily walking at 35°C (70%RH) were 105 min and 132 min as an alarm and a danger criterion, respectively. While walking, PSI estimated older males's heat strain at a lower level becasue of their diminished heart rate capability compared to young males. A modified heat strain index based on non-invasive variables (foot temperature, ear canal temperature and thermal comfort) for older males while walking in hot and humid environments was developed and evaluated.

Ballistic Protection Coverage Effects the Heat Exchange Properties and Predicted Thermal Strain of Combat Uniforms

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Introduction: Ballistic protection is critical to safeguarding against physical injuries on the battlefield. However, it also restricts the avenues for body heat exchange between the skin and environment. This study aimed to assess the effect of ballistic protection coverage on ensemble heat exchange properties and to estimate thermal strain.

Method: Total thermal insulation (*It*), evaporative resistance (*Ret*), and Evaporative potential (*im*/*clo*) were measured on a heated sweating manikin according to ASTM standards (F1291-16, and 2370-16). Three clothing ensembles were evaluated. A combat uniform of long sleeve shirt and trousers, socks and boots (CON), to which a protective ballistic vest was added (BPC). The third ensemble included a combat uniform with additional extremity protection on the collar, shoulders and upper arm, waist, and abdominal flap, and a helmet (BPC-E). The Heat Strain Decision Aid predicted deep body temperature elevation during light (225 W), moderate (400 W), and heavy (654 W) work in 35 °C air temperature and 40% relative humidity (33 °C Wet-Bulb Globe Temperature).

Results: BPC-E imposed greater restrictions to heat exchange (*It* 1.53 clo, *Ret* 0.038 kPa·m^2/W, *im*/*clo* 0.24) compared to the BPC (*It* 1.37 clo, *Ret* 0.033 kPa·m^2/W, *im*/*clo* 0.29) and CON (*It* 1.37 clo, *Ret* 0.031 kPa·m^2/W, *im*/*clo* 0.30) ensembles. For light, moderate, and heavy work, time to a deep body temperature elevation of 38.5 °C was 88, 54 and 32 min for BPC-E, 113, 59 and 35 min for BPC, and 122, 66 and 40 min for CON. Overall, work times were reduced ~20-30% for the BPC-E compared to CON, and 10- 20% compared to BPC.

Conclusions: Ballistic protection coverage around the upper body restricts heat exchange and elevates thermal strain. Risk management strategies, such as reduced exposure times, will be required in hot training environments where additional ballistic protection is worn.

A wearable core temperature estimation system for real-time monitoring of heat strain in workers

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Introduction: Industrial workers are at risk from heat illness whenever they work for a prolonged time in hot and humid conditions. In 2018, ~1100 cases of heat injury are reported in Japan, despite a continuing focus on prevention. Wearable technology is now being adopted, but a system that accurately measures core temperature using wearable devices has yet to be reported. We propose a model based on a dual-heat-flux method that predicts core temperature using data from patch-type sensors on the chest.

Method: We performed experiments that compared our predicted temperatures (Tpre) with actual temperatures, both esophageal (Teso) and rectal (Trec), during exercise in hot conditions. Fifteen males and six females walked for 60 min at 4-5 km/h (at 35°C, 50% RH) while wearing standard work uniform. Seven male subjects among them participated in another trial with protective clothing.

Results: In the work uniform, Teso, Trec, and Tpre increased from 37.1 ± 0.2°C, 37.0 ± 0.2°C, and 37.1 ± 0.3°C to 37.9 ± 0.1°C, 37.9 ± 0.1°C, and 37.9 ± 0.1°C (mean ± SD), respectively, during exercise. The difference between Tpre and Teso was 0.01 ± 0.18°C and that between Tpre and Trec was 0.26 ± 0.26°C, using data sampled at 5-minute intervals during exercise. In the protective clothing, Teso, Trec, and Tpre increased to 38.2 ± 0.2°C, 37.9 ± 0.3°C, and 38.0 ± 0.2°C after exercise. In this case, the difference between Tpre and Teso was –0.20 ± 0.23°C and that between Tpre and Trec was 0.30 ± 0.31°C.

Conclusions: Error ranges for our model are similar to those in previous studies involving noninvasive core temperature measurements. Although our system uses simple wearable devices, influencing factors such as body size and composition, intense and upper-body exercise, and environmental temperature should be investigated in future work.

Diurnal variation in the cutaneous sensation thresholds may be related to diurnal change in psychological responses

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Introduction: In the previous study (Kakitsuba and Chen, UTCI2019), it was demonstrated that the subjects voted "warm" in the morning at 70% Rh and 80% Rh but "slightly warm" in the evening although mean sin temperature (Tsk) increased with time when seven male and seven female subjects were exposed to 60%, 70% and 80 % Rh at ambient temperature (Ta) of 28 °C from 9:00 to 18:30. Assuming that diurnal change in psychological responses may be related to cutaneous warm and cold sensation thresholds, diurnal change in these thresholds was studied in the present study.

Methods: Five male and five female young Japanese subjects were exposed to 60%, 70% and 80 % Rh at 28 °C from 9:00 to 18:30. Cutaneous warm and cold sensation thresholds at three sites were measured using 1-cm^2 and 2-cm^2 probes. Skin temperatures at four sites and tympanic temperature (Tty) were continuously monitored at 2-min intervals throughout the experimental period. In addition, thermal sensation and comfort votes were recorded.

Results: The results showed that thermal sensation changed from "slightly warm" at morning to near "neutral" at evening in all Rh conditions for the male subjects but such change was observed only at 80% Rh for the female subjects. The Tty and Tsk increased from morning to afternoon regardless of Rh and sex, as observed in the previous study. The cutaneous threshold zone measured with 1-cm^2 decreased from morning to afternoon at 70% and 80% for the male subjects whereas that measured with 2-cm^2 changed in the same manner for the female subjects, as observed by Kakitsuba and Mekjavic (2018).

Conclusion: Diurnal change in psychological and physiological responses while Ta and Rh were consistently maintained during day time may be related to diurnal change in cutaneous sensation threshold zone.

The effect of using an electric fan in front of upper body on sweating efficiency during exercise in hot humid environment

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Introduction: To achieve high sweating efficiency (SE) during prolonged exercise in humid heat is of critically important to attenuate thermoregulatory strain and thereby protecting the human body from over-heating. From the previous studies, SE was evaluated with a minimum air flow velocity (~0.3 $m.s^{-1}$) in a hot environment at rest and during exercise. It has been assumed that SE is improved by increasing air flow velocity. Therefore, we examined the effect of air flow velocity on SE during prolonged exercise in hot-humid environment.

Method: Twelve healthy males (Age: 23 ± 3 yr; Height: 172.7 ± 6.9 cm; Weight: 64.5 ± 7.3 kg; % Body fat: 13.5 ± 3.2; BSA: 1.8 ± 0.1 m^2; VO2max: 44.4 ± 7.8 $mL.kg^{-1}.min^{-1}$) performed a fixed-intensity cycling exercise (40% of their VO2max) for 60 min in 32 °C and 75 % RH environment with a low airflow of 0.20 ± 0.04 $m.s^{-1}$ at the first 40 minutes and changing the frontal air flow of 1.12 ± 0.22 $m.s^{-1}$ in the last 20 minutes by an electric fan. Total (TSR) and ineffective sweat rate (ISR) were measured continuously by two different weight scales throughout the exercise. Effective sweat rate (ESR) and SE were derived from sweat drippage and body mass changes from the weight scales.

Results: Fan usage enhanced both ESR and SE whilst ISR was lower with fan (4.2 ± 0.6 vs 5.4 ± 0.9 $g.m^{-2}.min^{-1}$, $P < 0.01$: 63.4 ± 21.4 vs 80.4 ± 12.1 %, $P < 0.01$: 3.2 ± 2.3 vs 1.5 ± 1.1 $g.m^{-2}.min^{-1}$, $P < 0.01$). However, TSR remained similar before and after fan usage (7.4 ± 2.6 vs 6.9 ± 1.8 $g.m^{-2}.min^{-1}$, $P = 0.16$).

Conclusions: We concluded that changing air flow velocity enhanced both ESR and SE during exercise in hot humid environment.

Time course of sweat content during heat acclimation and re-acclimation by controlled hyperthermia

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Introduction: The purpose of this study is to determine the time course of changes in sweat rate and sweat content during 10 consecutive days of heat acclimation (HA) and 5 consecutive days of re-acclimation (RA) after a 28 day decay period.

Method: Eight participants (6 males, 2 females) completed 10 days of heat acclimation, including cycling for 60 minutes above 38.5 °C rectal temperature (controlled hyperthermia) in 33 °C and 65% relative humidity. Four of them (4 males) completed the 5 days of re-acclimation by controlled hyperthermia. Upper arm and back sweat was collected 3 times each day during heat exposure. Sweat rate, sweat [Na+], [Cl-], [K+] and [lactate] were determined.

Results: Values are expressed as a percentage of heat acclimation day 1. Average sweat [Na+], [Cl-] and [lactate] decreased after heat acclimation (50% $p<0.05$, 51% $p<0.05$ and 49% $p<0.05$ respectively) and re-acclimation (46% $p<0.05$, 47% $p<0.05$ and 38% $p<0.05$ respectively) for a given sweat rate. Average sweat [K+] did not change significantly after heat acclimation (18% $p>0.05$) nor after re-acclimation (12% $p>0.05$) for a given sweat rate.

Conclusions: Exercise induced heat acclimation and re-acclimation by controlled hyperthermia improved reabsorption of sweat constituents in the eccrine sweat gland and possibly whole-body losses of ions and small organic molecules.

NO mediated activation of KATP channels contributes to cutaneous thermal hyperaemia in young adults

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Introduction: Local skin heating to 42ºC causes cutaneous vasodilatation, known as cutaneous thermal hyperaemia. This response is widely employed to diagnose microvascular dysfunction or to evaluate whether interventions improve microvascular function. Nitric oxide (NO) synthase (NOS) is a major player in mediating cutaneous thermal hyperaemia. We recently reported that ATP-sensitive K+ (KATP) channels are involved in cutaneous vasodilatation occurring during whole-body heating, though it remains to be determined if these channels also contribute to cutaneous thermal hyperaemia. In the present study, we tested the hypothesis that the NOS-mediated elevation in NO activates KATP channels, partly mediating the cutaneous thermal hyperaemia response during local heating to 42ºC in young adults.

Method: In thirteen young adults (7 men and 6 women), cutaneous vascular conductance (CVC, laser-Doppler signal/mean arterial pressure) was measured at four intradermal microdialysis sites that were continuously perfused with either 1) lactated Ringer (Control), 2) 5 mM glybenclamide (KATP channel blocker), 3) 20 mM Nω-Nitro- L-arginine methyl ester (NOS inhibitor), or 4) a combination of glybenclamide and Nω- Nitro-L-arginine methyl ester. Local skin heating to 42ºC and subsequent administration of 1.25 mM Pinacidil (KATP channel opener) or 25 mM sodium nitroprusside (NO donor) were applied to all four skin sites.

Results: Glybenclamide attenuated the local-heating induced increase in CVC relative to the Control site, but this response was not observed in the presence of NOS inhibition. Pinacidil caused an elevation in CVC, but this response was abolished at the skin site treated with glybenclamide, demonstrating the effectiveness of glybenclamide as a KATP channel blocker. The pinacidil induced increase in CVC was unaffected by NOS inhibition, whereas the increase in CVC elicited by sodium nitroprusside was partly inhibited by glybenclamide.

Conclusions: We show that the NOS mediated increase in NO activates KATP channels, partly underlying the cutaneous thermal hyperaemia response in young adults.

Does alpha adrenergic receptor blockade modulate sweating during incremental exercise in habitually trained men?

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Introduction: Human eccrine sweat glands respond to intradermal administration of ⍟⍟ adrenergic receptor agonists. However, whether α adrenergic receptors functionally contribute to sweating during exercise remains to be determined.

Method: Twelve endurance trained men performed two incremental cycling until exhaustion on separate days. Bilateral forearm sweat rates (ventilated capsule) were measured at two skin sites that were transdermally administered via iontophoresis with either 1% terazosin (⍟1 adrenergic receptor antagonist, visit 1) or 1% phentolamine (α_1 and α_2 adrenergic receptors antagonist, visit 2) as well as saline (Control) at the opposite arm. Follwoing 10-20 min of postexercise recovery period wherein increased sweat rate returned back to baseline level, 0.25% phenylephrine (α_1 adrenergic receptor agonist) was iontophoretically administered to confirm the blockade of α_1 adrenergic receptor.

Results: Administration of terazosin did not affect sweat rate relative to the Control site during incremental exercise (interaction, $P = 0.848$). Postexercise administration of phenylephrine increased sweat rate at the Control site (0.07±0.08 mg cm^{-2} min^{-1}), which was suppressed by 81% at the terazosin-treated site (0.01±0.02 mg cm^{-2} min^{-1}) ($P = 0.026$). Sweat rate was increased at the phentolamine-treated site at the end of incremental exercise relative to the Control site (0.85±0.35 vs. 0.68±0.36 mg cm^{-2} min^{-1}, $P = 0.033$). Phenylephrine-induced sweating was attenuated by 87% at the phentolamine- treated site relative to the Control site after the exercise (0.06±0.06 vs. 0.01±0.01 mg cm^{-2} min^{-1}, $P = 0.008$).

Conclusions: α_1 adrenergic receptors located at sweat glands do not contribute to sweating during incremental exercise in habitually trained men. Results from phentolamine administration combined witht the fact that α_1 adrenergic receptos do not modulate sweating during exercise, implied that α_2 adrenergic receptors located at the noradrenergic nerve terminals may suppress sweating during exercise (e.g., inhibits the release of noradrenaline).

Development of a New Moisture Management Test Method to Mimic Sweating Phenomena from a Single Sweat Gland

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Typical liquid moisture management property tests of textiles such as vertical wicking test (AATCC 197) and moisture management test (AATCC 195) are conducted with infinite reservoirs or limited, but large amounts of liquid. Therefore, those methods may not represent human sweating circumstances with continuous microfluidic flow from sweat pores. Even though a fabric received a favourable evaluation from these typical wicking tests, we cannot be sure the fabric would remove sweat well in realistic physiological sweating conditions. In terms of textile structures, typical wicking tests could not explain how yarn-level wicking plays a role within the fabric, even though liquid transport in the void space between the fibers within a yarn (or between yarns) is known as the most critical phenomenon in fabric wicking.

For this reason, we developed a new method called 'Single Point Source Wicking within Fabric' to investigate how liquid is transported in fabrics based on within-yarn and yarn-to-yarn transfer wicking. This measurement system was conducted by supplying continuous liquid flow to a single yarn within the fabric at a similar flow rates to a single sweat gland (approximately 50 nl/min/gland). In order to mimic the sweating phenomenon, this single point source method avoided the flooding liquid stage by controlling flow rate and choosing a diameter of liquid source similar to sweat gland pore size.

From microscope video analysis, we quantitatively evaluated the wicking phenomena of fabrics. We successfully measured directional wicking rates and individual yarn wicking performance, which has not previously been shown. The realistic point source sweat rates provided very different wicking results than were observed from standardized tests. A better understanding of wicking performance with this new method promises to provide a predictive model of textile wicking and should allow to improve physiological comfort of fabrics for sportswear, military apparel and personal protective equipment.

Revisiting the hemihidrotic, sudomotor reflex

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Introduction: Posture-induced reductions in sweating from the lower, along with concurrent sweating elevations from the upper skin surfaces, have been described during lateral recumbency. This is known as the hemihidrotic reflex, which is also reported to accompany localised, lateral pressure applications. Since sudomotor inhibition in heated individuals elevates heat storage, then more pronounced sweating from untreated regions would be expected. Therefore, we examined that reflex in isothermally clamped, but mildly hyperthermic individuals.

Method: Pre-heated, thermally clamped males participated in supine (N=12) and seated trials (N=12). In each trial, pressures were applied (5 min, 10 cm^2) to the left side of the chest (6 $N.cm^{-2}$) and the left heel (3 $N.cm^{-2}$). Sudomotor activity was measured (ventilated capsules) from the left forehead, left dorsal hand, left and right medial chest, left and right lateral abdomen and the left calf.

Results: Sweating was reduced at the ipsilateral forehead, hand and chest during the supine pressure application to the chest (P<0.05). However, sudomotor enhancement was not observed from any contralateral surface (P>0.05). Heel-pressure applications when seated did not elicit any ipsilateral responses (P>0.05), but when supine, excitatory effects were seen across all spinal segments (P<0.05).

Conclusions: As a consequence, the universal acceptance of the hemihidrotic reflex can no longer be sustained, although pressure-induced inhibitory influences were apparent. That inhibition is believed to result from a spinal reflex that commences with cutaneous mechanoreceptor activation. The resulting sensory feedback enters the spinal cord (dorsal root ganglia) and ascends ipsilaterally (dorsal columns). Segmental variations in the pressure-dependent sudomotor inhibition are possibly mediated by interactions between those afferents and descending sympathetic neurones. However, unilateral inhibition was only apparent upstream of the pressure application, possibly as a segment-specific reflex. That mechanism cannot explain the heel-pressure responses, which might have arisen as an adaptation to bipedal locomotion.

Evidence for the existence of multiple hypothalamic controllers of thermoeffector function

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Introduction: In this presentation, three sources of evidence will be reviewed to evaluate the possibility that the mammalian thermoeffectors (thermogenesis, cutaneous vasomotor activity and thermolysis) are under independent, central nervous system control.

Method: The first, perhaps circumstantial, evidence will be drawn from the evolution of reptiles, monotremes and the Old World monkeys, apes and humans. Secondly, neurological evidence gathered from rodents will be presented, commencing with the early hypothalamic ablation experiments. Finally, a comprehensive series of human experiments will be described, in which the critical temperature (threshold) for each thermoeffector was determined in thermoneutral and thermally pre-conditioned (pre- heated and pre-cooled) individuals.

Results: The phylogenetic evidence revealed a sequential acquisition of those effectors across the animal *phyla*, over millions of years. Ablation studies first demonstrated that hypothalamic microcuts could deactivate one thermoeffector, whilst the others remained effective. Recent human experiments revealed that the lower and upper critical temperatures for the vasomotor zone differed from those of the inter-threshold zone. Moreover, those thresholds were found to move independently of one another following thermal pre-conditioning.

Conclusions: Critical (mean) body temperatures for the activation of human thermoeffectors were neither unitary points, nor were they fixed. Instead, they represented unique and adjustable thresholds. Shifts in the vasomotor and thermogenic thresholds appeared to depend upon changes in mean body temperature. Following whole-body pre-cooling, the vasomotor and sudomotor thresholds varied independently, and in opposite directions. Those outcomes are interpreted to signify the presence of independent central controllers for the vasomotor and sudomotor responses, and possibly also for thermogenesis. Such a conclusion is consistent with the phylogenetic acquisition of those thermoeffectors, and also with neurological evidence obtained from animal studies.

Elite populations and preparation for Tokyo 2020

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Exercise-heat acclimation induces physiological adaptations that improve thermoregulation, attenuate physiological strain, reduce the risk of serious heat illness, and improve aerobic performance in warm-hot environments. The heat acclimation phenotype is generally achieved through four broad induction pathways: constant work rate exercise, self-paced exercise, controlled hyperthermia or isothermic heat acclimation, and the controlled heart rate approach. A key question for elite athletes regarding the implementation of heat training is when to schedule it in the overall training program, and in particular ahead of competing in the heat. Indeed, elite athletes adhere to regimented training programs and traditional heat acclimation regimens require manipulation to ensure that heat exposures are properly programmed into the training cycle, in order to result in optimal benefits. It is therefore imperative to explore the ways in which heat acclimation regimens can be modified (e.g. fragmented and/or combined) to ensure that elite athletes adapt through carefully implemented regimens.

Mixed active and passive, heart rate-controlled heat acclimation is effective for Paralympic and able-bodied triathletes

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Introduction: Given the popularity of the Paralympic Games, surprisingly few studies have examined the effectiveness of heat acclimation (HA) for Paralympic athletes thus little information exits regading adaptation differences to able-bodied (AB) athletes. Therefore, the aim of the study was to investigate the efficacy of a novel HA protocol for Paralympic and AB triathletes.

Method: Seven elite paratriathletes and thirteen AB triathletes undertook an 8-d HA intervention consisting of five, HR-controlled sessions and three passive heat exposures (35°C, 63% relative humidity). On the first and last day of HA, heat stress tests were conducted whereby thermoregulatory changes were recorded at a fixed, submaximal workload. The AB group undertook 20 km cycling time trials pre- and post-HA with performance compared to an AB, non-acclimated control group.

Results: In both groups, HA resulted in lower core temperature (~0.3°C), blood lactate concentration (~0.3 mmol·l^{-1}), and perceptual improvements with concomitant plasma volume expansion (6.2-12.7%) ($p \leq 0.047$). In the HA group, a lower skin temperature (0.58°C) and HR (5 bpm) with a greater sweat rate (0.17 l·h-1) was evident post-HA ($p \leq 0.045$) but this was not present for the paratriathlon group ($p \geq 0.177$). The AB group improved their performance by an extent greater than the smallest worthwhile change based on the normal variation present with no HA (4.5 vs. 3.7%).

Conclusions: Paratriathletes are capable of displaying partial HA, albeit not to same extent as AB triathletes. The HA protocol used was effective at stimulating thermoregulatory adaptations with performance changes noted in AB triathletes.

Adaptation to the heat using short-term acclimation with dehydration in matched females and males

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Introduction: Short-term heat acclimation (STHA) with dehydration, has been reported to improve adaptations and performance during heat exposure but have tended to use male participants. Therefore, the aims of this work were to investigate STHA over 5-days (permissive dehydration), using the controlled-hyperthermia technique, with a matched female and male cohort.

Method: Ten, moderately-trained, females (Mean [SD]; age 22.6 [2.7] y; stature 165.3 [6.2] cm; body mass 61.5 [8.7] kg; VO_2 peak 43.9 [8.6] $mL \cdot kg^{-1} \cdot min^{-1}$) and ten males (Mean [SD]; age 25.6 [8.9] y; statureb180.7 [5.6] cm; body mass 83.2 [10.8] kg; VO_2 peak 45.3 [6.5] $mL.kg^{-1}.min^{-1}$) participated in a STHA programme. This 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 [Tre] 38.5°C). A number of blood plasma constituents were measured: percent plasma volume (%PV), aldosterone, total protein, albumin, Na^+, K^+, Cl^-, cortisol and HSP70. Pre and post STHA, a gender-specific, heat stress test (HST) (35°C; 50%rh) was performed consisting of 45-mins of intermittent exercise and a repeated, maximal sprint performance test. The HST was specific to exercise intensities of professional football players for females and males.

Results: Pre vs post HST there was a reduction in Tre at 45-min in females by -0.20°C (95%CI -0.30 to -0.05°C; P=0.01; ES=1.13) and males (-0.20: -0.40 to -0.05°C; P=0.03; ES=-0.56). Cardiac frequency decreased in females by -3 $b \cdot min^{-1}$ at 45-min (-10 to 3 $b \cdot min^{-1}$; P=0.06, ES= 0.64) and males (-3: -5 to -1 $b.min^{-1}$; P=0.01; ES=-0.20). In females there was an increase in mean average power across maximal sprints by 56W (-26 to 139W; P=0.03; ES=0.69) and males (87: -8 to 182 W; P=0.05; ES=0.52).

Conclusions: 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 for matched females and males.

Examining the effects of short-term heat acclimation on markers of thermotolerance in young and older healthy adults

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Introduction: Heat acclimation (HA) reduces the thermoregulatory stress and consequently delays the risk of heat illness during heat stress. Evidence suggests heat shock proteins (HSPs) are contributors to heat adaptation at a physiological and cellular level and are key markers of thermotolerance. Specifically, Hsp72 and Hsp90α have been used as markers of the cellular response to stress The aim of this study was to explore the effect of short-term heat acclimation (STHA) on leukocyte Hsp72 and Hsp90α mRNA response in the elderly population compared with young individuals.

Method: Nine, active younger (Y) individuals (Mean [SD]; age 22.2 [1.9] years; height 177 [0.05] cm; mass 75.4 [11.47] kg; 1 female) and six, active older (O) individuals (age 66.7 [2.6] years; height 178 [0.07] cm; body mass 76.8 [9.55] kg; 6 males) completed five consecutive days of HA in 35°C/50% R.H. The STHA protocol increased resting rectal temperature (Tre) by 1.5°C or to 38.5°C within the first 60mins and subsequently maintained Tre for a further 60mins. Leukocyte Hsp72 and Hsp90α mRNA responses assessed using reverse transcription polymerase chain reaction (RT-QPCR) were determined within and between the first and final day of HA, with comparisons made between groups using ANOVA.

Results: Resting Tre and heart rate (HR) showed no improvements after STHA in the O group (+0.20±0.21°C, 1±9 b.min^{-1}) but did so in the Y group (-0.21±0.29°C, -6±10 b.min^{-1}). Thermal sensation decreased in O (-0.3±0.4) and Y (-0.3±0.4) with a significant change only in Y ($p<0.05$). Thermal comfort did not change in the O group (0±1) but decreased in the Y group (1±1). Changes in Hsp72 and Hsp90α mRNA transcription in response to each session in the older and younger group is currently being analysed.

Conclusions: STHA appears less effective in active older individuals compared younger participants given reduced phenotypic adaptation.

Glucose metabolism in overweight men improves after passive heat acclimation

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Introduction: It has been suggested that certain thermal conditions might have positive implications for metabolic and cardiovascular health. Acute heat exposure has been suggested to enhance glucose metabolism, possibly via an increase of heat shock protein 72 (HSP72) in muscle. This study investigated the effect of a 10-day passive heat acclimation (PHA) intervention on glucose metabolism, thermophysiological and cardiovascular parameters, and muscle HSP72 levels in an overweight population.

Method: 11 overweight men (65.7±4.9y, BMI 30.4±3.2kg/m^2) underwent PHA (10d, 34.4±0.2˚C, 4-6h/d). Pre- and post-PHA, fasting plasma glucose and insulin samples were collected to assess glucose metabolism. A temperature-ramp-protocol (28.8±0.15˚C to 41.3±0.33˚C, 10K/h) was conducted to assess thermophysiological parameters (core temperature, mean arterial pressure [MAP] and heart rate), before and after PHA. To assess HSP72-levels, muscle biopsies were taken before and after PHA.

Results: Fasting plasma glucose (FPG), fasting plasma insulin (FPI) as well as core temperature (Tcore) decreased significantly after PHA (ΔFPG: -0.27 mmol/L, p=0.036; ΔFPI: -12.69 pmol/L, p=0.026; ΔTcore: -0.17±0.19˚C, p=0.017). Also, MAP decreased (ΔMAP -2.91±2.67 mmHg, P=.007) and heart rate tended to decrease (Δ -2.98±3.50bpm, P=0.065) post-PHA. Mean HSP72 levels in muscle did not change significantly.

Conclusions: Core temperature decreased after passive heat acclimation, confirming the effectiveness of the applied acclimation protocol. We show that passive heat acclimation beneficially affects glucose homeostasis, denoted by changes of fasting plasma glucose and insulin levels. Reduced mean arterial pressure and heart rate indicate that heat may positively affect cardiovascular health. HSP72 in muscle was not affected by this heat acclimation protocol. Together, results encourage further research to explore the underlying mechanisms.

Differential effects of short-term heat acclimation on whole-body heat loss in middle-aged males with and without type 2 diabetes

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Introduction: Aging reduces whole-body evaporative heat loss (EHL) and exacerbates body heat storage in middle-aged compared to young adults during exercise-heat stress. This maladaptive response is worse in middle-aged individuals with type 2 diabetes (T2D). While short-term heat acclimation can enhance heat dissipation in middle-aged adults, it remains unclear if the magnitude of improvement differs in individuals with T2D.

Methods: We therefore used direct calorimetry to assess EHL prior to (day 0) and following (day 8) seven days of heat acclimation (90-min cycling at 50% peak aerobic power ($\dot{V}O_2$peak)) in dry-heat (40°C, 20% relative humidity) in middle- aged (mean±SD; 60±6 years), physically active ($\dot{V}O_2$peak: 35.2±6.5 $mL \cdot kg^{-1} \cdot min^{-1}$) males with (n=8, HbA1c: 6.9±1.0%, duration of T2D: 10±7 years) and without (Control, n=10) T2D matched for age and $\dot{V}O_2$peak. On days 0 and 8, participants performed three 30- min bouts of cycling at metabolic heat productions of 150 (light), 200 (moderate) and 250 $W \cdot m^{-2}$ (vigorous) (equal to 37±6, 49±8, and 61±9% of $\dot{V}O_2$peak, respectively), each followed by 15-min recovery, in dry-heat (40°C, 15% relative humidity).

Results: EHL increased following acclimation in T2D (day 0 vs. day 8; light: 179±25 vs. 192±22 $W \cdot m^{-2}$, moderate: 216±25 vs. 239±25 $W \cdot m^{-2}$, vigorous: 242±29 vs. 279±27 $W \cdot m^{-2}$; all $P<0.05$) and Control (light: 185±11 vs. 198±21 $W \cdot m^{-2}$, moderate: 237±16 vs. 254±16 $W \cdot m^{-2}$, vigorous: 276±26 vs. 294±19 $W \cdot m^{-2}$; all $P<0.05$). The magnitude of that increase was similar between groups during light and moderate exercise (both $P>0.05$), averaging 7±7% and 9±5% across groups, however it was greater for T2D during vigorous exercise (Control: 7±6%; T2D: 16±7%, $P=0.01$).

Conclusions: Our preliminary findings demonstrate that the magnitude of improvement in whole-body EHL during a short 8-day heat acclimation intervention is greater in middle-aged males with well-controlled T2D compared to their healthy counterparts during vigorous exercise in the heat.

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Dosed intensity of heat strain for adaptation in passive heat acclimation

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Rationale

Passive heat acclimation (HA, without exercise) elicits cardiovascular, thermoregulatory and muscular adaptations, and can be especially useful for those with limited exercise capacity. Such people may be less tolerant of heat-strain intensities that typify HA (core temperature (Tc) >38°C). Cardiovascular adaptations are key aspects of HA, and cardiovascular responses to heating saturate at modest heat strain. The purpose of this study was to further identify the heat-strain dose:adaptation relations of thermoregulatory and cardiovascular adaptations to passive HA.

Methods

Nine recreationally-active participants (23 ± 4 y; 4 female) completed three spa-bath HA regimens in cross-over fashion: Tc was clamped at baseline in water (NEUT) on six days, or elevated by +0.75 °C (WARM) or +1.5 °C (HOT) on nine days. Exposures were 60-min·d^{-1} immersed in water, with thermal strain controlled using depth and water temperature (36.5, 38.5 and 40.5 °C). A heat stress test was conducted on days 1, 5, and 9 in WARM and HOT, and one week prior and on day 6 for NEUT; involving nipple-depth immersion in 40 °C water. Regimens were 6-wk apart.

Results

No dose effect was evident for the adaptation in resting plasma volume or stressed heart rate, sweat rate, thermal sensation, discomfort or affect (interactions: $p = 0.11$ to 0.98). For example, the expansion in resting plasma volume ($p < 0.01$) was similar ($p = 0.98$) across HOT (3 ± 7%), WARM (3 ± 4%) or NEUT (3 ± 6%). Resting Tc was reduced ($p < 0.01$) but not reliably more across HOT (-0.25 ± 0.16 °C) than WARM (-0.19 ± 0.16 °C) or NEUT (-0.03 ± 0.21 °C, $p = 0.11$).

Conclusion

There was minimal evidence to show greater heat dose led to greater adaptation during passive HA.

Daily cold-water recovery may impair training load tolerance during short-term heat acclimation

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Introduction: Currently, there is limited understanding of the effects of heat acclimation (HA) on perceptual training load (TL) or the interaction with common thermal recovery strategies. This study aimed to examine the effects of daily cold- and hot-water recovery on perceived TL during short-term HA training.

Methods: Eight healthy, trained males undertook 5-days of cycle training for 60 min in four different conditions, using a block counter-balanced order design. Three conditions were completed in the heat (35 °C) and one in a thermoneutral environment (24 °C, CON). Each day after cycling at 50% peak power output (PPO), participants' completed recovery 20 min seated rest (CON and HA), cold- (14 °C; HACWI) or hot-water immersion (39 °C; HAHWI). Heart rate, rectal and skin temperature, and rating of perceived exertion (RPE) were collected during training. Session RPE (sRPE) was collected after training for the determination of perceived TL. Data was analysed using Bayesian hierarchical regression, Cohens *d* was calculated, and for perceived TL, the probability that *d* >0.5 was also computed.

Results: Bayesian analysis showed evidence of increased perceived TL in HACWI compared to HA on days 3–5 (*d*=2.26-2.69). The probability that the *d* >0.5 for days 3, 4 and 5 were 0.98, 0.98 and 0.96, respectively. There was evidence that the increased perceived TL coincided with a greater exercise heart rate (3–8 b·min^{-1} higher; *d*=2.34-3.00) and higher RPE on days 4 (*d*=2.46) and 5 (*d*=2.27). There was little evidence that hot-water altered perceived TL or heat adaptation.

Conclusion: Daily cold-water recovery increases perceived TL, interefers with heat adpatation, and impairs TL tolerance during 5-days of fixed-intensity HA, and hot-water immersion provides no additional benefit. Considerations for the effects of thermal recovery strategies on TL are required when implementing to avoid counteracting the desired HA outcomes.

Short-term heat acclimation training enhances knee extensor strength and improves cycling performance in hot conditions

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Introduction: The redistribution of blood flow from splanchnic regions during exercise in the heat may compromise gastrointestinal permeability and facilitate endotoxin leakage. Subsequent inflammatory responses are suggested to cause neuromuscular fatigue. This study examined the protective neuromuscular and inflammatory effects of short-term heat acclimation (HA) on cycling performance in the heat.

Methods: Eight recreationally-trained males completed a 5-day cycling training block (60 min·day^{-1} at 50% Pmax) in hot (HA: 35±1 °C, 53±4% relative humidity (RH)) and thermoneutral (CON: 22.2±2.6 °C, 65±8% RH) conditions using a randomised cross-over design. Pre- and post-intervention TT's were completed in the heat. Neuromuscular assessment of the knee extensors was completed pre- and immediately after the TT's and on the first and last day of each training block. Blood samples were also collected at these same time points and analysed for endotoxins, inflammation and markers of gut damage. Data were analysed using Bayesian hierarchical regression, and Cohens *d* effect sizes were also calculated.

Results: Statically faster TT completion times was apparent after HA compared to CON (MD=55s [11, 98], *d*=2.51 [0.49, 4.46]). While pre- to post-intervention improvements were observed in HA (MD=62s [18, 104], *d*=2.86 [0.82, 4.75]), no clear difference was seen in CON (MD=30s [-6, 67]). Interestingly, knee extensor strength increased with HA but declined in CON. Further, despite the faster post-intervention HA TT performance, no difference was found for central fatigue, circulating endotoxin levels, inflammation, or markers of gut damage between conditions.

Conclusion: Short-term HA training improves subsequent 20TT cycling performance in the heat by 2.9% [0.8-4.9] without an associated increase in intestinal damage or inflammation. These findings suggest that short-term HA training may be a time-efficient training method to improve neuromuscular function and cycling performance in hot conditions.

The Physiological and Perceptual Adaptations to an Isothermic Short and Medium-Term Heat Acclimation Protocol

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Introduction: The aim of the present study was to investigate the effect of short-term (STHA) and medium-term (MTHA) isothermic-controlled (ISO_{CON}) heat acclimation (HA) on the physiological and perceptual responses to exercise heat stress.

Methods: Sixteen, non-heat acclimated, endurance runners visited the laboratory on 13 occasions. A heat stress test (HST) was completed on the 1st (HST1), 7th ($HST2_{STHA}$) and 13th ($HST3_{MTHA}$) visit. During each HST participants cycled at 40% VO_{2max} for 45 min in the heat (40 °C, 50% relative humidity). Participants completed 5 consecutive days of a 60 min active ISO_{CON} HA protocol (40 °C, 50% relative humidity; target T_{re} 38.5°C) between HST1 and HST2-STHA and 5 more between $HST2_{STHA}$ and $HST3_{MTHA}$. Heart rate (HR), rectal temperature (T_{re}), perceived exertion (RPE) and thermal perceptions (TS, TC) were recorded every 5 min. Expired air was collected using the Douglas bag method at 15, 30 and 45 min.

Results: STHA and MTHA lowered resting (STHA: -0.38 ± 0.26°C; MTHA: -0.40 ± 0.26°C) mean (STHA: -0.36 ± 0.26°C; MTHA: -0.52 ± 0.26°C), and peak (STHA: -0.39 ± 0.64°C; MTHA: -0.59 ± 0.38°C) T_{re} ($P<0.05$). Resting ($P=0.84$), mean ($P=0.07$), and final ($P=0.16$) T_{re} were similar in $HST2_{STHA}$ and $HST3_{MTHA}$. Mean resting HR was similar in HST1 compared to $HST2_{STHA}$ ($P=0.08$) but was higher than $HST3_{MTHA}$ ($P=0.04$). HR increased throughout all trials, with an overall mean HR higher in HST1, compared to $HST2_{STHA}$ and $HT3_{MTHA}$. In all HSTs perceptual measurements increased, with the highest perceptual strain in HST1 compared to $HST3_{MTHA}$ ($P<0.001$). Reductions in VO_2 (2.2 ± 0.8; 1.7 ± 0.1), VCO_2 (1.8 ± 0.1; 1.3 ± 0.7) and RER (0.8 ± 0.1; 0.7 ± 0.1) were revealed when comparing HST3 to HST1.

Conclusion: An active, ISO_{CON} STHA and MTHA protocol was successful at reducing the thermoregulatory, cardiovascular, and perceptual strain experienced when exercising in the heat.

10-day Heat Acclimation Using a Water-perfused Garment Post-exercise

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Introduction: Little research investigated benefits of further elevating core temperatures using a heating garment after exercise for HA. This study aimed to explore changes in physiological and perceptual responses after a 10-day HA program with a water-perfused skin heating suit after exercise.

Method: Twelve males were randomly assigned to either the control HA (HAEXE; N=6) or post-exercise HA (HAEXE+SUIT; N=6) group. Before (PRE) and after (POST) participating in the HA program, subjects were exposed to a Tair of 33^{o}C and 60%RH immersing legs in 42^{o}C water for 1-hour as a heat tolerance test. The HA program involved 10 consecutive days of 2-hour exposure to a Tair of 33^{o}C and 60%RH. HAEXE finished 1-hour treadmill exercise (6km/h) followed by a 1-hour seated rest. HAEXE+SUIT conducted the same 1-hour exercise and then were dressed in the developed water- perfused suit which heated the chest, abdomen, upper and lower back, thigh with 44.2^{o}C water, to complete 1-hour post-exercise HA program.

Results: During the 10 days, increases in Tre during exercise were 1.06±0.19^{o}C and 0.97±0.17^{o}C for HAEXE and HAEXE+SUIT respectively, with no significant difference. 1-hour additional skin heating using the water-perfused suit further increased Tre by 0.54±0.15^{o}C in HAEXE+SUIT whereas Tre decreased by 0.40±0.12^{o}C in HAEXE during rest (P<0.001). HR for HAEXE+SUIT significantly decreased in POST (PRE: 90±4 bpm; POST: 82±4 bpm) (P<0.01). Body mass loss (PRE: 3.25±0.62 g/h/kg; POST: 4.12±0.82 g/h/kg, P<0.01), chest (PRE: 0.09±0.08 g/h/cm^2; POST: 0.17±0.11 g/h/cm^2, P<0.01) and forearm local sweat rates at the end of the immersion (PRE: 0.42±0.13 mg/cm^2/min; POST: 0.62±0.20 mg/cm^2/min, P<0.05) significantly increased in POST only for HAEXE+SUIT. In both groups, systolic blood pressures dropped, subjective responses were improved and no significant differences in Tre were found.

Conclusion: Post-exercise skin heating using the water-perfused suit better induced HA than when only the active HA strategy was applied.

Thermal cardiac reactivity and Q10 effect related to heat acclimation

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Introduction: Heat acclimation (*HA*) is an essential modifier of the physiological strain when working in the heat. It is unknown whether *HA* influences the increase of energy expenditure (*Q10* effect) or heart rate (thermal cardiac reactivity *TCR*) due to increased body temperature.

Method: We studied these questions using a heat stress database of climate chamber exposures performed by 5 young males in either non-acclimated or acclimated state. Measured oxygen consumption rates ($\dot{V}O2$), heart rates (*HR*) and rectal temperatures (*Tre*) averaged over the third hour of each exposure were obtained from 273 trials organized in 10 series (5 persons x 2 states of acclimation). While workload (walking at the level, 4 km/h) and clothing (predominantly *Icl* 0.1) were kept for all series, heat stress conditions varied widely (*ta* 25-55 °C, *pa* 0.5-5.3 kPa, *va* 0.3-2 m/s, *tr=ta*). *HA* was induced by repeated exposures over a minimum of three weeks in a way that the subjects could sustain three hours of heat exposure reaching a *Tre* of 38.5 °C. Non acclimated exposures were done in wintertime with a maximum of two exposures per week. The influence of *Tre* and *HA* on $\dot{V}O2$ and *HR* was analyzed separately with mixed model ANCOVA.

Results: Rising *Tre* increased significantly ($p<0.01$) both $\dot{V}O2$ (by about 7 % per degree increase of *Tre*) and *HR* (by 38-40 bpm per degree *Tre*); neither slope nor intercept depended significantly on *HA* ($p>0.1$).

Conclusions: The effects of *Tre* in this study agree with former outcomes for $\dot{V}O2$ (an increase of 7 % corresponds to a *Q10* factor around 2) and for *HR* (*TCR* of 33 bpm/°C in ISO 9886). Our results indicate that both relations are independent of *HA*; this may be important when assessing physiological strain at workplaces (e.g. ISO 8996 or ISO 9886) and for modeling heat balance.

Impact of cold exposure on individuals with clinical disease: cardiovascular diseases, cold exposure and exercise

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Both acute and prolonged cold exposure affect cardiovascular responses, which may be modified by an underlying cardiovascular disease. These can lead to a higher amount of cardiac symptoms, as well as adverse events during the cold season. Exercise in a cold environment increases cardiovascular strain further, and potentially also health risks, but its effects among persons with cardiovascular diseases are not well known.

Controlled studies employing whole-body or local cold exposure demonstrate comparable or augmented increase in cardiac workload, but aggravated cutaneous vasoconstriction in persons with mild hypertension (HTN). So far, it is not known how exercise modifies cardiovascular responses among persons with HTN. Cold exposure reduces myocardial oxygen supply in coronary artery disease (CAD), possibly leading to ischemia. Simultaneously, exercise in cold augment cardiac workload in persons with CAD more than in a neutral environment. This can lead to earlier ischemia, angina and impaired performance. Also having a heart failure (HF) impairs submaximal and maximal performance in the cold.

Antianginal medication is beneficial in the cold for lowering blood pressure, but does not affect the magnitude of cold-related cardiovascular responses in HTN. Cardioprotective medication also reduces the risk for ischemic sudden deaths due to cold. Similarly, the use of blood pressure lowering drugs improves exercise performance in cold both among persons with CAD and HF. Finally, also protection of the head region lowers blood pressure increase in cold.

Both the acute and seasonal effects of cold and added with exercise may contribute to the higher morbidity and mortality of those with cardiovascular diseases. Yet, more studies are warranted for understanding the pathophysiological mechanisms underlying the adverse cold- related health effects.

Impact of cold exposure on individuals with clinical disease: respiratory responses to cold exposure

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Cold dry air can have several effects on the respiratory system, especially in individuals with chronic lung diseases. Asthma is a chronic inflammatory airway disease characterized by repeated episodes of wheezing, coughing and breathlessness, and the global prevalence of doctor-diagnosed asthma in adults has been reported to be 4.3%, with wide differences between countries. Exercise-induced asthma (EIA) is present in up to 90% of all individuals with asthma, and the cold, dry air during the winter months is particularly conducive to the development of EIA in susceptible individuals.

Asthma rates vary widely among sports, and both the type of exercise and the environment influence the severity of EIA in the individual asthmatic athlete. The main determinants of the bronchoconstrictor response to exercise are intensity (minute ventilation), the temperature and humidity of the inspired air, and baseline airway reactivity. Invasive studies have found pathological changes in airway mucosa that suggest airway remodelling, indicating that hyperventilation of cold, dry air represents a significant stress to the airways that could lead to asthma. Occupational studies indicate that prolonged exposure to cold air may induce a chronic asthma-like condition, even in healthy subjects.

EIA should be treated in athletes according to the same principles as in ordinary asthma patients. Competitive athletes must also consider doping control issues, since not all antiasthmatic medications are approved by the World Anti-doping Agency. The severity of EIA can also be reduced by raising the temperature and humidity of the inspired air, and heat-exchanging masks and devices have been developed for this purpose.

Impact of cold exposure on individuals with clinical disease: impact of cold acclimation on glucose- and lipid metabolism in type 2 diabetes mellitus

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The number of people with type 2 diabetes mellitus (T2DM) is increasing worldwide. This metabolic disorder is characterised by reduced insulin sensitivity, leading to a negatively affected glucose and lipid metabolism. Because of this deranged metabolism, patients with T2DM have an increased risk of developing cardiovascular disease. Prolonged cold exposure with correspondingly increased energy expenditure could be used to improve insulin sensitivity and the disrupted metabolism in T2DM.

Mild cold exposure, both acute and prolonged, can increase non-shivering thermogenesis via activation of brown adipose tissue (BAT) and skeletal muscle (SM). The activation of these tissues increases insulin sensitivity, for instance by changing glucose transport characteristics of skeletal muscle (Glucose transporter (Glut4) translocation).

Cold exposure can also improve lipid metabolism, via an increased uptake and combustion of lipids such as fatty acids and triglycerides. These combined effects of regular cold exposure therefore decrease insulin resistance and reduce the risk of cardiovascular diseases in patients with T2DM.

With the use indirect calorimetrics, hyperinsulinemic euglycemic clamp techniques and high-fat meal tests, we aim to further unravel these effects of cold exposure in human metabolism. Currently we are focusing on the effects of acute mild cold exposure on lipid metabolism and the role of BAT and SM activation in clearing lipids from the blood stream.

A patient-centred evaluation of thermal resilience practices in temperature- sensitive people with Multiple Sclerosis

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Introduction: Multiple sclerosis (MS) is neurodegenerative disease characterised by temperature sensitivity, where changes in body temperature induce transient symptoms worsening. There is no pharmacological intervention for this condition and patients often develop their own thermal resilience practices. Yet, there is no formal evaluation of the variety and perceived effectiveness of those practices. The aim of the study was to survey the experience of temperature sensitivity and the individual strategies used to combat it, in MS.

Method: 458 people with MS (58.7% relapsing-remitting; 20.7% secondary-progressive; 14% primary-progressive; 6.6% unknown) completed an anonymous online survey. The questionnaire comprised sections aimed at characterizing participants' general medical history; the symptoms worsening as a result of heat or cold, and thermal resilience techniques for heat and cold sensitivity.

Results: Overall, 53% of responders reported suffering from heat sensitivity, 15% from cold sensitivity, and 32% from both. Fatigue (79%), weakness (60%) and balance difficulties (56%) were prominent heat-induced symptoms. Muscle cramping (43%), fatigue (40%) and poor walking (36%) were prominent cold-induced symptoms. Participants reported exercise (91%) and long periods of inactivity (92%) as the greatest triggers of heat and cold sensitivity, respectively, that affects their MS symptoms. The most common thermal resilience practices in the heat were wearing lightweight, loose, breathable clothing (95%) and using fans (91%) ($p<0.01$), whereas wearing layers of clothes (93%) and staying in a heated environment (91%) ($p<0.01$) were commonly adopted to combat cold sensitivity.

Conclusions: Temperature sensitivity in MS worsens quality of life and disease management. The patient-centred information presented here will help guiding evidence-based interventions and investigations that are individually tailored to the specific experiences of temperature-sensitive people with MS.

Age differences in cardiac autonomic modulation during intermittent exercise in the heat

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Introduction: Heat exposure is associated with higher morbidity and mortality among older individuals. This can in part be attributed to age-related impairments in heat dissipation. While the mechanisms underlying this maladaptive remains unclear, age-related differences in cardiac autonomic function may play an important role. Thus, this study aimed to detect potential differences in heart rate variability (HRV) during a moderate-intensity intermittent exercise in the heat among young (25.8±1.9 years), middle-aged (43.5±2.8 years), and older (62.9±3.7 years) men.

Method: Thirty-three participants (11 per group) performed four successive bouts of 15-min cycling at a moderate fixed rate of metabolic heat production at ~400 W; each separated by a 15-min recovery with 1 hour of final recovery in a hot and dry environment (35°C, 20% relative humidity). Twelve HRV indices (e.g. low and high frequency power, Shannon Entropy, and others) characterizing common domains of variability and complexity of heart rate were computed and assessed at baseline resting, end of each successive exercise and recovery cycle and final 1-hour recovery.

Results: Cardiac autonomic modulation during intermittent exercise in the heat, as well as during resting and recovery was significantly affected by age, as changes were observed among the three different aged groups in five indices ($p \leq 0.05$). Similarly, time influenced cardiac autonomic modulation as three indices showed changes across time ($p \leq 0.05$) during intermittent exercise whilst four indices displayed significant changes ($p \leq 0.05$) during rest and recovery in the heat.

Conclusions: We show that intermittent exercise in the heat is associated with cardiac autonomic dysregulation in older men, as compared to young and middle-aged men even when a brief 15-min break is intersperse between exercise bouts. Protective measures must be developed to safeguard older adults against heat-related illness during exercise in hot environments.

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Eccrine sweat glands ion reabsorption in healthy older adult after heat acclimation

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Introduction: The adaptation of older adults' eccrine sweat glands to a controlled hyperthermic (CH) heat acclimation protocol is not well known. However, CH is a challenging protocol, therefore we investigated these adaptations in healthy older adults to a modified CH protocol.

Method: 10 healthy older adults (>65 yrs) completed 9 non-consecutive days (over 2 weeks) via cycling in 35˚C, 45% RH with 1.0˚C increased rectal temperature for a controlled hyperthermia. The sweat glands maximum ion reabsorption rate, sweat rate, sweat sodium chloride concentration, number of activated sweat gland were used as markers of sweat gland adaptation These were assessed via a passive heating protocol (lower leg 42˚C water submersion) pre and post heat acclimation (HA).

Results: Some markers of thermoregulatory adaptations were evident after HA; lower resting rectal temperature, plasma volume expansion, reduced thermal sensation ($p<0.05$) but no changes in heart rate ($p>0.05$). Ion reabsorption was enhanced at the chest ($p<0.05$) but not at the forearm or thigh ($p>0.05$). Gross sweat loss and local sweat rate increased, whilst sweat sodium chloride concentration decreased ($p<0.05$). The number of heat-activated sweat glands did not increase post HA nor in response to an iontophoresis stimulus ($p>0.05$). The Tre threshold for the onset of sweating improved for some but not all participants.

Conclusions: Healthy older adults are able to acclimate to an adapted (i.e. easier) CH protocol as evident by the changes in the key thermophysiological markers of acclimation. Improvements in the maximum ion reabsorption rates were observed more clearly at the chest compared to the forearm or thigh. Sweat gland function showed modest improvements after HA. Sweat production is usually higher on the torso and the decline with age is attenuated compared to the extremities, which may explain the improvements observed at the chest only. Further analysis is required to confirm these findings.

Care provider assessment of thermal state of children in day-care centers

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Introduction: Young children are vulnerable to extreme temperatures due to physiological and anatomical characteristics and behavioral dependability. The latter is a relatively unexplored area. To quantify this, the current study investigated the effects of ambient temperature on the thermal state of children and care providers in day-care centers and the ability of the care providers to estimate the thermal state of the children.

Method: From 6 different day-care centers in the Netherlands, 104 children (<4 years old) and 58 caregivers were recruited. Three times a day, during summer and winter, Wet Bulb Globe Temperature (WBGT) was measured out- and inside the day-care center. Skin temperature of the ring finger, forearm and cheek of the children and care providers were measured. Thermal sensation of the care providers about themselves and of the children were recorded and compared.

Results: Care providers have higher forearm and cheek skin temperatures than children ($p<0.05$), but no differences in skin temperature of the ring finger were observed ($p=0.10$). Significant relations ($p<0.05$) between the thermal sensation of the care providers and their own skin temperature in summer and winter were observed. However, no significant relation was found between the thermal sensation of the children estimated by the care provider and the skin temperature of the children for summer ($p=0.13$) and winter ($p=0.24$) separately.

Conclusions: Preliminary analysis shows that care providers in day-care centers can correctly estimate their own thermal state, but may incorrectly estimate the thermal state of the children.

Heat Related Issues and Practical Applications for Paralympic Athletes at Tokyo 2020

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International sporting competitions, including the Paralympic Games, are predominantly being held in hot and/or humid environmental conditions. Thus, a greater emphasis is being placed on preparing athletes for the potentially challenging environmental conditions of the host cities. Despite previous Olympic and Paralympic Games being held in Athens, Beijing and Rio, the impending Tokyo 2020 Games could be the most thermally demanding for both athletes and spectators alike. It is well recognised that exercising in hot and or/ humid ambient conditions increases physiological and psychological strain, causing an decline in sporting performance compared to competition in cooler conditions. However, for athletes that are eligible to compete in Paralympic sports, evidence-based practices for reducing thermal strain whilst competing in the heat are limited. This review aims to provide an overview of heat-related issues for Paralympic athletes at the greatest thermoregulatory risk, alongside current recommendations to reduce thermal strain and technological advancements in the lead up to the Tokyo 2020 Paralympic Games. When competing in challenging environmental conditions a number of factors may contribute to an athlete's predisposition to heightened thermal strain. These include the characteristics of the sport itself (type, intensity, duration, modality, environmental conditions), fitness and physical attributes, but also the complexity and severity of the impairment of the athlete. For heat vulnerable Paralympic athletes, strategies such as the implementation of cooling methods and heat acclimation, can be used to combat the increase in heat strain. At an organisational level, regulations and specific heat policies should be considered for several Paralympic sports. Both the utilisation of individual strategies and specific heat health policies should ensure both the health of the athlete and maintenance of their sporting performance when competing in environmental conditions, such as those expected at the Tokyo 2020 Paralympic Games.

Inter-individual variation in the adaptive response to heat acclimation; impact on temperate performance

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Introduction: Typical heat acclimation (HA) responses are well characterised at the cohort level, however, individual data demonstrate considerable heterogeneity. Recent research suggests that HA indicies are independent and not influenced by aerobic capacity, previous HA or thermal dose. However, some baseline responses may be useful in estimating the potential benefits that an individual may obtain from HA. It remains to be establised whether the extent of individual HA will translate to aspects of individual endurance performance and thermophysiological indicies in temperate conditions, and if these can be related to any prior variables.

Method: 17 males (VO2max=58.8[8.4] $mL \cdot kg^{-1} \cdot min^{-1}$) undertook 10-days HA (exercise + heat-stress [40°C, 50% RH]). Adaptation was assessed by heat stress tests (HST; 60 minutes cycling, 35% peak power output), and performance was assessed by a graded exercise test and 30 minute work done trial (22°C, 50% RH), pre- and post-HA (within- participant repeated-measures design). The controlled hyperthermia (CH) protocol for HA was used (90 minutes 40°C, 50% RH, rectal temperature 38.5°C). Nine of the participants had previously undertaken a HA programme (3 to 18 months washout).

Results: At the group level HA was evident (hypervolemia, reduced rectal [*T*re] and body temperature, reduced heart rate and increased sweating during HST; $P<0.05$). However there was notable inter-individual variation in the range of adaptive responses. These data have already established that aerobic capacity does not influence the degree of HA, however it has not yet been determined whether the magnitude of an individual's HA response influences temperate endurance performance and associated changes in thermophysiological variables. Full data analysis is not yet complete and it is proposed that comparisons will be made to advance the evidence from Corbett at al. (2018) with considerations for previous HA and thermal dose.

Heat acclimation does not alter heart rate variability at rest in normobaric hypoxia.

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Introduction: Cross acclimation is the process of inducing physiological adaptation utilising one environmental stressor (e.g. heat) with resultant beneficial physiological response in another (e.g. hypoxia). To this end, heat acclimation (HA) improves physiological responses at rest, as well as during submaximal and maximal exercise in hypoxia. Heart rate variability (HRV) describes autonomic activity and improvements in HRV have been evidenced during heat stress following HA, and in hypoxia following cold adaptation. The aim of this study was to examine whether heat-hypoxic cross acclimation altered HRV. It was hypothesised that HA would improve indices of HRV at rest in hypoxia.

Method: Sixteen healthy male participants completed ten 90-min sessions of isothermic HA (40°C/40% relative humidity [R.H.]) or exercise training ([CON]; 20°C/40% R.H.). A 10-min normobaric hypoxic exposure (FiO_2 = 0.12; ~4,300 m) was undertaken 24 hours prior too, and 24 hours following HA or CON. During this trial a 3-lead ECG was performed, and ventilation was measured via a metabolic cart in the supine position. Time (R-R interval and standard deviation of R-R intervals [SDNN]) and frequency (total power, low frequency power [LF; range 0.04–0.15 Hz], high frequency power [HF; range 0.15–0.4 Hz] and low:high frequency ratio [LF:HF]) domain parameters were calculated using Kubios HRV analysis software on the final 5 min of ECG sampling. HRV data was analysed using mixed 2-way ANOVA on absolute values.

Results: HA, but not CON, reduced resting rectal temperatures and HR, and increased sweat rate and plasma volume in normoxia ($p<0.05$). No changes over time, or between groups were observed in breathing frequency, R-R interval, R-R SDNN, total power, LF, HF or LF:HF in hypoxia ($p>0.05$).

Conclusions: HRV did not change in hypoxia following HA, suggesting autonomic activity at rest is not altered as part of heat-hypoxic cross acclimation.

The effects of short- and medium-term heat acclimation on the sensations of fatigue

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Introduction: The physiological adaptations following heat acclimation (HA) are well documented, although, data considering an individual's sensation of fatigue following repeated exercise-heat stress are less well understood. Previously, ultra-endurance runners report lessened percieved fatigue following short-term HA (STHA) (Willmott et al., 2017). However, if STHA is extended and/or includes more than one exposure per day, as found during fire instructors' shift patterns (Watt et al., 2016), there is a risk of increased sensations of fatigue, which may be detrimental, and negate the efficacy and applicability of HA. Therefore, the aim of this study was to describe the sensations of fatigue following short- (STHA: 5 session) and medium-term heat acclimation (MTHA: 10 sessions) during once-daily HA (ODHA) and twice-daily HA (TDHA).

Method: Twenty male participants (mass: 77.9 ± 11.9kg, peak oxygen uptake [V̇O2peak]: 3.75 ± 0.47L.min^{-1}) completed a V̇O2peak test before and after 10-sessions (60-mins cycling at ~2W.kg^{-1}) of ODHA (n=10) or non-consecutive TDHA (n=10) (45°C, 20% R.H.). Sensations of fatigue (*General, Physical, Emotional, Mental, Vigour a*nd *Total Fatigue*) were assesed using the multi-dimensional fatigue scale inventory-short form (Stein et al., 2004) pre and post session 1, 5 and 10.

Results: HA adaptation (reductions in resting rectal temperature and heart rate, plasma volume expansion and increased sweat rate) was induced following ODHA and TDHA (P<0.05) (Willmott et al., 2018). *General*, *Physical* and *Total Fatigue* increased from pre to post session 1 within both groups (P<0.05). However, pre to post session changes for *General, Physical* and *Total Fatigue* were lower (P<0.05) in session 5 and 10 of ODHA, but were only lower after session 10 of TDHA.

Conclusions: Whilst comparative heat adaptations followed non-consecutive TDHA, the increased sensation of fatigue following HA only reduced by session 10 (MTHA), whereas this response occured by session 5 (STHA) of ODHA.

The effect of heat acclimation on cognitive performance

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Introduction: The increasing frequency of summer heat waves as a consequence of climate change presents a significant detrimental impact on human health. In occupational settings, this is reflected in the drop in productivity. While not affecting routine work performance, prolonged heat exposure might impact cognitive performance and extend task duration. Several studies indicate that heat acclimation improves physical performance. Whether this is reflected in mental performance was investigated in the present study.

Methods: Eight male participants underwent a 10-day normobaric hypoxic confinement (13.5% F_iO_2) with daily 90-min normoxic controlled-hyperthermia (ambient temperature: 37.4±0.5°C, target rectal temperature: 38.5°C) heat acclimation protocol. On days 1 and 10, the participants were passively heated for an additional 2-hr after the training sessions. Before and after these training sessions (pre- and post- training, respectively) and after 2-hr of passive heat exposure they completed a Trail Making Test (TMT), connecting letters with suitable numbers on tablets. The number of errors, total duration and calculated fatigue were recorded.

Results: Compared to pre-training, participants demonstrated greater fatigue after completing the 90-min training session post-training, which was not evident after 2-hr of additional heat exposure in both testing days. Heat acclimation improved participants` pre- and post-training reaction time by 11-sec and 8-sec, respectively. Additional 2-hr of passive heat exposure did not indicate heat acclimation improvements in TMT results. Heat acclimation did not facilitate cognitive performance assessed after participants were exposed to the 2-hr passive heat.

Conclusions: Heat acclimation incorporating exercise significantly improved reaction time and time to complete cognitive tasks.

The impact of a controlled hyperthermia heat acclimation program on aerobic exercise capacity

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Introduction: The effect of heat acclimation (HA) on aerobic exercise capacity is subject to debate. Therefore, the aim of this study was to investigate the impact of controlled hyperthermia HA on aerobic exercise capacity.

Method: Twenty-three recreationally active to well-trained participants (14 males, 9 females; VO_2max range 36.2 – 68.6 mL/kg/min) performed a graded exercise test (GXT) in thermoneutral conditions (~22°C, ~35% relative humidity), four to eight days pre and post HA. Cycling started at 25 W and power output was increased with 25 W/min until exhaustion. HA included two heat stress tests (HSTs) and 10 days of controlled hyperthermia HA sessions (33°C, 65% relative humidity). HSTs were performed one day prior to and two days after HA and involved 35 min cycling at 1.5 W/kg bodyweight, followed by an incremental time to exhaustion test (25 W/min).

Results: VO_{2max} was not altered following HA (+0.7 [-1.2 2.5] ml/kg/min, p = 0.46). A negative association was observed between initial VO_{2max} and the change in VO_{2max} from pre- to post HA ($\Delta VO_{2max,post-pre}$; r_s = -0.5, p = 0.02). Time to exhaustion (TTE) for both GXTs could only be derived for a subset of participants (n = 14; 8 males, 6 females; VO_{2max} range 38.7 – 68.6 mL/kg/min). For this subset, TTE was improved following HA (+2.7 [0.4 4.9] % ; p = 0.02), while VO_{2max} was not (+0.1 [-2.2 2.4] mL/kg/min, p = 0.92).

Conclusion: HA using controlled hyperthermia did not improve maximal oxygen uptake. However, less fit individuals – indicated by a lower initial VO_{2max} – exhibited a larger improvement in VO_{2max} compared to those who were more fit. TTE for the GXT was increased following HA. It should be noted that further analysis is required to confirm these findings.

Does Heat Thermotherapy Improve Cardiovascular and Cardiometabolic Health? A Systematic Review and Narrative Synthesis of the Literature

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Introduction: A systematic review and synthesis of the literature were conducted to assess whether heat thermotherapy improves cardiovascular and cardiometabolic health, whilst comparing different heat thermotherapy modalities.

Method: Three major electronic databases (Medline, Embase and Web of Science) were searched from the earliest available date until 24th November 2018 and a manual literature search, using the key terms of 'induced hyperthermia', 'trial' and 'adults' was conducted. Inclusion criteria were articles with a control trial study design and a passive heating intervention. In total 1036 articles were identified and screened, with 31 articles meeting the inclusion criteria. A narrative synthesis was undertaken in four stages, including the development of a theory, developing a preliminary synthesis, exploring relationships and assessing the robustness of the synthesis.

Results: In the 31 included articles, thermotherapy was delivered acutely (one bout; n=13), short term (2-15 bouts; n=12) and chronically (>15 bouts; n=6). The stimulus was hot water immersion (n=22; water temperature 38-43°C), heated air exposure (n=7; air temperature 31- 90°C) and a water-perfused suit (n=2). The heat exposure duration was from 10 to 240 minutes. Cardiovascular and cardiometabolic measurement techniques varied across articles, alongside participant age (≤35 years, n=365; >35 ≤60 years, n=166 and >60 years, n=366) and health status. 17/23 articles measuring cardiovascular outcomes reported positive cardiovascular health benefits, including increased flow-mediated dilation (1.3-5.3%) and systolic blood pressure (4-16mmHg). 10/14 articles measuring cardiometabolic outcomes reported positive cardiometabolic health benefits, including reductions in postprandial glucose concentration and C-reactive protein. Only two papers investigated the decay effect of thermotherapy.

Conclusion: Overall, 23/31 papers demonstrated significant positive cardiovascular or cardiometabolic health benefits by thermotherapy, despite varied study design and modality. This review has quantified the different thermotherapy interventions and concluded thermotherapy does result in cardiometabolic and cardiovascular health benefits. However, the duration of these health benefits post-thermotherapy is unknown.

Thermal and cardiovascular strain in middle-aged adults with and without type 2 diabetes during a brief exposure to hot-dry heat

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Introduction: Aging exacerbates hyperthermia and cardiovascular strain during exposure to extreme heat, but it remains unclear whether those effects worsen in older adults with type 2 diabetes (T2D).

Methods: We examined whole-body heat exchange in habitually active, middle-aged (mean±SD; age: 60±7 years) adults (10 males and 2 females per group) with (n=12, HbA1c: 7.0±1.0%, duration of T2D: 11±5 years) and without T2D (Control, n=12) matched for age, sex, and physical characteristics while resting in extreme heat (44°C, 30% relative humidity) for a brief 3-hour exposure. Metabolic heat production, whole-body net heat loss (dry±evaporative heat loss), body heat storage (temporal summation of heat production and net heat loss), and rectal temperature were measured continuously. Cardiovascular responses (heart rate, cardiac output, mean arterial pressure, and forearm and calf blood flow) were measured before and after the 3-hour exposure.

Results: No between-group differences for metabolic heat production (T2D vs. Control; 111±17 vs. 113±18 W), evaporative heat loss (170±29 vs. 173±32 W), dry heat exchange (-99±28 vs. -98±21 W), and net heat loss (71±22 vs. 75±25 W) were observed over the 3-hours (all $p>0.05$). Consequently, the change in body heat storage (T2D: 344±111 kJ; Control: 346±139 kJ) and core temperature (T2D: 0.4±0.2°C; Control: 0.5±0.3°C) was similar between groups over the 3-hours (both $P>0.05$). Furthermore, no between-group differences in heart rate (T2D vs. Control; +19±9 vs. +15±7 beats·min^{-1}), cardiac output (+0.2±0.6 vs. -0.4±0.7 L· min^{-1}), mean arterial pressure (+0±6 vs. +2±7 mmHg), and forearm (+1.5±1.9 vs. +2.2±1.5 ml·100 ml tissue^{-1}· min^{-1}) and calf blood flow (+1.3±0.8 vs. +1.4±1.2 ml·100 ml tissue^{-1}· min^{-1}) were observed when expressed as a change from baseline (all $P>0.05$).

Conclusions: Habitually active middle-aged adults with well-controlled T2D do not experience greater hyperthermia and cardiovascular strain compared to their healthy counterparts during a brief 3-hour exposure to hot-dry heat.

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Active local cooling for the prevention of onycholysis during docetaxel-based chemotherapy

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Chemotherapy-induced onycholysis is a severe form of nail toxicity and is characterized by partial or complete detachment of the nail from the nail bed. Ice gloves can be effective in preventing nail toxicity as they enable cold-induced vasoconstriction, or reduction of blood flow, and therefore limit the transport of chemotherapeutic agents towards the nail bed. After several minutes, the ice gloves induce cold-induced vasodilation, which reduces the effectiveness of the preventive treatment. Moreover, the gloves cause pain and additional distress during chemotherapy. The objective of this article is to examine the usefulness of an innovative active local cooling device for the prevention of onycholysis during docetaxel-based chemotherapy, while limiting pain and discomfort.

In this research, a prototype of an active cooling device was developed that allows the cooling of the palmar side of the distal phalanges with an alternating temperature of 2°C to 20°C every three minutes. Six cancer patients – five men and one woman – undergoing a docetaxel-based treatment participated in this study. The hands of the patients were photographed and discoloration was evaluated by quantifying average RGB-values over time of every fingernail.

The results indicate that the patients experienced the ice glove as significantly less comfortable, which led to reduced therapy-loyalty towards the ice glove. Furthermore, two of the six patients experienced frostbite – at one and respectively two fingers – caused by the ice glove, which resulted in discoloration of the fingernails. Nevertheless, no symptoms of onycholysis were observed on both hands.

In conclusion, the results of this study show that the active local cooling device can be useful for preventing nail toxicity, while offering a relatively painless treatment compared to the ice glove. Further research is necessary to investigate and compare additional cooling strategies where patient comfort and usefulness of the device are in balance.

Development of thermoregulation model and thermal comfort model based on neurophysiology

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A multi-segmented model based on neurophysiology was developed to predict regulatory dynamic responses and physiological variables of a clothed person in non-uniform transient environment. This model consists of two systems, i.e. the passive model and the active model. The passive one is that of Wissler's model (2018). It splits the body into 21 cylindrical segments. Each segment is divided into 21 of which 15 for body tissues and 6 for clothes of covered skin. The production of heat is ensured by the metabolism within the body tissues and the heat exchange with the environment is established by convection and radiation. The active system consists of three main components: the thermoreceptors, the control center and the afferents. Local skin and core temperatures are transduced into neural impulse responses by cold and warm thermoreceptors. The hypothalamus receives these responses and sends neural drives to the afferents. At this level, the neural drives are transformed into physiological mechanisms such as vasomotion, shivering and sweating to maintain thermal homeostasis. This model is coupled to another one based on Zhang's model (2003). It is dedicated to assessing thermal sensation and thermal comfort level of occupants in indoor environments. A comparison is made between our thermoregulation model and the original one of Wissler. Our thermal comfort model is also compared to the static model (PMV) and the dynamic thermal sensation model proposed by Fiala (1998).

Comparison of the Predicted Heat Strain and the Fiala-based Human Thermophysiological Model for normal and protective clothing under various ambient temperatures

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Introduction: Currently, it is important to have models for prediction of the human thermal stress to predict the risk of human exposure to extreme conditions or to propose preventive measures during using protective clothing. For these purposes, a lot of models have been developed that mainly differ in their complexity and time- consuming. The aim of this paper is to compare Predicted Heat Strain (PHS) and Fiala- based model (FMTK) with the experimental data.

Method: For experiments, one male participant (80 kg, 1.75 m) and three types of ensembles were used: Klimatex underwear, protective clothing: FOP M2000, Tychem-F. The activity during the tests was 1 met for resting and 3.2 – 4.3 met for exercise. FMTK model with created MATLAB module "Bodybuilder" to enter individual anthropometric characteristics and PHS calculation software based on the standard ISO 7933 were used for the simulations.

Results: In case of Klimatex underwear (0.37 clo), it was possible to observe for all tested temperatures (25 °C – 40 °C) that FMTK and PHS can predict both rectal and mean skin temperature accurately. Similarly, for protective clothing FOP M2000 (1.08 clo, 35 °C – 40 °C), however, PHS index slightly underestimated mean skin temperature. In case of Tychem-F (1.06 clo, 30 °C – 40 °C) PHS index also underestimated mean skin temperature, but the problem comes with the prediction of the rectal temperature, where PHS index gives unrealistic results and predicts rectal temperature up to 41 °C versus 38.5 °C from FMTK and the experiment (ambient temperature 40 °C).

Conclusions: PHS index is possible to use for normal clothing under various ambient temperatures and can give results like FMTK model and experiment. For protective clothing, which has the value of clothing insulation higher than 1 clo (maximum value in the norm for using PHS index), it depends on the value of the static moisture permeability index imst. For its higher value (FOP M2000, imst =0.34), it is possible to use PHS index for prediction of the rectal temperature and mean skin temperature with sufficient accuracy. But for low values of imst, (Tychem-F, imst = 0.03), PHS index overpredicts the rectal temperature and give unrealistic results in comparison with the FMTK model and experiment.

On the development of a hybrid of Fiala's and Wissler's shivering models: A preliminary investigation

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Introduction: One application of human thermo-physiology models (HTMs) is to predict time-to-comfort for occupants of vehicles that have been subjected to a cold- soak and then heated. We have used both Fiala's (2001) and Wissler's (2018) shivering models integrated into an HTM. Our experience has been that Fiala's model tends to over-predict shivering metabolism while Wissler's model tends to under-predict. We compared HTM predictions to cold air test (SCAT) data published by Launay (2006). Fiala's model over-predicted shivering metabolism and skin temperature (at the end of the SCAT) by 30 percent and 2.4 °C, respectively. Wissler's model under-predicted by 10 percent and 0.7 °C. Despite the seemingly better predictions from Wissler's model, we cannot use it for human comfort studies since it lacks a dynamic term, i.e., one that incorporates the derivative of skin temperature, which is essential for comfort evaluation at the beginning of a cold-soak test.

Method: Fiala's model uses a sigmoid function to predict the contribution of the skin temperature error signal to metabolic shivering. Wissler's model uses an "effective temperature" that provides similar functionality. We developed a "hybrid" model by modifying Fiala's shivering equation to use the proportionality constants for the core and skin afferent signals from Wissler's model.

Results: When compared to Launay's measurements, the hybrid model under-predicts shivering metabolism and skin temperature by 6 percent and 0.1 °C. However, the transient portion of the prediction is still inaccurate.

Conclusions: The results of the SCAT investigation matched our experience that Fiala's model tends to over-predict shivering metabolism while Wissler's model tends to under-predict. To avoid lengthy regression analyses, we created a modified version of Fiala's model to match the predictions from Wissler's model while still maintaining a dynamic term. The hybrid model yielded better results for this data set than either of the original models.

Moisture accumulation in sleeping bags and sleep quality in warm and cold bivouac during eight days military ski march

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Introduction: In the Norwegian Military the conscript soldiers will usually stay in tents which are heated during winter operations (warm bivouac -WB). The soldiers take care of and guard the heating device and usually they take one to two hours heating guard each during the night. An improved quality of the sleeping bag and mattress give the possibility to stay overnight in the tents without heating (cold bivouac - CB) and in this way probably increase the sleep quality. However, the accumulation of moisture of the sleeping bag system may probably increase in the cold bivouac compared to the warm one.

Method: The objective of the study was to compare both the moisture accumulation in the sleeping bag system and sleep efficiency in warm and cold bivouac over a time of 8 days. Two squads, with six soldiers in each, were divided into two tents, with and without heating. The sleeping bag system with both sleeping bag and overbag (overbag from Jerven of type Hunter) were weighted both before the first night and just after the last night. The sleeping efficiency was measured by accelerometer Actigraph on the wrist on the non- dominant hand all the time (one stopped after 5 days after a "dip" in the ice water). The sleep algorithm "Cole-Kripke" was used. The study was conducted in the Norwegian mountains in February and the ambient night temperature varied from – 6 to – 17 °C.

Results: The moisture accumulation in the sleeping bag systems increased significantly in both the cold and the warm bivouac with 11 and 5 % respectively. However, even if it is a tendency to lower accumulation in the warm bivouac compare to the cold, the difference was not significant.

Conclusions: In conclusion, the moisture accumulation in the sleeping bag systems increase significantly in both cold and warm bivouac during a 8 days field trail with temperature between – 6 to – 17 °C. However, the difference between the cold and warm bivouac was not significant in this study. The sleeping quality was significant better in the cold bivouac compare to the warm.

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Fiber-pore-structure of outdoor clothing

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Introduction: In an experimental study, data about arrangement and distribution of fibers and pores around the dressed human body are derived. Backgrounds are investigations about temperature regulation of outdoor clothing.

Method: The pore size distributions of knitted and woven textiles from PES and PA yarns are derived from geometry and physical fiber, yarn and fabric properties with aid of mathematical equations. From these materials, two outdoor clothing systems are made to measure for five test persons. With scanner and fit simulation methods, distances between human body and different clothing layers are individually determined.

Results: In the volume balance, the outdoor clothing systems investigated consist of about 3 to 7 % fibers, 5 to 20 % yarn or meso pores, 5 to 20 % textile or macro pores and 50 to 90 % clothing pores. In absolute terms the volume of the fibers are about 500 to 2,000 cm^3, of the yarn and textile pores about 600 to 6,000 cm^3 each and of the clothing pores about 14,000 cm^3.

Conclusions: As premise for further investigations, the quantity of micro, meso, macro and mega pores significantly affects temperature regulation properties of outdoor clothing.

Thermal Insulation of Padded Winter Jackets according to Design and Materials

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Introduction: Clothing weight has been reported as the main determinant of thermal insulation. In Korea, lighter and warmer padded winter jackets have been popular in recent years because of newly developed light weight winter fabrics along with various types of down materials. However, few studies report the thermal insulation of the padded winter jackets. This study examined the thermal insulation of padded winter jackets using a thermal manikin to provide appropriate guidelines for selection.

Method: Eighteen padded jackets commercially available were tested on a dry thermal manikin at an air temperature of 20°C with 50%RH (ISO 9920, 2007). The padded jackets consisted of various designs [66 ~ 113 cm in garment length, 0.28 ~ 1.57 kg in garment weight, 60 ~ 62 cm in sleeve length, 49 ~ 52 cm in chest width], outer covering materials [polyester (10 jackets) or nylon (8 jackets)], filling materials [10 jackets with goose down and 8 jackets with duck down], and lining materials [polyester (10 jackets) or nylon (8 jackets)].

Results: The thermal insulation (Iclu) of padded jackets was 0.589 ± 0.289 clo (0.342 ~ 1.271 clo) and positively correlated with garment length ($r=0.945$, $p<0.0001$), garment weight ($r=0.651$, $p=0.003$), and covering area ($r=0.614$, $p=0.007$). The Iclu of a padded jacket can be estimated using the following equation: 0.014×garment length(m)-0.534 (corrected $R^2=0.893$, $p<0.001$). The thermal insulation of duck down padded jackets was greater than that of goose down padded jackets, over a certain weight. There were no significant differences in the thermal insulation of padded jackets according to the mixture ratio of chest down (beneath feathers) or feathers (outer covering of birds) filling materials.

Conclusions: Garment length was the major determinant of thermal insulation for padded winter jackets. Garment weight or covering area followed garment length. Testing the thermal insulation of synthetic filling is necessary and it will follow up on the next research.

Maximum Exposure Time while Wearing Protective Clothing in Extreme Heat Environment

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Introduction: Due to global warming, the frequency and intensity of heat waves have been increasing. In Korea, since weather observation started, the maximum temperature of 39.6°C was recorded in summer 2018. This study examined maximum exposure limit time to extreme heat stress while wearing protective clothing.

Method: Nine males (21.3±2.6 yr in age, 175.2±4.0 cm in height, and 70.1±7.9 kg in weight) participated in this study. A trial consisting of a 10-min rest was followed by 60-min of walking at a 4 $km \cdot h^{-1}$ (135 W/m^2) and by 10-min of recovery. Subjects were exposed to the following six conditions in random order: air temperatures (T_{air}) of 28, 33, 38°C with 70%RH, with clothing condition of summer wear (SW) and protective clothing (PC, Level D). During all trials, rectal temperature (T_{re}), heart rate (HR) and subjective perception were recorded.

Results: T_{re} showed significant differences between clothing conditions in recovery period at 33°C (SW: 37.4±0.2, PC: 37.7±0.3°C, P=0.04) and at 38°C condition (SW: 38.2±0.2, PC 38.5±0.3°C, P=0.016). Increases in HR were significantly greater for PC than for SW at 33°C (SW: 26±15, PC: 46±8 bpm, P=0.003) and at 38°C (SW: 59±10, PC: 75±13 bpm, P=0.003). During recovery at 38°C, T_{re} continued increasing and HR did not recover. Thirst sensation showed no significant difference between 28°C and 33°C conditions, but participants expressed very severe thirst sensation for both 38°C conditions (P<0.05). At the 38°C-PC condition, five of nine subjects abandoned the experiment due to dizziness or nausea (cessation time 54±3 min), while this was not the case for subjects in the 80-min exposure of the other five conditions.

Conclusion: Healthy workers wearing protective clothing at T_{air} of 38°C should take a longer recovery than 20 min after a bout of work (approx. 50~60 min). A more elaborative analysis will be following.

The effect of respiratory muscle activation on the blood volume in locomotor muscle during incremental ramp cycling

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Introduction: Respiratory muscle activation during severe exercise may prevent the blood flow increase for locomotor muscles and then it is a putative factor to limit several works under various environments. However, it is still unclear whether locomotor muscle blood volume as a factor changing blood flow is influenced by activated respiratory muscle during severe exercise. We investigated the deoxygenated [Hb+Mb] (HHb, index of fractional O2 extraction) and total [Hb+Mb] (THb, index of total blood volume) in respiratory (intercostal muscle and diaphragm, IC-DP) and locomotor muscle (vastus lateralis, VL) using near-infrared time-resolved spectroscopy.

Method: Ten males performed ramp incremental cycling (20 $W.min^{-1}$) to exhaustion with measuring pulmonary VO2 and absolute concentrations of HHb and THb at the left 9-10th intercostal place and VL muscle.

Results: The HHb values were greater for VL than IC-DP from 55 to 100 % of normalized power output (PON) (95.7 ± 35.7 vs. 65.6 ± 10.7 μM at 100 % PON, $P < 0.05$) with the plateau response following linear increase in VL and the steep increase after plateau in IC-DP. The THb values were greater in VL than IC-DP from 30 to 100 % PON (200.7 ± 18.1 vs. 162.6 ± 11.6 μM at 100 % PON, $P < 0.05$) with the plateau response following linear increase in VL and the linear reduction in IC-DP. Onset of steep HHb increase in IC-DP was slower than that of plateau THb in VL (76.9 ± 6.1 vs. 59.0 ± 10.5 % PON, $P < 0.05$) without a significant correlation ($r = -0.32$).

Conclusions: These suggest that respiratory muscle activation investigated in the present study may not inhibit blood flow regulation associated with local blood volume in locomotor muscles.

WATson – Development of a new measurement tool to determine the cooling function of textiles

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Introduction: Textiles with new function are coming in the market and new test methods are necessary. Nowadays, cooling textiles are found in the field of sports and protective clothing. Cooling textiles should support the efficiency of athletes and workers. The cooling effect should improve comfort and wellbeing. During high activity and/or in warm environments the body core temperature can increase and human starts sweating to prevent an overheating of the body. The evaporation of liquid sweat is the most effective process to cool the body. Cooling textile should support the body to keep the body temperature constant.

Method: To determine the cooling power of fabrics, the heat release tester WATson was developed to determine the cooling power. However, the measured cooling power is only a physical value. Without correlation of these physical values with data of subject trials, the cooling power do not give any information about the perception of the human body and the achieved cooling effect. Subject trials were made under controlled condition and typical use conditions.

Results: The cooling power of various cooling textiles was measured with WATson; Controlled wearer trials in the climate chamber gives information about the perception and feeling of coolness. The correlation of the physical data and the data of wearer trials is the base to evaluate the new test device WATson.

Conclusions: A new clothing physiological device was developed. The cooling power is a new material specific parameter. After correlation of the new test device with wearer trials the cooling power is combined with the cooling perception. WATson is a logical extension for the clothing physiological testing tool to determine the cooling and comfort of textiles.

A New Method to Capture the Dynamic Liquid Transport on Fabrics Using a Sweating Guarded Hot Plate and Thermal Imaging Camera

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Introduction: Liquid transport on fabrics is essential to wear comfort. When humans sweat, an ideal fabric should have the ability to transport liquid from the skin surface quickly and to dry fast to minimize the discomfort sensation caused by sweat while optimizing cooling. The way the liquid interacts with the fabric and the skin can affect wearer's thermal and tactile wet comfort. In this study, a new method to capture the dynamic liquid transport process on fabrics was developed.

Method: A sweating guarded hot plate was used to provide a steady liquid and heat source to the fabrics and to measure the total heat loss. During the test, the fabric sample was placed on the heated plate (35℃) and a total of 0.8ml distilled water was supplied to the fabric sample (10x10cm) through four sweat pores of the plate. A thermal imaging camera and a cell phone camera were set on top of the fabrics to simultaneously record the dynamic wetting and drying process.

Results: The corresponding thermal and regular video indicated that there are different liquid spreading and drying patterns among different fabrics. By analyzing the corresponding videos, a sticking effect was identified between the wetted fabrics and the heated plate in some wool and polyester knitted fabrics. The maximum wetted area of each fabric was identified by utilizing ImageJ software.

Conclusions: The development of this method provided a new way to capture the dynamic liquid transport process on fabrics and is helpful in characterizing wetting and drying properties of textile materials for assessing wet thermal and tactile comfort on the skin. Furthermore, the method provides better insight in the determining factors of comfort of wet fabrics on the skin.

Validation of Wearable Blood Pressure Monitor in the Hypertensive Elderly

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Introduction: Of late, the smart watch for measuring blood pressure has become popular. It has proven especially useful for hypertensive individuals. However, there were few studies on the effectiveness of wearable blood pressure monitors for hypertensive individuals. We examined the effectiveness of a recently developed blood pressure watch for measuring blood pressure as well as pulse frequency in hypertensive elderly individuals.

Method: Twenty-two older males (76.2±4.0 yr) and 22 older females (73.1±5.7 yr) participated in this study. The experiment was conducted in a climatic chamber (an air temperature 20.0±0.1^{O}C with 51±2% RH) for 150 min. During the initial 60 min, subjects' blood pressure was measured while they were kept comfortable (estimated clothing insulation of 1.1 clo [Icl]). After that, they took off all their outer garments and socks, and wore only underwear, short-sleeved T-shirts and half-length pants (0.3 clo estimated) during the 90 min. Two other types of sphygmomanometers (automatic digital blood pressure monitor [OM] and manual sphygmomanometer of aneroid type [AS]) were compared with the smart watch (WS). Blood pressures and pulse frequency were measured three times with each sphygmomanometer during the initial and last 60 min of the 90 min, respectively.

Results: Systolic and diastolic blood pressures in WS were higher than those in OM and AS (P<0.01). Also, the Bland-Altman plots of WS and OM or AS had wider ranges in the 95% limit of agreement (LoA), while OM and AS had narrow range in 95% LoA and showed uniform distribution without any tendency. However, WS and OM in pulse frequency showed good precision, narrow ranges in 95% LoA and uniform distribution.

Conclusions: When compared to automatic or manual sphygmomanometers, the smart watch has limited application as blood pressure monitor while it measures pulse frequency accurately for the hypertensive elderly.

Comparisons of Core Body Temperatures during 7- Hour Sleep: Rectal at 6, 10, 14 cm Depth, Ear Canal, and Sublingual Temperatures

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Introduction: The on-going debate concerning which body site is the most appropriate for thermal core measurement has remain unresolved. While substantial studies have been documented comparing different measurement methods at rest or during exercise, little research explored differences between core body temperature measurements in sleep. This study aimed to compare body temperature of different body sites as measurements of core body temperature during a 7-hour sleep considering rectal temperature at the deepest depth as a gold standard.

Method: Nine females participated in the experiment 48 hours after a first night of sleep to adapt to the new sleeping environment. The bedroom was maintained at Tair of 27℃ and 50%RH. Subjects slept from 00:00 AM to 07:00 AM. Rectal temperature (Tre) at 6, 10, 14 cm depth, ear temperature (Tear), heart rate, sleep variables were monitored throughout the night. Sublingual temperature (Tsublingual) was measured before and after sleep.

Results: Average Tre at 14 cm depth during sleep was 36.6 ± 0.3℃. Average Tre at 6 and 10 cm were 36.3 ± 0.5℃ and 36.5 ± 0.3℃, respectively, without any statistical difference from the 14 cm value. Average ear canal temperature (36.3 ± 0.4℃) was significantly lower than Tre at 14 cm depth ($P<0.05$). Before sleep, Tre at 6 cm depth (36.6 ± 0.3℃) and sublingual temperature (36.6 ± 0.3℃) was significantly lower than Tre at 10 (36.8 ± 0.3℃) and 14 cm (36.9 ± 0.3℃) depth ($P < 0.05$). After sleep, both Tear (36.2 ± 0.4℃) and Tsublingual (36.3 ± 0.3℃) were significantly lower than Tre at 14 cm depth (36.5 ± 0.3℃) ($P < 0.001$).

Conclusions: During sleep, Tre at 10 and 14 cm depth showed the highest and the most stable values whereas Tre at 6 cm depth and Tear seemed to be more influenced by the ambient temperature.

Comparison of sixty-minute urine excretion to 24-hours in determining proteinuria at altitude

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Introduction: Expeditionary research teams have relied on 24-hour urine collections to examine glomerular status (e.g. urinary orosomucoid excretion, uORM, μg/min) during ascent, however, the nature of these collections can be impractical in these extreme environmental conditions. Utilising shorter-duration (60 min) collections would be advantageous, although no comparisons have been made between short-duration and 24-hour uORM excretion rates at altitude. The objective of the present study was to compare uORM excretion rates obtained from 24-hour and 60-min urine collections during an altitude expedition.

Methods: Urine studies were conducted on sixteen (n=16) individuals. Sixty-min urine samples were collected at 3 separate timepoints surrounding exercise experiments (pre-, post-120, and post-180 min) at the Whymper Hut (5035m), Mt Chimborazo, Ecuador on a single day and were compared to the 24-hour sample produced on that day. Ample time (> 60min) was allotted to eliminate any post-exercise effect. Samples were aliquoted, frozen, and transported back to the UK, where they were stored at -80℃ until urinalysis on the Optilite (The Binding Site, Ltd., Birmingham, UK) turbidimetric analyser using a latex-enhanced immunoassay measuring range: was 0.077 to 148.2 mg/L; analytical time 10 mins). Friedman's test was used to compare uORM excretion rates between 24-hour and 60-min samples (chi square, $p<0.05$), with *post hoc* Wilcoxon's signed rank tests (Z score, $p <0.025$) performed where appropriate.

Results: Sixty-min uORM excretions were comparable to 24-hour uORM excretions at all the 3 timepoints ($X^2(3)=2.66$, $p=0.45$) but were, on average, lower by ~0.25μg/min. Mean percent error (accuracy) of the 60-min excretion rates was 42%.

Conclusion: Sixty-min and 24-hour uORM excretion rates were comparable, however the large percent error between the two suggests that that an underestimation by 60-min collections cannot be excluded. Further research is required to evaluate any such diurnal variation and should aim to better control for hydration status.

A new device for continuously collecting sweat samples for measuring both sweat composition and volume

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Introduction: Sweat is important for regulating body temperature in the heat and maintaining healthy skin. Sweat can be used as a non-invasive biomarker for assessing human performance, health and wellbeing. Recently, wearable biosensor devices are reported to measure sweat composition (Gao et al. 2013, Anastasova et al. 2016, Glennon et al. 2016). However, the sweat measured by these devices are contaminated due to the accumulation of sweat under the sensors which is not continuously removed. To solve these points, we developed a new device which flushes sweat continuously and allows for an accurate measurement of both sweat compositions and volume.

Method: A new device, consisting of a microfluidic chip, was attached onto the skin and two external micro-pumps to flush accumulating sweat in the fluidic channel (area: 2.72 cm^2) at defined time intervals, was assessed. To fabricate the microfluidic chip, a disposable double-sided medical tape was cut with a laser ablation system and then the upper surface was covered with a silicone rubber sheet to provide the fluidic channel. To evaluate the device, we performed passive heating for 45 min with a water-perfused suite in a temperate environment (25°C, 50%Rh) with a healthy participant. During passive heating, we measured cardiovascular, thermoregulatory variables, sweat compositions and volume of the new device, sampling every 5 min.

Results: The new device could collect enough volume for measuring Na+, Cl- and K+ from forearm sweat at each 5 min intervals and these compositions at the end of passive heating were 56.6, 31.7 and 6.8 mmol/l, respectively. Sweat rate by the new device showed an almost 1.5 time higher rate than that of the ventilated capsule method.

Conclusions: Sweat composition measured by the new device were acceptable based on the earlier research. However, we need to improve the devices ability to measure sweat rate accurately.

Estimation of core temperature from near-infrared imaging of hand vein dynamics

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ABSTRACT WITHDRAWN

How Much Heat Can a Thermal Manikin Handle?

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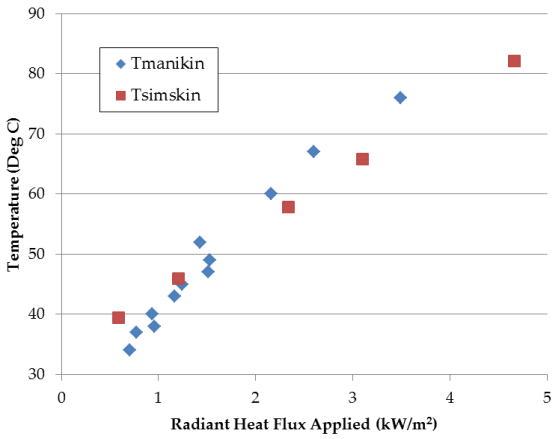
Introduction: Thermal manikin research is well established for cool and cold environments, and also for heat exposure within compensable conditions where the manikin does not overheat. High intensity heat exposure and potential skin burn injury is typically characterized using flame manikins exposed to short-duration flash fire conditions. There exists a large range of human exposure conditions between these two ranges which can be challenging to characterize with existing manikin technology.

Method: A prototype thermal manikin segment based on the Thermetrics ANDI water-cooled manikin technology was constructed and exposed to a range of radiant heat conditions (0.5 to 3.5 kW/m^2) using a variable output radiant lamp array. The incident heat flux was recorded using a thin film heat flux transducer (Vatell Co.) at each interval. Surface temperature was reported for the manikin segments after reaching quasi- steady-state at 2 minutes exposure duration. Benchmark data to represent typical human skin temperature was generated using the three layer skin model described in ASTM F1930-13 also computed over a 2 minute exposure interval.

Results: The quasi-steady state temperatures for the manikin segment and the benchmark simulation are illustrated in the figure below.



Conclusions: When exposed to a radiant heat load of comparable magnitude, the quasi-steady state temperature of the water cooled manikin segment is comparable to a simulated human skin response. At lower heat fluxes, the manikin under-predicts the skin temperature which can easily be corrected with addition of heat from the manikin heaters. At the higher heat fluxes, the manikin over-predicts versus the simulation, potentially indicating upper limits of instrument operation. Further evaluation and optimization of the manikin segment design may yield additional heat removal capability at higher heat flux levels.

Effects of ice slurry ingestion on occupational heat strain amongst indoor manual workers in Singapore: A pilot study

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Introduction: Occupational heat stress (OHS) has been shown to be detrimental for workplace productivity and safety. OHS studies have largely been conducted in dry, outdoor environments in temperate countries. However, the level of OHS in humid, indoor environments in tropical countries has not been well studied. Therefore, we aimed to determine the level of OHS in an indoor manual labour setting in Singapore. We also sought to determine the efficacy of ice slurry ingestion in ameliorating the negative effects of heat strain in occupational settings.

Method: Six male manual labourers (mean±SD: age 26±4; BMI 25.6±2.8kg/m2) working in an indoor warehouse (WBGT: 26.6±0.4°C; Tdb: 29.5±0.2°C, RH: 62±4%) participated in the study. Participants completed their normal work activities in a familiarization and two experimental trials, consuming either ice slurry (ICE) or ambient drink (AMB) following ad libitum drinking schedule in a crossover counterbalanced manner.

Results: Mean Tc was elevated in both ICE and AMB trials. However, Tc was largely below 38°C, indicating low levels of thermal strain. Compared to AMB trials, participants in ICE had a lowered rate of rise of Tc (ICE: 0.093±0.063°C/h vs AMB: 0.151±0.087°C/h; $p<0.05$) and reduced estimated sweat rate (ICE: 0.213±0.096L/h vs AMB: 0.299±0.046L/h; $p<0.05$). However, RPE ($p=0.925$), thermal sensation ($p=0.834$), maximal back strength ($p=0.580$), maximal arm strength ($p=0.136$), work done ($p=0.699$), body mass change ($p=0.436$) and amount of fluid ingested ($p=0.222$) were similar between ICE and AMB trials. Tc, chest Tsk and HR profiles were similar between trials ($p>0.05$).

Conclusions: We observed low levels of thermal strain in an indoor manual labour warehouse setting. As OHS is low, the efficacy of ice slurry ingestion could not be fully delineated. However, there is potential for ice slurry to be effective in reducing thermal strain and preventing dehydration. This effect may be enhanced when employed in occupational settings with higher levels of OHS.

Ice Vests Extend Physiological Work Time While Wearing Explosive Ordnance Disposal Protective Clothing in Hot Conditions

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Introduction: Explosive ordnance disposal (EOD) technicians may be required to work in hot environments while wearing heavy protective clothing. The uncompensable heat stress experienced limits their work time in such conditions. We investigated the ability of an ice vest to attenuate physiological strain and subsequently extend work tolerance.

Method: Eight male participants (24.3±4.1 yr, 51.9±4.6 $mL \cdot kg^{-1} \cdot min^{-1}$) walked (4.5 $km \cdot h^{-1}$) on a treadmill in an environmental chamber (35 °C; 50 % relative humidity). Participants wore either an EOD suit (EOD) or EOD and ice vest (EOD+IV). Heart rate, rectal and skin temperature were recorded continuously. Trials were terminated due to: rectal temperature 39 °C; 60 minutes walking duration; heart rate 90 % of maximum; volitional fatigue. Order of trials was randomised across participants, separated by at least seven days and commenced at the same time of the day.

Results: The majority of trials (15/16) were terminated based on heart rate criteria. Participants walked longer in EOD+IV compared to EOD (8.1±7.4 min, $p<0.05$). EOD+IV resulted in cooled skin and subsequently whole body temperatures ($p<0.001$). An interaction between condition and time was identified for heart rate, with EOD+IV becoming significantly lower after 30 minutes of exercise ($p<0.001$).

Conclusions: Work time improved by 21% in EOD+IV. For a comparable metabolic cost, participant's heart rate, skin and whole body temperature were lower while wearing the ice vest. With heat dissipation via the periphery facilitated by the EOD+IV, the observed reductions in heart rate may reflect the preservation of central blood volume enabling the heart to maintain cardiac output. Thus, the cardiovascular inefficiency that limited performance time in the EOD condition was attenuated. Overall, the results highlight the benefit of an inexpensive cooling devices in assisting EOD technicians working in a hot environment.

Study on working duration limitation in the hospital workers wearing protective clothing

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Introduction: Medical workers who perform medical procedures wearing protective clothing to prevent infection are required not only to carry out highly active tasks such as transferring patients, but also to perform accurate work. Protective clothing worn at the time of nosocomial infection is highly sealed and makes medical workers feel hot thermal sensation. The medical workers are not satisfied with the comfort and mobility of the protective clothing. The present study examined the working duration limitation wearing protective clothing.

Method: Ten healthy men wore low- or high-moisture permeability protective clothing respectively (TY or AZ) and performed 20 minutes of step exercise (3 Mets) and took a sitting position for 20 minutes before and after the exercise at 23℃, 50%RH. Body weight loss, sweat absorbed by clothing, subjective vote, heart rate, and oral temperature were measured. Also, we conducted an experiment on the stair climbing exercise (6 Mets) in the same environment.

Results: Although there was no difference in the oral temperature between protective clothing in any of the exercises, thermal sensation of TY was hotter than AZ, and the subjective wettedness and discomfort of TY were larger. In the step exercise, TY induced more weight loss than AZ, and sweat absorbed by clothing of TY was increased significantly ($P < 0.01$) compared with AZ. Two subjects were unable to continue the experiments 10 minutes after the start of the stair climbing exercise when wearing TY.

Conclusions: Although the medical practice for patients with infections usually takes about 2 hours, it is suggested that the current protective clothing has a limit on wearing time because of the thermal sensation, which may restrict the medical practice. Protective clothing for infection control for medical workers needs some improvement. This study was supported in part by Grants-in-Aid for Scientific Research (215H02581) from JSPS.

Assessment and improvement of work environment in the sewing production situated in an older type of building

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Introduction: According to previous studies sewing machine operators spend over 90% of their time indoors and over 30% of their time at work. Because the quality of indoor air is very important for the work environment. The target group of this study was completed of 130 workers from the garment industry in North-East Estonia.

Method: To measure physical and chemical hazards in the present case study, international methods according to Estonian legislation were used. There were studied the chemical (like dust) and physical hazards (like temperature, relative humidity, CO^2 etc) in a medium-sized sewing industry building where employees of small groups (7- 12 sewing machine operators) are located. The measured values were compared to the data of the large hall. The anonymous e-questionnaire was carried out. The rate of responses were over 35%.

Results: Chemical hazards (dust and CO^2) and physical hazards (microclimate, noise and lighting) were collected from various types of workplaces. Five different workspaces were investigated during the summer and winter period. Most of the respondents complained about the temperature being too hot in the workstation in summer and the air inflow being too scarce during winter. From the anonymous online questionnaires came out main problems with ventilation, temperature and dry skin, eyes and throat.

Conclusions: From this study turns out that there are less problems with physical and chemical hazards in the old type industry building because there are small rooms separated by walls. It is easier to achieve the regulation of the mechanical ventilation and suitable microclimate in a small room, where smaller groups of workers are situated. They can use natural ventilation through opening windows. Chemical hazards like dust and carbon dioxide are lower. Illumination aspects like intensity and distribution are better achieved. Small work groups implement the correct ergonomic work postures.

Improving Individualized Thermal Exposure Warning and Advising Systems via User Feedback

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The smartphone application ClimApp (freely available in Google Play and App Store) has been developed to integrate climate service data (weather forecasts) with individual physiological characteristics to provide personalized alerts and advice during challenging thermal conditions. This presentation will provide an overview of the implementation of an adaptive feedback system that has been integrated in ClimApp application to optimize the level of individualization and improve accuracy in the alert-advice system based on feedback from the user.

ClimApp combines individual user characteristics, human thermal models and weather forecast data in a mobile application with the goal to provide protective strategies for an individual. The decisions are made based on output from models for heat (WBGT ISO7243 or something, PHS ISO7933), comfort (PMV ISO7730) and cold (IREQ ISO11079). By calculating the recommended alert limit (RAL), a heat risk indicator is provided to the user in to indicate the severeness of the exposure accompanied by textual advice on how to act in the current situation. The expected thermal strain caused may vary between individuals due to differences in anthropometric characteristics such as height, weight and gender but also as a consequence of different levels of adaptation. Therefore, to fully customize advice to the individual, population averaged output from models will be insufficient, and feedback could be used to tune the advice to the individual demand. Examples of individualization at higher resolution will be presented and discussed along with the benefits of prompting users for feedback in situations that were perceived as more extreme than what the app advice may have indicated on a particular day. This is expected to allow for assessment and updating of individualized adaptation strategies suggested by the ClimApp application to promote better coping strategies and further improve individual health and performance of people exposed to thermally stressful conditions.

Maintenance of high physical fitness by firefighters in Poland

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Introduction: In Poland, firefighters obtain recommendations to maintain physical fitness which is assessed during annual fitness checks. However, access to exercise rooms and exercise equipment varies across individual fire departments. Most often, firefighters train on their own without having an exercise plan. They train favorite sport disciplines. The aim of the project was to develop a physical training program for firefighters. After its preparation, a test training was conducted to determine the weaknesses of the program and to verify it. The objective and subjective test assessment and conclusions are presented.

Method: An 8 week test training, organised in 90 minute sessions, occurring twice a week, was carried out. Younger (25-35 years old) and older (36-45 years old) firefighters, 11 participants in each group, took part in the training. Before starting and after the completion of the entire training cycle, fitness tests with counting the number of repetitions of three selected exercises and physical performance tests with the measurement of oxygen consumption were conducted. Subjective judgments regarding the effectiveness of the training were collected and body mass was registered.

Results: Fitness tests showed better results by 17% to 39% depending on the exercise being performed. The level of physical performance has increased slightly, to a larger extent in the older group. Weight loss was recorded in the younger group of firefighters. Subjective assessments of the training were positive to a higher degree in the older group of firefighters.

Conclusions: The conducted test training was used to verify the developed physical training program. In the final version of the program, the proportion of efficiency exercises was increased and a higher frequency of trainings was proposed, up to a minimum of 3 times a week. The developed program will be made available to every fire department in Poland.

Combined effects of low-dose ice slurry ingestion and forearm cooling on thermoregulation and physical capacity during exercise in hot environments

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Introduction: Although both ice slurry ingestion and forearm cooling are practical strategies to prevent hyperthermia, no research has examined the combined effects of these two on thermoregulation and exercise capacity. The aim of the present study was to determine the combined effects of low-dose ice slurry ingestion and forearm cooling on thermoregulatory responses and exercise capacity in hot environments.

Method: Seven male subjects underwent four experimental trials at 35 °C and 60% relative humidity. The experimental trials consisted of cycle exercise at 55% maximal oxygen uptake (first exercise bout) until rectal temperature reaches 38.5 °C. At the end of the first exercise bout, subjects conducted a 15 min recovery period before continuing with exercise to exhaustion at 75% maximal oxygen uptake (second exercise bout). The four recovery periods were performed under the following conditions: only passive rest (CON), only ice slurry ingestion (SLU), only forearm immersion (ARM), and ice slurry ingestion combined with forearm immersion simultaneously (MIX).

Results: Rectal temperature was significantly lower ($P<0.05$) at the end of the recovery period in MIX compared with CON (MIX: -0.4 ± 0.3 °C, ARM: -0.3 ± 0.2 °C, SLU: -0.2 ± 0.2 °C, CON: 0.0 ± 0.2 °C). Mean skin temperature and subjective rating change was significantly lower ($P<0.05$) during recovery period in MIX and ARM compared with CON and SLU. However, exercise time to exhaustion was longer ($P<0.05$) in SLU compared with CON and MIX (SLU: 11.4 ± 4.0 min, ARM: 8.8 ± 2.4 min, MIX: 8.1 ± 3.1 min, CON: 5.7 ± 1.4 min).

Conclusions: These results suggest that ice slurry ingestion combined with forearm immersion during recovery period was effective in suppression of hyperthermia, but not effective on the exercise capacity in the heat.

Influence of age on perceptual responses to thermal stress at rest and following exercise

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Introduction: Studies have shown that older adults are less able to dissipate heat during exposure to high environmental temperatures. Recent work has indicated that older adults may also be less able than younger adults to implement protective behavioural changes during exercise in the heat, increasing their risk of heat illness.

Method: This study employed a randomised crossover design using Cool (22°C, 40% RH) and Hot (35°C, 40% RH) environmental conditions to compare thermoregulatory behaviour between young (18-35 yrs, n=10) and older (≥65 yrs, n=14) adults during 3 x 10 min of walking at a rating of perceived exertion (RPE) of 13. After a baseline visit including familiarisation with RPE, participants completed two experimental trials, (Cool and Hot). Participants sat at rest for 45 min upon entering the environmental chamber, after which they began walking on a motorised treadmill. Speed was blinded from participants and self-selected to elicit an RPE of 13. Distance (km) walked during each bout was recorded. Rectal temperature (Trec, °C) and heart rate (HR bpm) were recorded every 5 min.

Results: Markers of physiological strain between the Cool (22.1 ± 0.29°C, 42 ± 5% RH) and Hot (35.1 ± 0.23°C, 41 ± 5% RH) trial increased for the older (HR 80 v 93 bpm, $p<0.01$; Trec 37.03 v 37.85 °C, $p<0.01$) and younger group (HR 91 vs 98 bpm, $p<0.05$; Trec 37.57 vs 37.99 °C, $p<0.05$). The older and younger group reduced their total distance walked by 1.5% and 8.0% respectively. Within the older group, a gender difference was evident with the women (n=5) walking 6.7% less distance in the heat, but the men (n=9) walked 1.5% further in the heat.

Conclusions: Older adults, particularly men, appear to be less able to adapt their behaviour during heat stress, resulting in an increased thermal and physiological strain.

Upgrading a thermo-physiological model to predict children skin temperatures in cold environments

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Introduction: Sports clothing for children are currently designed using adult-based knowledge, without any certainty about their real performances in terms of thermal comfort. As far as we know, existing thermo-physiological models do not include children specificities yet. This is why Decathlon's Thermal Laboratory decided to upgrade the Fiala Physiology and Comfort (FPC) Model (ErgonSim) in order to take into account children anthropometry and thermal regulation.

Method: 8 years old boy and girl anthropometric parameters (heights, body regions dimensions, weights, body mass index, and body fat contents) were implemented in the model according to Decathlon's own database. Basal metabolic rates and thermoregulatory responses (sweating, shivering, peripheral vasodilatation and constriction) were adapted for children using available literature data. An experimental study was carried out at Loughborough University involving 9 children (8.4 ± 1.0 years old) walking at 30% VO2max on a treadmill in a climatic chamber set at 4 ambient temperatures (2°C / -5°C / -12°C / -19°C). VO2 uptakes and skin temperatures (forehead, cheek, chest, back, arm, hand, quadriceps, shin and foot) were recorded for each subject. Thermal resistances of the 3 layers clothing ensemble worn were measured using Thermetrics Jordi manikin (16 body regions). The experimental protocol was simulated using the adapted FPC model to compare experimental results with predictions.

Results: Skin temperatures were predicted quite well for covered regions (hands excluded) but not for nude regions. Mean skin temperature was also predicted well, with less than 1°C difference from measurements on average, despite an offset of 2°C at the beginning of the scenario.

Conclusions: First results of the modified model are quite promising. Mean skin temperatures for children in cold environments can be well predicted, which will surely provide new means to evaluate clothing thermal performances. Metabolic rates could be adjusted to improve model accuracy, reducing local differences between predictions and measurements.

Extended post-exercise hyperthermia in the heat in athletes with a spinal cord injury

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Rationale: Hyperthermia most often occurs during exercise, however athletes with a spinal cord injury (SCI) may also be at risk post-exercise due to impaired thermoregulatory function. This study investigated the influence of SCI level on thermoregulation post-exercise in the heat.

Methods: 8 tetraplegic (TP), 7 high paraplegic (HP), 8 low paraplegic (LP) and 8 able-bodied participants (AB) rested for 45 min in 35°C and 50% RH, following exercise at a metabolic heat production of 4 W/kg (TP, AB) or 6 W/kg (HP, LP, AB). Gastrointestinal (Tgi) and esophageal (Tes) temperature, local sweat rate (LSR) and cutaneous vascular conductance (CVC) at the forehead and back, and forearm blood flow (FBF) were assessed.

Results: Tgi in TP increased throughout recovery whereas in AB it reduced, reaching 38.77°C (95% CI: 38.63, 38.91) and 37.07°C (36.93, 37.21) respectively after 45 min ($p<0.001$). Similarly, Tes was highest after 45 min for TP (38.30°C [38.19, 38.41]) but lowest for AB (36.54°C [36.44, 36.65]). Immediately post-exercise, AB had a greater forehead LSR (0.76 $mg \cdot cm^{-2} \cdot min^{-1}$ [0.68, 0.84]) and back LSR (0.57 $mg \cdot cm^{-2} \cdot min^{-1}$ [0.52, 0.61]) compared to TP who exhibited no sweating ($p<0.001$). TP had greater forehead CVC ($p<0.001$) and FBF ($p=0.003$) than AB. Immediately post-exercise at 6 W/kg, Tgi and Tes reduced in AB, LP and HP. HP consistently demonstrated higher Tgi and Tes ($p<0.001$), despite greater forehead and back LSR relative to LP and AB ($p<0.001$), and greater forehead ($p=0.001$) and back CVC ($p=0.020$) than AB.

Conclusions: Both core temperature indices continued to rise post-exercise in TP, due to a lack of sweating and dry heat transfer. Greater LSR and CVC post-exercise in HP does not fully alleviate their higher core temperature compared to LP and AB, who demonstrate a similar return to baseline values. HP and particularly TP athletes are at greater risk of post- exercise hyperthermia.

Preliminary evidence of sex-related differences in the effect of aging on whole-body heat loss during exercise in dry-heat

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Introduction: During vigorous exercise in dry-heat, young females display attenuated whole-body total heat loss (evaporative ± dry heat exchange) relative to males. Similarly, older males and females demonstrate marked reductions in total heat loss relative to their younger counterparts during moderate-to-vigorous exercise in a hot-dry environment. However, the interactive effect of sex and age on total heat loss during exercise in the heat remains unexplored. Given that older females are known to be at a greater risk of heat-related mortality compared to males, it is possible that the age-related decline in heat loss is accelerated in females relative to males. We therefore sought to evaluate this hypothesis.

Method: 24 young (18-30 years; 12 males, 12 females) and 24 older (50-65 years; 12 males, 12 females) habitually active adults completed three, 30-min bouts of semi-recumbent cycling at increasing metabolic heat productions of 150 [Light], 200 [Moderate], and 250 [Vigorous] W/m^2 (equivalent to ~30/37%, 42/49%, and 53/61% VO2peak in young/older adults), each seperated by 15-min recovery, in dry heat (40°C, ~15% relative humidity). Metabolic heat production and total heat loss were measured using indirect and direct calorimetry, respectively.

Results: The effect of age on total heat loss was dependent upon sex during light, moderate, and vigorous exercise (all $p<0.05$), such that total heat loss was 15, 14, and 16% lower in older compared to young females. In contrast, older males demonstrated a 12% reduction in total heat loss relative to young males during vigorous exercise only ($p<0.05$).

Conclusions: Our preliminary findings indicate that females demonstrate a greater age-related decline in whole-body heat loss relative to males, which may explain, at least in part, the increased heat-related mortality in older females.

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An evaluation of whole-body heat exchange in older adults exposed to extreme day-long heat.

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Introduction: Investigations into the physiological strain experienced by older adults during extreme heat events (EHE) have typically employed short-duration exposures (≤3 hours), even though EHE occur over extended periods. This study was therefore designed to advance our understanding of whole-body heat exchange and the development of hyperthermia during a day-long exposure to EHE-like conditions.

Method: Five young (22 [SD 2] years; one woman) and six older (70 [3] years; two women) adults rested in ambient conditions of 40°C (10% relative humidity) for nine hours; representative of exposure conditions experienced during EHE. During the initial and final three hours, body heat storage was assessed as endogenous heat production (indirect calorimetry) minus whole-body heat loss (direct calorimetry). Rectal temperature was monitored continuously.

Results: Young adults achieved heat balance (heat storage = 0 W) during the nine-hour exposure (hour three: -1 W [95% CI: -6-4]; hour nine: 5 W [-4-14]). Conversely, heat balance was not achieved in the older adults, as evidenced by a positive rate of heat storage at the end of the initial (7 W [3-10]) and final three hours (8 W [1-15]). Rectal temperature was elevated from pre-exposure values (young: 37.03°C [0.29]; older: 36.89°C [0.26]) by 0.52 (0.46-0.58) and 0.97 (0.67-1.37) in the young (37.55°C [0.28]) and older (37.83°C [0.47]) adults, respectively, at hour three. However, while rectal temperature had not changed (0.10°C [-0.18-0.34]) from the three-hour value in the young (37.65°C [0.20]) at hour nine, an additional 0.23°C (0.11-0.45) increase was seen in the older group (38.07°C [0.15]).

Conclusions: These preliminary outcomes indicate that during exposure to EHE-like conditions, older individuals do not achieve heat balance and experience progressive hyperthermia. Data gleaned from short-duration exposures (≤3 hours) may underrepresent the physiological strain, and therefore risk of adverse health events, incurred by older adults during EHE.

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Development of a methodological approach used to assess comfort and thermal tolerance of children exercising at zubzero temperatures

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Introduction: Human thermoregulatory models along with thermal sensation data have been effective predictors of thermal comfort for adults, however, differences in thermoregulatory and perceptual responses in children questions the validity of using adult- based models to predict children's thermal comfort. Aim is to test a methodology investigating thermoregulatory and perceptual responses of children exercising in cold environments and determine if the data can be translated into thermal comfort for later modelling.

Method: A heavily insulating clothing combination was tested at 2, -5, -12 & -19°C and lighter clothing at 16, 9, 2 & -5°C (wind speed <0.3m/s, relative humidity <50%). Anthropometrics were taken and a submaximal test on the treadmill performed. Pre- pubescent participants dressed into the assigned clothing and walked continuously at a relative intensity of 35% VO2max for up to 60 minutes in the climatic chamber. Heart rate (bmp), oxygen uptake (ml/min/kg), clothing microclimate (°C, %) and skin temperature at 9 body sites (°C) were measured, thermal comfort (yes/no), sensation and preference (-3 to +3) ratings were asked every 10 minutes. Additionally, 15-minute pre- and post-cold exposure data were collected.

Results: This methodology allowed to determine the ambient temperatures at which pre-pubescent children were most thermally comfortable in by establishing the limits of hot and cold discomfort in each clothing combination. Preliminary data show that participants (n=9) were most thermally comfortable at -12°C in the heavily insulated clothing (62.5% were in comfort, 12.5% in hot discomfort and 25.0% in cold discomfort). In lighter clothing (n=7) the most comfortable temperature was 2°C (85.7% were in comfort, 14.3% were in hot discomfort and 0% in cold discomfort).

Conclusions: Providing specific data on thermal responses and comfort in children allows clothing companies to improve the design, and in the present, the communication of their products for children.

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High-resolution whole-body mapping of warm and cold thermosensitivity in people with multiple sclerosis

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Introduction: Multiple sclerosis (MS) is a chronic autoimmune neurological disease affecting >2.5M people worldwide. Sensory symptoms (e.g. altered thermal sensations) are common in MS. However, data is lacking on whether and to what extent warm and cold sensitivity is impaired across the body in MS. The aim of this study was to map with high resolution warm and cold sensitivity across the body of people with MS and compare it to a control group.

Methods: Fourteen people with MS (48±15y; BSA 1.94±0.25m^2) and 9 age-matched healthy controls (CTR; 47±14y; BSA1.84±0.21m^2) underwent a quantitative sensory test in a thermoneutral environment (24°C, 50%RH) where they rated on a numerical rating scale (10=very warm, 0=neutral, -10 very cold) local thermal sensations arising from the application (2s) of a warm (38°C) and a cold (26°C) thermal probe (1.32cm^2) to 115 bilateral skin sites across the front and back of the body. We analysed the independent effect of MS and body region on thermosensitivity and on its inter-individual variability (standard deviation).

Results: Thermosensitivity to both warmth and cold varied significantly across body regions ($p<0.01$) with no differences between MS and CTR (warm-front: $p=0.483$, back: $p=0.112$; cold-front: $p=0.552$, back: $p=0.517$). Inter-individual variability was greater in MS than in CTR (warm-front MS=2.75±0.53, CTR=2.18±0.64, $p<0.01$; back MS=2.85±0.55, CTR=2.06±0.65, $p<0.01$) (Cold-front MS=2.97±0.61, CTR= 2.08±0.62, $p<0.01$; back MS= 2.96±1.12, CTR= 2.16±0.70; $p<0.01$).

Conclusions: We have developed the most detailed thermosensitivity maps in MS to date, and demonstrated that regional patterns of thermosensitivity are largely preserved in the presence of MS. Yet, we show that people with MS present greater individual variability in warm and cold sensitivity than CTR. Disability levels induced by MS likely contribute to a greater variability in regional patterns of thermosensitivity. This should be considered when assessing individual vulnerability to thermal stress in MS.

Delayed Time Course of Nitric Oxide-Dependent Reflex Vasodilation in Aged Human Skin

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Introduction: Attenuated nitric oxide (NO)-dependent reflex vasodilation at a fixed rise in core temperature has been observed in aged skin; however, the temporal development of this impairment during whole body heating is unknown. We hypothesized that the NO contribution to reflex vasodilation would be attenuated in older versus young adults at each 0.1°C rise in oral temperature (Tor). We further hypothesized that the Tor threshold for NO-dependent dilation would be higher in older adults, but would be normalized with the administration of antioxidant or cofactor interventions.

Method: Retrospective analysis of skin blood flow responses during whole-body heat stress (water-perfused suit) was performed for 11 young (22±1 yr) and 28 older (71±2 yr) participants under control, NO synthase-inhibition (20mM NG-nitro-L-arginine methyl ester; L-NAME), or intervention (local or systemic) conditions. Red cell flux was measured by laser-Doppler flowmetry (LDF). Cutaneous vascular conductance was calculated (CVC=flux/mean arterial pressure) and expressed as a percentage of maximum (%CVCmax; 28mM sodium nitroprusside+43°C). NO-dependent dilation was calculated for each 0.1°C rise in Tor as the difference in %CVCmax between control/intervention and L-NAME sites.

Results: NO-dependent dilation increased from baseline after a 0.2°C rise in Tor ($p<0.01$) in young, but after a 0.5°C rise ($p<0.05$) in older subjects. NO-dependent dilation was greater in young versus older subjects after a 0.2°C rise in Tor (all $p<0.01$). Intervention augmented NO- dependent dilation versus control at every Tor (all $p<0.05$) in older adults, but did not influence the threshold for NO-dependent dilation.

Conclusion: In addition to previously reported attenuations in NO-dependent dilation in older adults during passive heating, these data suggest greater increases in core temperature are necessary to elicit NO-dependent dilation in the aged cutaneous vasculature. Local or systemic antioxidant or cofactor treatment augments NO-dependent dilation, but does not alter the temporal development of the response in older adults.

Inducing an inflammatory response in people with a disability; time to raise the temperature?

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Introduction: The inflammatory response to a bout of exercise is suggested to exert beneficial effects on insulin signalling and chronic low-grade inflammation. However, severe disability, such as a cervical spinal cord injury (CSCI), may prevent individuals from inducing this response using exercise. As the increase in body temperature partly mediates the exercise-induced inflammatory response, passive heating may be a viable alternative to improve metabolic health in people with a disability.

Methods: Here we present five studies investigating the efficacy of exercise and hot water immersion (HWI) to induce an inflammatory response in people with CSCI as well as able-bodied individuals. First, the acute interleukin-6 (IL-6) response to a wheelchair half-marathon and HWI was studied in people with CSCI. Thereafter, the acute and chronic effects of HWI on plasma IL-6 concentration and the expression of monocyte intracellular heat shock protein 72 (iHsp72) were investigated in able-bodied individuals, as well as its impact on fasting glucose and insulin concentration. Finally, an ex-vivo model was employed to further mechanistic understanding into the hyperthermia-induced acute inflammatory response.

Results: The acute IL-6 response to exercise was markedly dampened in people with CSCI. However, in both able-bodied individuals and people with CSCI, HWI induced an acute IL-6 response. Neither the acute or chronic HWI-intervention increased iHsp72 expression. Nonetheless, fasting glucose and insulin were reduced following the chronic HWI-intervention. Incubation of whole blood at 40℃, but not 38.5℃, induced an acute iHsp72 response, suggesting that a large increase in core temperature is needed to elevate iHsp72 expression.

Conclusions: The elevation of body temperature can independently induce an acute IL-6 response, while a chronic HWI-intervention may enhance glucose metabolism. Although its efficacy to alter iHsp72 expression requires further investigation, these findings may be exploited to create alternative health promoting strategies for people with a disability.

Managing occupational heat stress in a diverse working population

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Despite extensive implementation of procedures to mitigate heat-illness in workers, heat-related morbidity/mortality remains elevated. This can in part be attributed to the fact that exposure limits for work in the heat recommended by occupational safety agencies worldwide assume a "one size fits all" approach to safeguard the health and safety of workers. They fail to consider key factors such as sex, age, health status and others which we reported can markedly alter a person's tolerance to heat thereby leaving a large segment of the workforce under-protected. For instance, we showed that the body's response to heat is impaired in healthy adults as young as 40 years. This impairment is worse in women and in older adults, especially in those with health conditions (e.g., diabetes, hypertension, other). In these individuals, heat tolerance is reduced as the body is unable to cool itself via the evaporation of sweat, placing them at increased risk of heat-induced illnesses/death. These limitations are exemplified by our findings on exposure limits for workers. For decades, industry has relied upon government recommended exposure limits such as the American Conference of Governmental Industrial Hygienists Threshold Limit Values to manage the health and safety of workers exposed to heat. However, we showed these guidelines fail to protect workers, especially older (≥40 years) workers, from potentially dangerous increases in core temperature which is an underlying cause for many workplace injuries and reduced productivity. This presentation examines the shortcomings of the current 'one size fits all' approach to managing occupational heat strain. Further, we evaluate future directions for preventing heat-related illness and maximising productivity in our diverse working population through the application of individualized work exposure limits, and the protection of workers through the application of technologies to track heat strain.

Inter-individual factors and screening criteria for occupational heat strain

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Introduction: Climate-driven increases in heat exposure as well as societal changes such as population aging generate important public health risks, as specific population groups have increased susceptibility to heat stress. Most heat-induced deaths are of cardiovascular origin, yet there is no increase of cardiovascular admissions during heatwaves. This has led to the conclusion that deaths from cardiovascular disease during heatwaves occur rapidly before the patient is admitted to a hospital and that the first hours of heat exposure have a major impact on cardiovascular mortality. To address this vital public health issue, it is vital to develop criteria to identify and, ultimately, protect individuals who are more susceptible to heat stress, particularly those who are still part of the workforce and, thus, are physically active during periods of increased heat. This presentation will describe simple and practical sex-specific screening criteria for detecting susceptibility to heat stress during work and leisure activities in hot environments. The screening criteria have been developed from simple information derived from age, anthropometry, and cardiorespiratory fitness and have been recently validated during large studies in laboratory as well as occupational settings. This work has been supported by European Union's Horizon 2020 research and innovation programme under the project 'Heat-Shield' (grant agreement no. 668786).

Conclusions: The developed criteria are based on robust risk factors that have been rigorously studied during the past decades and can be used as simple and effective means for detecting the vast majority of people who are less able to work or play in hot environments owing to their reduced capacity to dissipate heat. Therefore, the proposed criteria can play an important role in preventing and mitigating the public health risks caused by increased ambient temperatures.

How well do thermal Indices Quantify the Magnitude of Occupational Heat Strain?

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Introduction: Hundreds of thermal indices have been introduced aiming to quantify the magnitude of heat stress/strain, reduce heat related illness, and enhance productivity. However, the exact number of thermal indices which are depended to at least one out of the four environmental factors (air temperature, humidity, radiant heat, and air velocity) remains unknown. Moreover, it is unclear which of these thermal indices actually reflect heat strain and physiological function in occupational settings. Therefore, the purpose of this study was to identify all the thermal indices developed during the last century, by conducting a systematic review and meta- analysis of the literature.

Methods: Following PRISMA guidelines, we searched six databases for relevant studies. No language or any other study design limits were applied. Furthermore, we supplemented the electronic database searches with manual searches for published studies in international trial registers, ISO standards, and websites of international agencies (e.g., World Health Organization and World Meteorological Organization). Funding was provided by 'Heat-Shield', European Union's Horizon 2020 research and innovation programme under the Grant agreement no. 668786.

Results: Of 556 records identified through our systematic search, 104 studies written in 9 different languages met the eligibility criteria for inclusion in the study. The analyzed studies included 172 thermal indices. The first index identified was developed in 1915 while the last one in 2016. Interestingly, a very strong relationship was found between the year of development and the number of thermal indices developed ($r=0.97$, $p<0.01$), indicating that more indices should be expected in the future. Finally, a computer software has been developed to simplify the calculation of the identified thermal indices.

Conclusions: Based on the systematic review, this presentation will describe the relationship between thermal indices and the thermophysiological responses of workers who work in different industrial sectors around the world.

Interactive effectsof aging and other individual factors on occupational heat strain

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Workers in many industries (e.g. mining, electric utilities, among others) often perform prolonged, strenuous work in the heat. Such conditions cause considerable heat strain, which can elevate heat illness risk. The challenge to temperature regulation posed by occupational heat stress is particularly great for the rising number of older workers, who demonstrate marked reductions in heat loss capacity (primarily via sweating) relative to their young counterparts. However, while our understanding of the independent effects of aging on thermoregulatory function is extensive, we know considerably less regarding the interactive effects of aging and other inter-individual factors (e.g., sex, chronic disease, others) and intra-individual factors that vary commonly both within and among work days (e.g., hydration and acclimation state, consecutive work shifts, work type). Although some of these factors may exert a restorative effect on thermoregulatory function in older adults, others may exacerbate occupational heat strain by increasing the magnitude of any age-related impairments in heat loss. Improving our understanding of these effects is therefore critical for stratifying risk of heat-related injury during occupational heat exposure. In recent years, work from our laboratory has begun to uncover the interactive effects of age and other inter-individual factors (e.g., aerobic fitness, chronic disease, sex) as well as intra- individual modulators (e.g., hypohydration, heat acclimation) on whole-body heat exchange. This presentation will describe these observations, providing attendees with a unique calorimetric perspective on the potentially divergent effects of these factors in young and older workers, while also highlighing important gaps in our understanding that warrant futher invesigtation.

Personalized Heat Warning - Alert and Advising Systems for improved Health

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[a] www.Heat-Shield.eu (EU Horizon 2020 grant agreement No 668786)

[b] http://www.lth.se/climapp/ (ClimApp - Free installation via Google Play and App Store)

The present talk will provide two examples on personalized heat alert-advice systems, both aiming at improving information targeting the individual to minimize negative effects of thermal stress on human health and daily day functioning.

Excess deaths during heat waves signify the importance of weather-warning systems and accompanying preventive plans for minimizing hazardous effects of extreme thermal events. However, human health and performance are affected at much lower environmental heat strain levels than those directly associated with increased mortality. This presentation will discuss and present examples of the importance for individualized, appropriate heat alert. One example from the Heat- Shield project specifically focused on occupational health and the second system developed as a smartphone application (ClimApp) with several thermal models covering a broader range of thermal scenarios to support suitable thermoregulatory behavior during challenging climatic conditions. Both systems rely on thermo- physiological models and translation of general weather warnings into individual alert and personalized adaptation strategies. For a scenario representing a typical sunny summer day in southern Europe (30°C dry air and WBGTsun = 27°C; equal or higher heat observed more than 80 days in Italy in 2018), an outdoor worker performing demanding manual tasks may experience high heat stress and a total sweat loss of ~ 10 liter during a work shift, while an age and gender matched indoor worker performing light manual tasks may loose only ~1½ liter over an entire day. Considering, that inter- individual and gender differences will add further variation, it becomes clear that personalized guidance on hydration and behavior to secure health is of major importance. This should be incorporated in heat-alert systems aiming at supporting workers ability, maintaining healthy and productive lives, which in addition should be considered as integrated parts of public health.

The effect of ethnicity on whole-body heat exchange in first-generation Black and White Canadians during exercise in the heat

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Introduction: Studies show that Black individuals born in temperate climates (e.g., North America) display higher heat-related mortality than their White counterparts, suggesting that Blacks may be at a thermoregulatory disadvantage during heat stress. However, evidence of ethnicity-related differences in heat loss is equivocal. We therefore used direct calorimetry to evaluate the effects of ethnicity on whole-body heat exchange in first-generation Canadians during exercise in the heat, hypothesizing that Blacks would display reductions in total heat loss (evaporative ± dry heat exchange) that exacerbate body heat storage relative to Whites.

Method: Whole-body total heat loss and body heat storage were assessed in 8 young, first-generation Black and White Canadians, with matched fitness and physical characteristics. Participants performed three, 30-min bouts of cycling at fixed rates of metabolic heat productions of 200 [Light], 250 [Moderate] and 300 W/m^2 [Vigorous] (equivalent to ~30, 45 and 60% of VO2peak), separated by 15-min recovery, in dry-heat (40°C, 15% relative humidity).

Results: Total heat loss (mean ± SD) was similar between groups (all P>0.05), averaging 181±9 [Light], 224±11 [Moderate] and 251±21 W/m^2 [Vigorous] in Blacks, and 176±15, 222±19 and 254±15 W/m^2 in Whites. Accordingly, cumulative body heat storage across all exercise bouts did not differ significantly between Blacks (492±146 kJ) and Whites (535±125 kJ) (P=0.54).

Conclusions: In first-generation Black and White Canadians, ethnicity does not significantly modulate whole-body total heat loss nor body heat storage, regardless of the exercise-induced heat load. These outcomes indicate that increases in vulnerability among first-generation Black Canadians are not owed to impairments in the body's capacity to dissipate heat.

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Skin Wettedness Independently Modulates Thermal Behavior during Passive Heat Stress

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Introduction: Increased skin wettedness contributes to thermal behavior. We tested the hypothesis that greater skin wettedness augments thermal behavior during passive heat stress (HS).

Methods: Eleven healthy subjects (25±2 y; 5 females) donned a water perfused suit (WPS) initially perfused with 34ºC water, and completed three trials in a 28.5±0.4ºC environment. The trials involved a 20 min baseline, a 60 min period in which ambient humidity was elevated to 26±3 (HUM30), 49±4 (HUM50) or 67±5% RH (HUM70), and 60 min of progressive HS with a stable ambient humidity. Subjects thermally behaved when their neck was thermally uncomfortable by pressing a button. Each button press initiated 30 s of -20ºC antifreeze perfusing through a custom-made device on the dorsal neck. Mean skin temperature (Tsk, 10-site), intestinal temperature (Tcore, telemetry pill), mean skin wettedness (Wsk, 10-site), and neck device temperature (Tdevice) were measured continuously. Thermal behavior and the motivation to behave were determined from Tdevice and cumulative button presses. Data are presented as mean +/- SD.

Results: Tsk (by +1.9±0.1ºC) and Tcore (by +0.4±0.0ºC) increased during HS ($P \leq 0.04$), but were not different between conditions ($P \geq 0.15$). Wsk was elevated in HUM70 vs. HUM30 at 30-60 min (60 min: by +0.06±0.09 a.u.), and in HUM70 vs. HUM50 at 40-50 min (50 min: by +0.10±0.08 a.u.) of HS ($P \leq 0.03$). Tdevice was lower for HUM70 vs. HUM30 at 40-50 min (50 min: -3.4±5.7ºC), and in HUM70 vs. HUM50 at 30-40 min (40 min: -5.5±5.6ºC) of HS ($P \leq 0.04$). Cumulative button presses were greater for HUM70 vs. HUM30 (60 min: +3±4 presses) and HUM50 (60 min: +2±7 presses) from 40-60 min of HS ($P \leq 0.02$).

Conclusions: Skin wettedness independently modulates thermal behavior during passive HS. Therefore, an impaired ability to generate skin wettedness may delay thermal behavior and theoretically increase the risk of a heat-related health event.

Quantifying Physical Work Capacity in the Heat: One Hour versus Full-Day Heat Exposure

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Introduction: Physiological responses to heat stress are commonly assessed during short experimental exposures. Under the climate change context, this approach has been used in laboratories to quantify the effects of high workplace temperatures on physical work capacity (PWC). However, in real world occupational settings, workers typically experience heat stress over much longer periods (i.e. up to a full shift). This ongoing study examines both the changes in PWC and physiological responses during a 7-hour simulated working day in the heat.

Methods: A crossover study design was employed with four males (age = 24.7 (2.6 SD)) each completing four separate experimental trials (separated by a minimum of 7 days) consisting of six 50-min work-bouts, interspersed by 10-min rest intervals. Between the third and fourth work-bout, a standardised meal was provided during a 1-hour lunch break. Work was performed on a treadmill at a fixed cardiovascular strain (heart rate of 130 b·min^{-1}). Rectal (Tre) temperature was monitored continuously, and PWC during each work-bout was quantified as the energy expended (kJ). Counterbalanced work days were performed in a cool (reference) environment (WBGT = 12°C) and in heat (WGBT = 29; 33; 36°C).

Results: PWC declined as WBGT increased. Relative to the reference condition, percentage PWC as quantified from the first work-bout of the day versus the sum of all 6 work-bouts was: 29°C WBGT: 90.4 vs. 89.6%; 33°C WBGT: 68.9 vs. 66.6%; 36°C WBGT: 37.9 vs. 27.9%. Hence, a synergistic degradation of PWC with repeated work bouts was observed at 36°C WBGT only. Additionally, Tre increased with WBGT but did not differ within conditions across repeated work-bouts.

Conclusion: The preliminary evidence suggests that changes in PWC during a full working day may be estimated from a single work-bout. Only under the most severe, uncompensable heat stress conditions may this approach underestimate the degradation of PWC. Ongoing data collection aims to extend these findings.

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Drinking to thirst sufficiently off-sets dehydration during a 3-h simulated heatwave exposure in young healthy individuals

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Rationale: To compare the impact of different fluid replacement practices on the development of dehydration and the associated changes in thermal and cardiovascular strain during an ecologically valid heatwave simulation.

Methods: Twelve participants (25±4 years) completed four separate 180-min trials, exercising at a fixed average intensity of 3 METs in 40.1±0.6°C, 40.4±2.1%RH. In each trial a different hydration plan was employed; i) *ad libitum* consumption of 20°C water (ALTAP); *ad libitum* consumption of 4°C water (ALCHILL); iii) no fluid replacement (NOFR); iv) full replacement of sweat loss (FULLFR). Fluid consumption (FC), resultant dehydration (%DEH), rectal temperature (T_{re}), rate pressure product (RPP), mean skin temperature (T_{sk}), and local sweat rate (LSR) were measured/determined.

Results: FC was greater in ALTAP (1.30±0.41 L) than ALCHILL (1.03±0.32 L; P=0.003). %DEH in NOFR was 1.93±0.28%. In comparison, %DEH was lower in ALCHILL (0.43±0.64%; P<0.0001), ALTAP (0.11±0.76%; P<0.0001), and FULLFR (0.01±0.12%; P<0.0001). The change in T_{re} from rest was greater in NOFR trial (1.05±0.27˚C) compared tobALTAP (0.72±0.30˚C; P<0.0001), FULLFR (0.74±0.35˚C; P<0.0001) and ALCHILL (0.76±0.25˚C; P<0.0001). After 180 min, RPP was higher in NOFR (12389±1578 mmHg·min^{-1}) than in FULLFR (11067±1292 mmHg·min^{-1}; P<0.0001), ALCHILL (11089±1795 mmHg·min^{-1}; P<0.0001) and ALTAP (11214±2078 mmHg·min^{-1}; P<0.001).
No differences in T_{sk} or LSR were observed between trials.

Conclusions: No fluid replacement throughout a 180-min exposure to realistic heatwave conditions at a work rate matching everyday activity levels exacerbated both thermal and cardiovascular strain. *Ad libitum* consumption of 4◎C or 20◎C water was sufficient to prevent levels of dehydration that exacerbate physiological heat strain, with 4°C water seeming to blunt thirst more, and hence fluid intake relative to 20°C water.

Extending work tolerance time in the heat in protective ensembles with commercially available cooling methods

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Introduction

Physical roles necessitating the use of chemical, biological, radiological, or nuclear (CBRN) protective ensembles in the heat accentuate thermal and cardiovascular strain during work. As a result, work tolerance times are shortened with an increased threat of heat exhaustion if work is continued. We, therefore, investigated commercially available cooling methods and their ability to reduce physiological strain and/or extend work tolerance time in those working in the heat dressed in a CBRN protective ensemble.

Methods

Eight males wore a CBRN ensemble (MT94, Lion Apparel, USA; 15.3 kg) and walked for a maximum of 120 minutes at 35 °C, 50 % relative humidity. In a randomised order, participants completed the trial with no cooling and one of four cooling protocols: 1) ice-based cooling vest (IV), 2) a non-ice-based cooling vest (PCM), 3) ice slushy consumed before work, combined with IV (SLIV) and 4) a portable battery-operated water-perfused suit (WPS). Mean with 95 % confidence intervals are presented.

Results

Tolerance time was extended in PCM (46 [36–56] mins, $P = 0.018$), SLIV (56 [46–67] mins, $P < 0.001$) and WPS (62 [53–70] mins, $P < 0.001$), compared with control (39 [30–48] mins). Tolerance time was longer in SLIV and WPS compared with both IV (48 [39–58 mins]) and PCM ($P \leq 0.011$). After 20 min of work, HR was lower in SLIV (121 [105–136] beats·min^{-1}) and WPS (117 [101–133] beats·min^{-1}) compared with control (137 [120–155] beats·min^{-1}), IV (130 [116–143] beats·min^{-1}) and PCM (133 [116–151] beats·min^{-1}) (all $P < 0.001$).

Conclusion

All cooling methods utilised in the present study can reduce physiological strain, while SLIV and WPS are most likely to extend tolerance time for those working in the heat dressed in a CBRN ensemble.

The Application of Menthol in Sport, Exercise and Occupational settings: to apply, ingest or discard?

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The cold-receptor agonist menthol has been utilised to improve performance by imparting feelings of coolness and freshness to alleviate thermal discomfort. These effects are mediated by peripheral cold-sensitive neurons and trigeminal nerves of the face and oral cavity via activation of TRPM8 channels by either applying, ingesting or swilling menthol solutions. The forcing function exerted by topically applied menthol is probably influenced by a combination of factors, including the percentage of body surface area (BSA) exposed, body region, and dose, but the weighting of each requires clarification, as do factors influencing oral administration. Topically, a greater menthol-mediated forcing function has been shown to alter thermoregulation resulting in heat gain, but the precise mechanisms require clarification. It is unknown whether there is a similar effect when menthol is administered orally, but higher concentrations are reportedly preferred. Consequently, menthol has the potential to improve thermal perception but evoke heat gain responses placing biophysical and behavioural thermoregulation in conflict. Nevertheless, there is a growing body of literature that supports the efficacy of menthol application to improve endurance performance and, more recently, muscular performance. Oral menthol application has been shown to improve time to exhaustion and time trial performance with emerging evidence in power based activities. Independently of the heat storage response, topically applied menthol has also been shown to improve endurance performance and enhance recovery from exercise-induced muscle damage, possibly due to increased motor unit activation. Both methods of application have consistently been shown to ameliorate subjective measures of thermal strain during exercise. Accordingly, the aim of this symposium is to present key literature on the perceptual, thermoregulatory and performance effects of menthol and actively debate the merits of: the medium of application, advised protocols for menthol use during these modalities, the timing of application and the resultant thermoregulatory effects.

Mechanisms through which menthol acts on human temperature regulation and perception, and possible effects on muscle function

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Menthol is one of the world's most widely used flavors and fragrances, and owing to its cooling and analgesic properties, it has long been used to alleviate symptoms arising from a number of maladies, from the common cold to musculoskeletal pain. More recently, menthol has been used as an ergogenic aid to alter perception and performance, and as part of an approach for studying the physical basis of temperature sensation and thermoregulatory function in humans. The purpose of this opening presentation is first to review the mechanisms whereby menthol is thought to exert its influence, and second, to explore its influence on muscle function *per se*. Specifically, Part One of this presentation will explore possible mechanisms through which menthol acts on human temperature regulation and perception. This will include an overview of what menthol is, and common uses. A more general review of the physical basis of human thermosensitivity will follow, with emphasis on the family of temperature- activated Transient Receptor Potential (TRP) ion channels, focusing on the TRP Melastatin 8 (TRPM8) ion channel and its interaction with menthol in primary sensory neurons. The afferent pathways and central sites of integration arising from menthol exposure will be reviewed, along with the associated perceptual and thermophysiological responses. Various factors thought to influence menthol's forcing function when taken orally or topically will also be presented. Part Two of this presentation will explore the possible influence menthol exerts on muscle function when applied topically. Specifically, menthol's possible influence on recovery of muscle soreness and gross measures of physical performance following exercise- induced muscle will be reviewed, along with its acute influence on muscular strength, power, and joint range of motion. Attendees will be given a comprehensive overview of current research in this area, as well as gaps in our knowledge, and directions for future studies.

The effectiveness of orally applied L-menthol on exercise performance in the heat

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During exercise in the heat, increasing thermal load leads to thermo-behavioral adjustments in exercise performance, due to greater perceptual and physiological strain. Behavioral reductions in exercise intensity in the heat are initially mediated via rises in skin temperature, which alter thermal perception (comfort and sensation) and later by rises in core temperature, which increase cardiovascular strain and perceived exertion. Therefore, thermoregulation may be ordered and dependant on the magnitude, timing and/or prioritisation of afferent signals.

Non-thermal cooling via L-menthol has been shown to enhance exercise performance in the early and latter stages when delivered orally at a concentration of 0.01%. Indeed, during periods of progressive thermal stress, imposed by the combination of maximal exercise and environmental heat and humidity, L-menthol has been shown to offer an immediate cooling stimulus thus extending exercise capacity. However, repeated administration of L-menthol during exercise in the heat, as thermal load increases, is unable to recover a decline in work rate. Therefore, it is unclear whether the potency of L-menthol is sustained upon frequent application and what strategies are needed in both sporting and occupational settings to optimise its effectiveness.
In this part of the symposium we will consider oral delivery of L-menthol and its potential for reducing an individual's perception of heat stress with associated effects on exercise tolerance in the heat. We will also examine the frequency of use, optimal concentration, timing and novelty of L-menthol in a sporting and occupational context.

The effects of single and repeated applications of menthol to the skin on endurance exercise performance in the heat

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Endurance exercise performance frequently takes place in conditions that pose an increased risk of heat illness. For example, the next Olympic games is set to be staged in Tokyo, Japan, and will take place in high ambient temperatures combined with a high relative humidity thereby minimising viable avenues for heat loss. Accordingly, exercise performance is likely to be impaired through multifaceted mechanisms. One early contributor to the slowing exercise pace is the sensation of becoming hot and uncomfortable caused by hot skin temperatures although elite athletes are accustomed to ignoring these sensations thereby increasing their risk of heat related collapse. The topical application of menthol to the skin may assist in facilitating the uncoupling of thermal state from perceptual state by stimulation of TRPM-8 thermoreceptor thereby stimulating cool sensations and alleviating thermal discomfort in a manner similar to temperature reduction itself. At low concentrations of sprayed Menthol (0.05% concentration) it has been noted that this altered thermal perception is not matched with any (measurable) change in thermoeffector response. At higher concentrations, it has been noted that topical menthol application impairs some heat defence mechanisms (i.e. vasoconstriction) and altered sweating thereby increasing the risk of heat illness whilst relieving thermal discomfort. This part of the symposium explores the extant literature on single and repeated topical applications of menthol to the skin with a view to describing the performance and thermoregulatory consequences of menthol use during sport. We will also consider the research evidence for menthol use in the occupational setting although little is known about the latter. This section of the symposium will conclude with an appraisal of the risk of heat illness that could be caused by menthol application, practical considerations of the application modality and future directions for menthol use in the sporting and occupational setting.

Oral application of L-menthol in the heat: from pleasure to performance

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When menthol is applied to the oral cavity it presents with a familiar refreshing sensation and cooling mint flavour. This may be deemed hedonic in some individuals, but may cause irritation in others. This variation in response is likely dependent upon trigeminal sensitivity toward cold stimuli, suggesting a need for a menthol solution that can be easily personalised. Menthol's characteristics can also be enhanced by matching colour to qualitative outcomes; a factor which can easily be manipulated by practitioners working in athletic or occupational settings to potentially enhance intervention efficacy.

This presentation will outline the efficacy of oral menthol application for improving time trial performance to date, either via swilling or via co-ingestion with other cooling strategies, with an emphasis upon how menthol can be applied in ecologically valid scenarios. Situations in which performance is not expected to be enhanced will also be discussed. An updated model by which menthol may prove hedonic, satiate thirst and affect ventilation will also be presented, with the potential performance implications of these findings discussed and modelled. Qualitative reflections from athletes that have implemented menthol mouth swilling in competition, training and maximal exercise will also be included.

Influence of core body temperature-mediated changes in cerebral blood flow regulation during exercise

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Introduction: Cerebral blood flow (CBF) decreases by approximately 10-15% for every 1°C rise in esophageal temperature (Tcore) during passive heat stress. Acute moderate-intensity exercise (e.g., 30-45 mins at 50-60% workload max) also increases Tcore (+0.7-0.8°C); however, likely due to small elevations in arterial PCO_2 and metabolism, such exercise increases CBF (+10- 20%). This study aimed to isolate the role of Tcore from PCO_2 on CBF regulation during submaximal cycling exercise.

Methods: Healthy adults (n=8 completed; 25±4 yrs) participated in two separate interventions: 1) 45 mins semi-recumbent cycling (EX; 50% workload max); and 2) 45 mins passive heat stress (HS; 49°C water-perfused suit) to match the exercise-induced increases in Tcore. Blood flow in the internal and external carotid (ICA and ECA, respectively) and vertebral (VA) arteries (Duplex ultrasound) was measured. End-tidal PCO_2 and PO_2 were "clamped" to resting values within each condition.

Results: The changes in Tcore with EX and HS were matched between conditions (Δ0.77±0.28°C, P=0.91). Chest skin temperature was higher during the HS intervention (HS: Δ2.96±1.30°C vs. EX: Δ0.40±1.25°C, respectively, P<0.01); whereas, increases in cheek temperature (Δ1.75±1.06°C) were not different between conditions (P=0.66). Related to this, although ECA blood flow increased during both EX and HS for thermoregulatory heat dissipation (EX: Δ37±46% vs. HS: Δ54±32%, time effect: P<0.01), there was no difference between conditions (P>0.05). Blood flow in the ICA was unchanged with EX and HS interventions (P=0.71), consistent with the unchanged end-tidal PCO_2 (P=0.42); whereas, VA blood flow was higher throughout both EX and HS (EX: Δ21±24% vs. HS: Δ20±25%, time effect: P<0.01) with no between condition differences. Global CBF was unchanged with either intervention (P=0.87). Including blood pressure as a covariate did not influence these CBF findings (P>0.05).

Conclusions: These data indicate a selective temperature-dependent influence mediating elevation in posterior CBF during exercise that is independent of PCO_2.

Effect of local lower limb heating on cardiovascular hemodynamics, core temperature, and perceptual measures in young healthy men and women

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Introduction: Passive heating may improve cardiovascular health in humans; however, whole-body protocols are not well-tolerated. Local heating protocols may be more feasible, enjoyable alternatives; but their efficacy for eliciting a sufficient cardiovascular response – defined here as achieving HR in the moderate intensity range for exercise (55-69% HRmax) – has not been well-established.

Method: Ten young, healthy males and females underwent two 45-minute leg heating protocols at 45 °C, with water level either up to the ankles or knees. Cardiovascular hemodynamics were measured using finger photoplethysmography. Core (Tcore) and skin temperatures (Tsk) were measured using telemetric pills and temperature probes, respectively. Perceptual measurements were assessed using general feeling, thermal comfort and sensation scales. Measures were taken pre- and post-intervention.

Results: Tcore (PRE: 37.1±0.1 *vs.* POST: 37.6±0.2 °C, $P<0.05$) and foot Tsk (PRE: 28.3±0.9 *vs.* POST: 43.1±0.4 °C, $P<0.05$) increased post-intervention regardless of condition. Calf, thigh, and arm Tsk increased over time within each condition, but was greater after 45- minutes in the KNEE condition. Chest Tsk increased over time within each condition. CO and HR increased post-intervention to the same extent with both conditions (CO: PRE: 5.2±1.4 *vs.* POST: 6.5±1.5 L/min, $P<0.05$; HR: PRE: 57±9 *vs.* POST: 76±9 bpm, $P<0.05$). HR post-heating was 39% of the age-predicted HRmax. Regardless of condition, affect decreased (PRE: 2.1±1.4 *vs.* POST: 0.1±2.5, $P<0.05$), and thermal comfort (PRE: 0.1±1.1 *vs.* POST: 2.7±1.6, $P<0.05$) and sensation (PRE: 3.8±1.3 *vs.* POST: 7.4±1.3, $P<0.05$) increased post-intervention.

Conclusions: While Tsk changes were more pronounced in the KNEE condition, both conditions created similar but insufficient cardiovascular stress demonstrated through changes in Tcore, HR, and CO. Participants rated general feeling, thermal comfort and sensation similarly between conditions over time, suggesting that the two protocols may be used interchangeably. Future studies should explore whether novel vascular outcomes change in response to either local heating protocol.

Interactions between morning light conditions, body temperature, thermal comfort, and reaction time

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Introduction: In earlier well controlled laboratory studies we showed that light conditions can affect thermal physiological parameters and that thermal discomfort can partly be alleviated by specific lighting conditions. Here we study whether light conditions can counteract the reduction in thermal comfort and alertness in a warm environment.

Method: Sixteen healthy females participated in a randomised crossover laboratory study, consisting of three overnight sessions per participant. Participants stayed in the respiration chambers and were allowed to sleep for 6.5 hours only in order to induce sleepiness. In the subsequent morning one of three different light conditions was offered in a warm environment (29°C), as to evaluate the effect of two illuminance levels (50 lux and 500 lux, both with a correlated colour temperature (CCT) of 2000 K) and two CCT's (2000 K and 6500 K, both with an illuminance of 500 lux). Outcome parameters were: alertness, thermal comfort, body temperatures, melatonin and cortisol levels.

Results: There were large inter-individual differences in visual comfort and thermal comfort. Visual and thermal comfort were significantly correlated. Interestingly, thermal comfort levels are higher in light conditions that are perceived as visually more comfortable. In addition, participants had shorter reaction times under low CCT light as compared to high CCT light. Subjective sleepiness did not differ between light sessions. Under 2000K light, core body temperature was significantly higher than under 6500K light.

Conclusions: Light conditions that improve performance do not necessarily yield a better visual and thermal comfort. Thermal comfort is higher in light conditions that are perceived as visually more comfortable. Altogether, the study shows that light conditions have the potential to affect thermal physiology, thermal comfort and reaction times. In practise individual preferences in light conditions need to be taken into account to enhance thermal comfort.

Application of an adjusted neurophysiological (foot) skin blood flow model to a real life case study

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Introduction: The neurophysiological skin blood flow (SBF) model advanced the prediction quality of thermo-physiological models. However, it was developed for low activity levels (0.8 met). A field case study showed that for walking (2.8 met), the predicted foot skin temperature (Tskin,foot) was underestimated by up to 10°C. One reason for this result was a low simulated SBF at the feet. In a follow-up study, SBF and skin temperatures were investigated in 15 subjects performing light to medium activities under laboratory conditions to develop an adjusted foot SBF model. Here, the model is applied to the case study to investigate the effect of field conditions.

Method: The case study included local skin temperature measurements of 5 human subjects while freely walking indoors (2.8 met) for one hour. The subjects wore three everyday outfits of 0.5, 0.8 and 1.1 clo. The three scenarios are simulated in the thermoregulation model ThermoSEM, firstly, using the (standard) neurophysiological approach, and secondly, using the adjusted foot SBF model. For both cases, ΔTskin,foot is calculated as the difference between simulated and measured data averaged over the last 15 minutes of the experiments.

Results: The application of the adjusted foot SBF model improved the average ΔTskin,foot from -6 – -11°C to 0.4 – 2°C. Hence, the average results are closer to an acceptable range for skin temperature prediction of the extremities. However, in some individual cases, the simulation is now overestimating Tskin,foot. This finding might be due to low control of actual walking speed and walking type (e.g. climbing stairs) of the subjects in a field setting, as well as variations in building local climate.

Conclusions: The advanced foot SBF model improves the skin temperature prediction of ThermoSEM for walking scenarios at medium speed for the case study. Further investigations should include a larger number of subjects which might perform also at higher walking speeds and different activities.

Effects of different duration of voluntary hypocapnic hyperventilation on physiological responses during and following supramaximal exercise

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Introduction: Voluntary hyperventilation increases carbon dioxide (CO2) elimination, reducing arterial CO2 pressure (hypocapnia). We have recently shown that pre-exercise voluntary hypocapnic hyperventilation reduces aerobic metabolic rate with a compensatory increase in anaerobic metabolic rate and an attenuated tachycardia response in comparison to spontaneous breathing condition without impairing exercise performance during the 30-s Wingate anaerobic test and 30-s high-intensity intermittent cycling exercise. To develop hypocapnia, a long-duration (e.g., 20 min) voluntary hyperventilation was typically employed in previous work. However, it is unclear whether shorter voluntary hyperventilation differentially modulate the aforementioned physiological responses in comparison to a longer one.

Method: Ten healthy young males performed a 60-s supramaximal cycling (120% peak oxygen uptake) that was preceded by either: 1) spontaneous breathing (control), 2) 5- min or 3) 20-min pre-exercise voluntary hyperventilation (30 L min^{-1} of ventilation). Respiratory gases, arterial blood pressure, and heart rate (HR) were assessed throughout.

Results: Both 5-min and 20-min hyperventilation decreased end-tidal CO2 pressure to ~24 mmHg, whereas it was maintained at normocapnic level of 35 mmHg in the control trial, prior to the supramaximal exercise. Oxygen uptake during the supramaximal exercise was similarly reduced by the two hyperventilation trials in comparison to the control trial. HR during and following supramaximal exercise was lower in the 20-min hyperventilation trial than the control trial, whereas it was similar between the control and 5-min hyperventilation trials.

Conclusions: Our results suggest that 5-min and 20-min pre-exercise voluntary hypocapnic hyperventilation similarly reduce aerobic metabolic rate during 60-s supramaximal exercise, and that only the 20-min hyperventilation lowers HR during and following supramaximal exercise. Regarding practical application, pre-exercise voluntary hyperventilation during high-intensity exercise may be a useful strategy to stress and thus improve anaerobic energy system, and shorter duration of hyperventilation (e.g., 5 min) is sufficient to provide this effect.

Cutaneous Activation of TRPM8 Receptors Does Not Mediate Cross Dermatome Changes in Blood Flow

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Introduction: Topical menthol-based analgesics induce an increase in skin blood flow (SkBF) through TRPM8 receptor-dependent activation of sensory nerves and endothelium-derived hyperpolarization factors. It is unclear if menthol-induced TRPM8 activation mediates a reflex change in cutaneous blood flow across the dermatome. The purpose of this study was to determine the effects of localized menthol application on SkBF across a common dermatome. We hypothesized that SkBF would be increased with menthol at the site of application and the contralateral dermatome through a spinal reflex mechanism.

Method: In a double blind, placebo controlled, cross-over design, 11 healthy participants (5 men; age=22±1yrs) were treated with direct application of 5% menthol gel (Biofreeze™) or vehicle control on the L4 dermatome. Red blood cell flux was measured using laser Doppler flowmetry over the area of application, on the contralateral leg, and in a separate dermatome (S1) to serve as control. Cutaneous vascular conductance was calculated for each measurement site (CVC=flux/MAP). Thermal sensation was measured every 10 minutes.

Results: Menthol elicited lower thermal sensation at all time points, compared to the vehicle control ($p<0.05$). At baseline there were no differences in CVC between menthol and vehicle control (VC) gels, or among sites (all $p>0.05$). After 30 minutes, CVC increased in the site treated with menthol but not the VC (110±24, vs. 12±4 flux.mmHg^{-1}, $p<0.001$). There was no effect on the contralateral dermatome to either treatments (16±6 vs. 7±2 flux*mmHg^{-1}, $p>0.05$), or on the S1 dermatome (9±7 flux.mmHg^{-1}, $p>0.05$).

Conclusions: A menthol containing topical analgesic increased SkBF over the area of direct application, but had no effect on the untreated contralateral dermatome. These data suggest that menthol-induced activation of the TRPM8 receptor does not mediate a spinal reflex to increase SkBF across the area of common innervation.

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Sustained Skin Erythema and Blood Flow Responses to Acute Ultraviolet Radiation Exposure

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Introduction: Acute exposure to ultraviolet (UV)-B light elicits an inflammatory response in the skin, resulting in erythema (reddening) and increased skin blood flow that lasts at least 24 hours. However, the acute time course (i.e., initial eight hours) of each of these responses is unclear. Likewise, it is unknown whether these responses differ following exposure to broad spectrum (UV-A/B) light compared to UV-B alone. The purpose of the current study was to investigate whether temporal differences exist in skin blood flow and erythema responses and whether there are differences between acute UV-B and UV-A/B exposure. We hypothesized that (1) the erythema and blood flow responses would track each other, and (2) both responses would be higher following UV-A/B compared to UV-B exposure.

Methods: The ventral aspect of both forearms of 14 healthy young adults (7M/7F) were exposed to either UV-A/B (750 mJ/cm^2; 450 mJ/cm^2 UV-A + 300 mJ/cm^2 UV-B) or UV-B (300 mJ/cm^2) alone. Erythema index (EI; reflectance spectrometry) and red cell flux (laser-Doppler flowmetry) were measured before, immediately after, and 2, 4, 6, and 8 h post-exposure. Cutaneous vascular conductance was calculated (CVC=flux/MAP) at each time point and both EI and CVC were expressed as change from baseline.

Results: EI increased linearly after exposure to UV-B ($p<0.01$ at 4, 6, and 8 h post- exposure) and UV-A/B ($p\leq0.05$ at 4, 6, and 8 h post-exposure). CVC did not increase above baseline until 6 h post-UV-B ($p=0.04$) or UV-A/B ($p<0.01$). There were no differences between UV-B and UV-A/B-induced responses in CVC or EI (all $p>0.05$).

Conclusions: Exposure to UV-B or UV-A/B induced an immediate and linear increase in EI, but a delayed increase in CVC. These responses were similar between UV exposures, suggesting that the blood flow and erythema responses to acute UV- exposure are primarily driven by UV-B radiation.

Toe and boot temperatures during Canadian Armed Forces operations in the Arctic: Challenges of establishing accurate field data

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Introduction: Canadian Armed Forces soldiers train in some of the harshest conditions on Earth, including the extreme cold of the Canadian Arctic. Without proper protective equipment and training, these soldiers are particularly at risk of developing cold weather injuries (CWIs) especially in their hands, feet, and face. However, much work remains to establish the best individual thermal protection to prevent CWIs during operations in the Arctic.

Method: 20 soldiers were recruited during a 5-day Arctic military exercise in 2018 and 2019. Operations involved sleeping in Arctic tents, fishing, snowmobile, and long patrols on foot. Boot (Tboot) and toe temperatures (Ttoe) were collected continuously using an iButton placed on the boot liner and a skin thermistors placed on the big toe, respectively. Statistics were conducted on measurements during outside operations 1) to quantify individual ranges in Tboot and Ttoe and, 2) to establish the relationship between ambient temperature (Tamb), Tboot and Ttoe.

Results: Complete Tboot and Ttoe data was obtained from 10 males over the 5 operational days with 4 to 10.5h spent outside at Tamb ranging from -30 to -40°C (without windchill). No CWIs on the feet were reported in these individuals. Results indicated that Tboot and Ttoes did not change significantly Day 1 to 5 (ANOVA; $p=0.18$ and $p=0.28$, respectively). Tboot averaged 4.0±1.2°C (min -6.0±1.1°C and max 19.3±2.0°C) and Ttoe averaged 22.0±1.4°C (min 14.2±1.7°C and max 31.1±0.5°C). Importantly, no significant correlations were found between Tboot, Ttoes and Tamb (Pearson; $r^2=0.76$ $p=0.13$, $r^2=0.60$ $p=0.31$ and $r^2=0.58$ $p=0.31$).

Conclusions: Results from this study indicate that although military personnel face temperatures that could results in CWIs, some individuals' foot temperatures are well controlled, independently of changes in environmental conditions. Most importantly, this study highlights the challenges researchers face when attempting to collect multi- day field thermal data in soldiers to obtain a reliable model for temperature management.

Optimization of Readiness in Extreme Cold: A Tool For Risk Evaluation and Mitigation

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Introduction: Cold stress degrades physical performance, results in casualties, and ultimately impacts military operation. Proper selection of cold weather ensembles is the primary mitigation strategy for preventing cold injury. However, the selection of cold weather ensembles are currently often based on experiences or very simple charts/tables, and do not reflect the complicated requirements of cold protection.

Purpose: Define the thermal performance of cold weather ensembles using human-centric metrics (i.e., physiological criteria or safety limits), and develop a cold weather ensemble decision aid (CoWEDA) to predict frostbite and hypothermia risks, and excessive sweating. **Methods**: Thermal performance is defined by endurance times, which are the durations before the physiological safety limits, corresponding to the onset of frostbite, hypothermia or skin wettedness, are reached. A database of thermal properties of individual clothing items was established. Algorithms were developed to predict thermal properties of multi-layer clothing configurations. The metrics of ensemble thermal performance, clothing database, algorithms and the validated six-cylinder thermoregulatory model were integrated into CoWEDA.

Results: CoWEDA is user-friendly and guides selection of the most appropriate cold weather ensemble(s) relative to anticipated activities and environmental conditions. CoWEDA allows users to build their own ensembles from the clothing inventory by body regions, and then interprets their selection in the context of safe operation times and cold injury risks. Comparisons with measured skin temperatures during exposure to 0 to -40°C environments shows that CoWEDA predictions are acceptable.

Conclusion: CoWEDA is the state-of-the-art tool for cold readiness optimization, mission planning, clothing selection, risk awareness, and cold injury prevention.

Disclaimer: 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.

Motor-cognitive performance in the heat – influence of hydration, radiation and heat acclimation

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Introduction: In a warming world, the occurrence and duration of heat waves will increase and for effective analyses (including modelling and proposed mitigation methods), it is important to evaluate the effects of heat stress on performance and productivity. In this presentation, the effect of hyperthermia on combined cognitive and motor performance and confounding effects of dehydration, solar-radiation and heat acclimation will be covered and contextualized to occupational settings.

Methods: Applying a comprehensive test battery with separate and combined motor- cognitive tasks, we have explored the effects of: 1) moderate [1°C] and severe hyperthermia [≥2°C], 2) dehydrations [2% loss in body mass], 3) solar radiation [500 W/m^2 applied to the head or lower-body] and 4) prolonged heat acclimation.

Results: For euhydrated participants exposed to dry heat (low/no solar radiation) a moderate core temperature elevation can be tolerated without impairing cognitively dominated tasks or motor performance. However, severe hyperthermia profoundly reduces complex motor task performance and this effect is markedly aggravated if moderate dehydration is superimposed. In addition, with combined hyperthermia and dehydration the risk of making mistakes in both cognitively dominated tasks is doubled and simple motor performance impaired. Direct exposure of the head to solar radiation (simulated sun equal to typical outdoor summer levels) profoundly reduces motor-cognitive performance, indicating that previous observations from laboratory experiments may have markedly underestimated the effects of heat stress on cognitive function. Heat acclimation may improve thermal resilience, but it cannot protect complex motor performance during exposure to uncompensable heat stress.

Conclusions: The present observations let us conclude that hyperthermia, dehydration and solar-radiation profoundly reduce motor-cognitive performance. Additionally, heat acclimation was unable to protect against the decline in motor-cognitive performance caused by hyperthermia. Collectively, these studies illustrate the detrimental effects of hyperthermia and associated conditions on motor-cognitive performance.

Passive Heat Stress Effects on Time Perception and Timed Decision Tasks

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Introduction: Research of time perception suggests that core body temperature mediates the subjective experience of time, and research in the field of decision making indicates the importance of a correct estimation of the passing of time for making decisions. Here we hypothesized that compared to a normothermic state, a hyperthermic state speeds-up time perception (EST), which leads to a decreased accuracy (ACC) and response times (RT) of a timed decision task. Furthermore it is hypothesized that the perception of time and accuracy of a timed decision task correlates with thermophysiological variables body core temperature (Tc) and heart rate (HR), and subjective task load, rate of perceived exertion (RPE), thermal sensation (TS) and thermal comfort (TCOMF).

Method: Young adult males (N=29) participated in two 60min head-out water immersion conditions (36.5°C NEUTRAL and 38°C WARM). Participants performed an interval timing task and an two-alternative forced choice task at t=-15, t=20 and t=60. Physiological measurements included core temperature (bodycap) and heart rate (polar).

Results: Tc and HR were significantly higher in WARM vs. NEUTRAL condition at t=60 (Tc: 38.4±0.2°C vs. 37.2±0.1°C, $p<0.01$; HR: 106±9BPM vs.88±7BPM, $p<0.01$, mean±SD). Change in estimation of passing of time (T=60vs.T=-15) was significantly larger in WARM vs. NEUTRAL condition (-0.11±0.18vs.0.07±0.32,$p<0.01$). Response times decreased both in WARM condition (-0.07±0.06,$p<0.01$) and NEUTRAL (- 0.03±0.06,$p<0.03$), however the decrease was larger in WARM vs. NEUTRAL ($p<0.02$). The accuracy decreased in WARM (-0.03+/-0.05,$p<0.01$) and NEUTRAL condition (-0.02 +/- 0.04,$p<0.05$), however no significant difference in accuracy was detected in WARM vs. NEUTRAL ($p>0.12$). ΔTc and ΔTS were significantly related to ΔRT ($r^2=0.42$,$p<0.01$; $r^2=0.1$,$p<0.04$ respectively), ΔTCOMF and ΔRPE were significantly related to ΔEST ($r^2=0.21$,$p<0.01$;$r^2=0.12$,$p<0.03$, respectively).

Conclusions: Passively induced hyperthermia (Tc=38.5°C) significantly affects time perception and response time but not accuracy of a decision task. Time perception revealed a small correlation with subjective indicators TCOMF and RPE.

Using WBGT Heat Risk from Weather Forecasts for Cancelling Sport Events: Focus on False Positives

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Introduction: Exertional heat stress can result in performance loss and health risks for athletes. One frequently used environmental heat stress index is the wet bulb globe temperature (WBGT). The WBGT is defined for outdoor conditions as the weighted average of dry bulb, wet bulb and black globe temperature. These variables can be calculated from weather forecast data. Therefore, heat related risk for athletes can be predicted, and used as a policy recommendation whether an event should be rescheduled or cancelled. However, given that rescheduling or cancellation can be costly, knowledge on the probability of false positives and false negatives is warranted.

Method: Air temperature, globe temperature, air velocity and relative humidity were measured during a 14-day outdoor summer sporting event in Melbourne, Australia. From these values the WBGT was calculated according to the Australian Bureau Of Meteorology. For the same period weather forecasts (1-2h forecasts;openweathermap.org) were collected at a position <3km from the event location at 11:00, 14:00 and 17:00. WBGT was calculated from forecasted data using the Liljegren method. WBGT cancellation levels were assumed to be the ACSM position statement (2007), WBGTextreme>32.3°C. WBGT calculated from measured data was considered the reference.

Results: WBGT False positive rate was 17% (6 false positive over 35 time points), and 0% false negative rate. The median and range of difference between estimated WBGT from measured data and WBGT from forecasted data was +2.5°C [-2.8°C to +6.7°C]. Overestimation of globe temperature is the largest factor +10.0°C[+1.2°C to +20.7°C], which may be caused by assuming zero cloud cover and an underestimated effect of wind.

Conclusions: Cancelling or rescheduling a sport event based on forecasted WBGT data has a relatively high false positive rate and no false negatives. Therefore the described forecast method is likely overprotective potentially to the extent that policy recommendations might be ignored.

Contribution of wetted clothing to body energy exchange and heat stress

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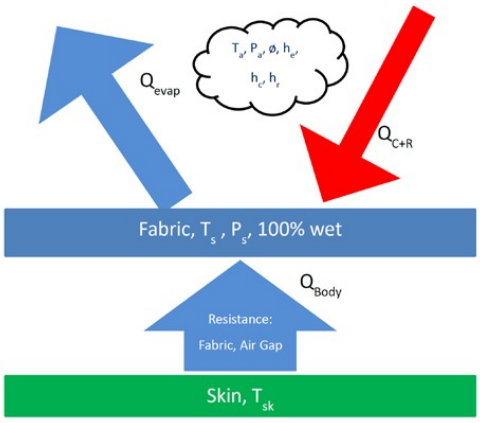
Introduction: Modelling the energy exchange between the body and the environment in extreme conditions can prove challenging as the certain assumptions built into the traditional models break down. Elson demonstrated that a two-node model can be used to predict performance, but two important constraints must be considered for the modelled population. First, the sweat rate models presented in literature should be tuned to the population of interest. Second, the effect of excess sweat must be included in any prediction if heat stress is of interest. The models developed by Elson are extended to more closely explain the heat transfer between the wet clothing and human body.

Method: Figure 1 shows the heat transfer process that dominate the energy exchange over the portions of the body covered by wetted fabric. For clothing not fitted to the body, three processes decide the energy exchange per unit area between the body and the fabric. The convective exchange, the evaporative exchange with the cooled fabric and the periodic touching of the fabric. The wetted fabric is predicted to drop 5°C below skin temperature. This creates both a temperature and humidity gradient that drives heat transfer.



Results: The result show that the combined effect of the three mechanisms and evaporative cooling of the fabric enhances the heat transfer between the body and the environment compared to traditional models.

Conclusions: The study shows that non-fitted fabric wetted by excess moisture dripping from the body or wicked by tight fitting underlayer can provide additional protection from heat stress. Optimization of this heat transfer process requires additional studies on the convective, evaporative and direct contact energy exchange between the body and fabric.

Development of a Thermoregulation Model Using Medical Image Data and the Finite Element Method

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Introduction: Advancements in medical imaging present an opportunity to improve human thermoregulatory (TR) model accuracy. The purpose of this study is to develop a human TR model using finite element methods.

Method: A human torso geometry was derived from medical images of a male, 1.76m, 81kg, and 22.7% body fat. The torso included skin, fat, muscle, and eight internal organs: heart, lungs, bones, etc. The finite element software, COMSOL, was used to create the model and run simulations. Each organ was given basal thermal properties, metabolic rates, and blood flow. TR functions were created to simulate shivering, sweating, and vasoconstriction/vasodilation. Heart and skin temperatures were control variables. Heat transfer within the body included conduction between organs and convection with blood. Heat exchange on skin surface included convection, radiation and evaporation. Model acceptability was examined by dynamically changing the ambient temperature. Two sets of dynamic environments were used: 30°C(0.5h)/48°C(2h)/30°C(1h) and 43°C(1h)/18°C(2h)/43°C(1h), and results compared to literature.

Results: Comparisons of simulated core/skin temperatures with observed temperatures were reasonable. This was assessed by whether or not the trajectories of simulated skin/core temperatures were similar to observed values. Predicted core temperatures were within 0.6°C of the mean literature temperatures. Predicted skin temperatures were up to 0.8°C warmer. The simulations illustrated similar temperature time course patterns to the literature. Predictions demonstrated the different time course of core temperature patterns between rectal/heart temperatures. Thus, the model can reveal detailed temperature profiles that cannot be obtained with traditional CAD models.

Conclusions: Merging medical image data with the finite element method appears to be a viable approach for human thermoregulatory modeling. Our next step is to apply this TR model to a whole body geometry

Disclaimer: Author views not official US Army or DOD policy.

Agreement between Chest and Mean Skin Temperature: Influence of Clothing Ensemble and Measurement Device

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Introduction: Physiological monitoring devices commonly employ a single skin temperature measurement location on the chest. This study aimed to measure the agreement between whole-body mean skin temperature and chest skin temperature measured by a conductive or infra-red sensor, wearing two types of clothing ensemble, during exercise in the heat.

Method: Twelve males (age: 24.2±3.7y; height: 180±6.5cm; body mass: 82.9±9.5kg; body fat: 16.0±6.5%) volunteered to participate in two trials. Wearing either an athletic (ATH: t-shirt, shorts, shoes) or a chemical protective ensemble (CPE: ATH plus coverall and respirator), participants commenced 30 minutes of seated rest (environment 24°C and 50%) followed by 60 minutes of treadmill walking at 4.5 $km \cdot h^{-1}$ and 1% grade (environment 35°C and 40%). Rectal temperature and mean skin temperature ($\bar{T}sk$, 8- site), chest skin temperature - conductive sensor (iButton) (*Tsk-C*) and infrared sensor (EQ-02) (*Tsk-I*), were recorded continuously. Systematic bias and 95% limits of agreement (LoA), accounting for repeated measures, were calculated between $\bar{T}sk$, *Tsk-C* and *Tsk-I*.

Results: Rectal temperature rose significantly from rest (ATH: 37.40±0.27°C; CPE: 37.32±0.30°C) to end of exercise (ATH: 37.96±0.21°C; CPE: 38.38±0.43°C), demonstrating significant interaction effects for clothing and time (p<0.001). The elevation in $\bar{T}sk$ from rest (ATH: 33.01±1.18°C; CPE: 33.53±0.74°C) to end of exercise (ATH: 35.90±0.76°C; CPE: 36.46±0.38°C), also showed a significant interaction (p=0.010). In ATH, $\bar{T}sk$ differed from *Tsk-C* by 1.53±0.57°C (±1.13°C LoA), and from *Tsk-I* by 2.23±0.84°C (±1.66°C LoA). Wearing the CPE ensemble, $\bar{T}sk$ differed from *Tsk-C* by 1.11±0.70°C (±1.44°C LoA), and from *Tsk-I* by 1.76±0.68°C (±1.33°C LoA).

Conclusions: Skin temperature measured on the chest overestimates whole-body mean skin temperature. The overestimate was greater for an infrared compared to a conductive temperature sensor, and in the ATH ensemble. These findings should be considered when monitoring skin temperature on the chest and using the data to calculate real-time indices of physiological strain.

A Free Software to Predict Heat Strain According to the ISO 7933:2018

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Introduction: Over the last century several thermal stress indices have been developed to estimate the thermal strain experienced by workers in occupational settings. Among them, it is worth mentioning the predicted heat strain (PHS) model which was specifically developed to predict the heat strain in occupational settings. However, it has been mentioned that its calculation is so sophisticated that is not used in industry. Therefore, our primary objective in this study was to design and implement the FAME Lab PHS Calculator software (PHSFL) (www.famelab.gr/research/downloads) to simplify the calculation of the PHS model. Our secondary objective was to assess: (i) the criterion-related validity of the PHSFL by comparing its results against those obtained using the original ISO 7933:2018 code; and (ii) the construct validity of the PHSFL by comparing its results against those obtained via field experiments performed in human participants during work in the heat.

Methods: Five grape-picking workers worked for eight consecutive hours in environmental temperature (28.5±3.3°C) ranging from 18.6°C to 35.1°C. Core temperature (Tc) and skin temperature (Tsk) data were collected throughout the work- shift. Thereafter, the measured data were compared with data predicted using PHSFL. Funding was provided by European Union's Horizon 2020 Marie Curie "ICI- THROUGH" project under the Grant agreement no. 645710.

Results: Criterion validity demonstrates that PHSFL provides valid results within the required computational accuracy, according to Annex F of ISO 7933:2018. The construct validity showed that the measured Tc (37.6±0.2°C) and Tsk (34.9±1.5°C) were strongly related with the predicted Tc (37.6±0.1°C) and Tsk (35.5±0.8°C) values (Tc:r=0.573; Tsk:r=0.850; all $p<0.001$). Furthermore, root mean square errors (RMSE) and 95% limits of agreement (LOA) were minimal between measured and predicted Tc (RMSE: 0.3°C; LOA: 0.06±0.58°C) and small between measured and predicted Tsk (RMSE: 1.1°C; LOA: 0.59±1.83°C).

Conclusion: The PHSFL software demonstrated strong criterion-related and construct-related validity.

Effectiveness of ventilated vest at various ambient relative humidities

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Introduction: Climate change presents one of the biggest global health threats of the 21st century. One of the direct consequences of global warming are more frequent and intense summer heat waves, which create greater heat stress in industrial settings. The maintenance of workers' health and well-being relies on strategies to mitigate such heat stress. The present study investigated the benefit of cooling vests in augmenting evaporative heat loss in a range of ambient relative humidities.

Methods: The study evaluated the evaporative capacity of a commercially available ventilated vest, using a thermal manikin. The vest, combined with body armour (BA) was tested at 35°C (equal to manikin temperature) at different ambient relative humidities (RH; from 10 to 90%), compared with just a T- shirt in combination with BA. The vest was also tested on three male participants, while walking on a treadmill at 20°C. During this trial we measured heat flux.

Results: At 50% RH the vest increased the evaporation to 5 $g.min^{-1}$, compared to T-shirt with 2 $g.min^{-1}$. At 10% RH the difference was doubled (with vest: 8 $g.min^{-1}$, without: 4 $g.min^{-1}$). The vest effectiveness was improved when fitting tightly on participant (ectomorph:56±29, mesomorph:67±23, endomorph:70±16 $W.m^{-2}$).

Conclusions: The cooling vest augmented evaporation from the manikin at ambient RHs ranging from 10 to 70%. A properly designed vest can contribute to the mitigation of heat stress in outdoor and indoor settings.

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Standard or myths – claims on accuracy of metabolic rate measurements by ISO 8996 revisited

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Introduction: ISO 8996 provides methods for the determination of metabolic rate (*M*) classified in terms of increasing levels of effort ('Screening', 'Observation', 'Analysis', and 'Expertise') and presumed accuracy. We assess those claims for estimating *M* from heart rate (*MHR*) at 'Analysis' level, as well as for *M* calculated from oxygen consumption rate (*MVO2*) measured by the partial or integral method representing 'Expertise'.

Method: We quantified the accuracy of these methods by comparing *MHR* with *MVO2* measured in 373 climatic chamber experiments under different workloads and widely varying heat stress conditions. We further scrutinized factors affecting *VO2* kinetics according to ISO 8996 against recent findings from the original literature.

Results: *MHR* considerably overestimated *MVO2* due to the rise in core temperature, which concomitantly increased heart rate by approximately 30 bpm/°C resulting in an overall error of 43%. After individually correcting for this bias, the accuracy was 10- 15% as stipulated by the standard. Moreover, our data supported the 5% accuracy level for *MVO2* with *VO2* below 1 L/min according to the partial method. The literature review identified *Q10* (~7% increase in *M* per degree increased core temperature), '*slow component*' (excess *VO2* beyond the lactic acid threshold), and *EPOC* (Excess Post- exercise Oxygen Consumption) contributing to the uncertainty of *M* to unknown extent. On the other hand, the so-called 'Simonson effect', an increased demand of energy at the start of work erroneously deemed causing underestimation of *M* by ISO 8996, does not exist.

Conclusions: Concerning the ongoing revision of ISO 8996 we propose (i) to include compulsory methods correcting for the thermal component of heart rate, (ii) to eliminate the 'Simonson effect', (iii) to restrict the partial method to the measurement of the oxygen uptake, (iv) to issue a warning against using the integral method without any quantitative estimation of the *EPOC* effect.

Coupling of Thermal Manikin Newton with Fiala-based Thermophysiological Model

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Introduction: The manikin control allows to integrate thermophysiological features to a thermal manikin. The review of A. Psikuta from 2017 describes state-of-the-art solutions of manikin control by thermophysiological model. In this paper, we present a coupled system formed by thermal manikin Newton and Fiala-based model FMTK.

Method: The coupling interface operating in real time has been established in Matlab. Manikin is controlled by FMTK using calculated skin temperatures, which are set to the manikin software. Based on these set temperatures, manikin measures heat fluxes, which are going back to the model to substitute a calculation of sensible heat losses. The coupling was tested in the climatic chamber for a standing manikin, air speed 0.1 m/s and different ambient temperatures and metabolic rates:

- passive system: 30 °C (nude)
- active system: 5 °C, 10 °C, 28-18-28 °C, 28-33-28 °C, 18-42-18 °C, 3-5-8 met (just briefs) and 28-18-28 °C (summer clothing: T-shirt, trousers).

Results: Generally, all test cases confirmed that in cold, neutral and warm conditions the coupling is functional. The Figure 1 demonstrates limits of the coupling for the hot environment (42 °C), when the coupled system was not able to operate properly after time 120 min, because of time delay in manikin control during transient change (blue vs orange line). The difference between the virtual simulation (grey line) and coupling (blue line) during transient changes was caused just by the delay of ambient temperature regulation inside the climate chamber, and it is not an error of the coupled system.

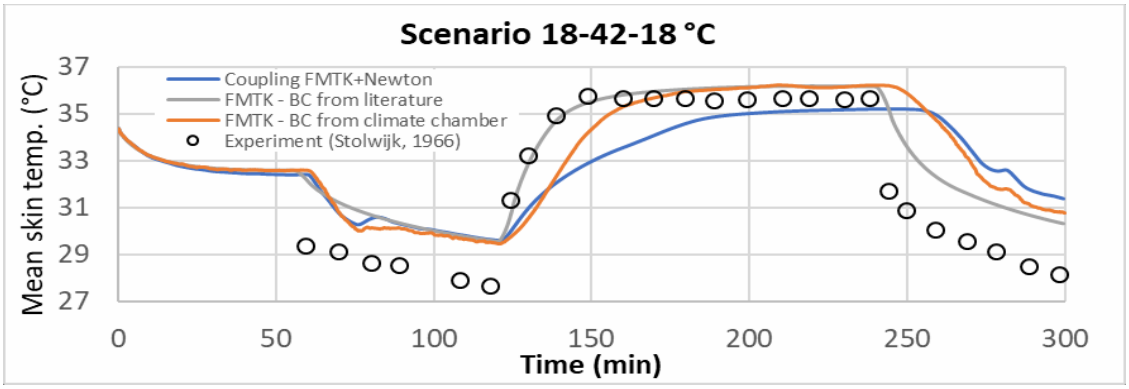

Figure 1. Results of scenario 18-42-18 °C

Conclusions: The coupling of FMTK with Newton manikin, which allows operating manikin with considering human thermophysiology, has been developed. However, in our case was not possible to use it for the hot conditions, because our Newton manikin has no ability to cool down by sweating.

Relationship between respiratory chemosensitivity and hyperthermia-induced hyperventilation

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Introduction: There are large individual differences in hyperthermia-induced hyperventilation, but the factors responsible for this variability remain unclear. There are also considerable individual differences in respiratory chemosensitivity. We hypothesized that there is a relationship between the magnitude of hyperthermia- induced hyperventilation and respiratory chemosensitivity.

Method: Twelve male subjects (mean (SD) age 22 (1) years, height 176.1 (4.9) cm, weight 73.7 (6.8) kg) participated in a study testing the above hypothesis. Subjects wore a water-perfused suit that was used to maintain or change body temperature. The temperature of the perfused water was initially set at 33°C at rest and 25°C during exercise, which prevented an exercise-induced rise in body temperature. Thereafter, the water temperature was increased to 38°C to raise body temperature during exercise. Subjects performed a cycle exercise at 90 W. We measured respiratory chemosensitivity to CO2 using a rebreathing method. Respiratory chemosensitivity was evaluated at rest, during exercise without an increase in body temperature (Ex.1), and during exercise with a 1°C rise in body temperature (Ex.2). We then assessed the relationship between the rate of increase in minute ventilation and the rise in body temperature and respiratory chemosensitivity.

Results: Respiratory chemosensitivities to CO2 were 2.7 (0.9) $L.min^{-1}.mmHg^{-1}$ at rest, 2.5 (0.9) $L.min^{-1}.mmHg^{-1}$ during Ex.1, and 2.5 (1.0) $L.min^{-1}.mmHg^{-1}$ during Ex.2. There were no significant differences among them. In addition, linear regression analysis showed that there was no significant relationship between the rate of increase in minute ventilation and the rise in body temperature or respiratory chemosensitivity ($r = 0.26$).

Conclusions: These results indicate that respiratory chemosensitivity to CO2 does not relate to hyperthermia-induced hyperventilation.

Human white-fat thermogenic capacity evaluation via experimental and meta-analysis studies

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Rationale: Exercise may increase thermogenic capacity of white adipose tissue (WAT), which could subsequently enhance energy expenditure and body weight loss. We aimed to identify browning of human WAT due to exercise by measuring both the uncoupling protein 1 (UCP1) mRNA and protein concentrations. Our approach based on both an experimental study and a systematic review and meta-analysis to confirm the results of the experimental study rather than made conclusions based on previous selected studies. This approach revealed differences between studies conducted in humans and those conducted in animals.

Method: We conducted one human experimental study and one systematic review and meta-analysis that included both studies conducted in humans and animals – PROSPERO registration (CRD42019120213).

Results: An 8-week exercise program had no effect on both UCP1 mRNA and protein concentrations of human WAT as well as on body composition. Our meta-analysis also revealed:
a) no effect of chronic exercise on human UCP1 mRNA; b) a main effect of chronic exercise on UCP1 protein concentrations (Std-md=0.59, CI=0.03-1.16, p=0.04) and UCP1 mRNA (Std- md=1.76, CI=0.48-3.04, p=0.007) in WAT of normal diet animals; c) a main effect of chronic exercise on UCP1 mRNA (Std-md=2.94, CI=0.24-5.65, p=0.03) and UCP1 protein concentrations (Std-md=2.06, CI=0.07-4.05, p=0.04) in WAT of high-fat diet animals.

Conclusions: Chronic exercise had no impact on both UCP1 mRNA and protein concentrations of human WAT, while in animals it increased UCP1 independently of their diet. In this regard, for the first time we confirm that the available evidence from studies conducted in animals may not be applicable in humans. This should be taken into consideration in future research.

Body Mapping of Skin Temperature Profiles during Exercise in Children

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Background: Mapping skin temperature (Tsk) and sweat-rate patterns has gained interest from academia and industry for applications in clothing design, thermophysiological modelling, and the development of thermal manikins. Studies focussed on males versus females, high versus low fitness, young adults versus elderly, and on the impact of acclimation. No information is to date available on skin temperature distribution in children. This is the focus of the present study.

Method: Four groups of children were studied; males and females of 9 (n=8/11) and of 13 (n=11/9) years old. They performed 45-minutes of treadmill exercise (23°C; 50%RH; 2 $m.s^{-1}$ wind) (3x15 minutes periods, alternating one-minute run, one-minute walk with Infra-red pictures taken in between each period). Heart rate (target 65-75% HRmax average over whole exercise), whole body sweat rate and tympanic temperature were collected. Each group's Infra-red pictures were morphed to a reference shape and mean, and median temperature maps were calculated (MATLAB).

Results: Before the start of exercise, Tsk was similar for legs and arms in all groups but slightly warmer for the torso in the younger groups. During the run Tsk initially dropped, then stabilised at a lower level before increasing again after the run stopped. Ten minutes after the run, Tsk remained below baseline values. Over the whole period, torso Tsk was higher in the younger groups compared with the older groups.

Conclusions: With equal relative but lower absolute exercise intensity, younger children had significantly higher Tsk than the older ones, mainly on the torso. This was linked to a lower sweat rate in the younger groups, providing less skin cooling and resulting in warmer skin (Tsk as a balance between heat input from blood flow and heat loss by evaporation and convection). Children at age around 9 seem to rely more on dry heat loss than older children.

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The effects of local thermal manipulations on motor unit properties during light and moderate contractions

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Introduction: Muscle temperature has a direct effect on the contractile and metabolic properties of muscle. In many experimental designs, submaximal workloads are determined from maximal force during thermoneutral, such that relative intensity may vary with muscle temperatures. We investigated how different muscle temperature affected motor unit properties with contractions performed at the same normalized percentage of maximal force during each temperature condition.

Method: Ten males and females completed evoked, maximal and trapezoidal voluntary contractions during thermoneutral-, hot-, and cold-muscle conditions on separate days. Forearm muscle temperature was controlled using 25-min of neutral (~32°C), hot (~44°C), or cold (~13°C) water circulated through a tube-lined sleeve. Motor unit properties were assessed during trapezoidal contractions to 30% and 60% force using surface EMG decomposition.

Results: Changes to contractile properties from muscle heating and cooling were evident in the twitch duration, rate of force development, and half-relaxation time, suggesting that muscle temperature was successfully changed (all $P<0.05$). Further, differences in flexor carpi radialis surface EMG root-mean-square amplitude and mean power frequency between temperature conditions also support muscle temperature changes. Maximal force was not different between neutral and hot ($P>0.05$) but decreased in the cold ($P<0.05$ *vs* both). For both the 30% and 60% contractions, motor unit action potential amplitude and duration was larger and longer in the cold compared to neutral and hot ($P<0.05$). As expected, the relationship between motor unit firing rate and recruitment threshold indicated by the slope and y-intercept was different between the normalized 30% and 60% contractions ($P<0.05$ *vs* both). However, these relationships did not alter across muscle temperatures (slope and y-intercept $P>0.05$).

Conclusions: Local muscle cooling decreased maximal force, whereas heating altered contractile properties of the muscle. However, when ramp contractions are normalized to maximal force of the respective temperature condition, the motor unit recruitment strategies remain similar.

The Effects of Cerebral Blood Flow on Working Memory and Executive Function during Passive Hyperthermia

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Introduction: Passive hyperthermia (≥1.0˚C in core temperature) impairs working memory and executive function, potentially from hyperthermia-induced hypocapnia that elicits a decrease in cerebral blood flow.

Method: Nine males completed a randomized, single-blinded study consisting of isocapnia (ISO, end-tidal CO2 clamped at eucapnic baseline) or poikilocapnia (PKC, no end-tidal CO2 control) during passive heating using a water-perfused suit (water temperature ~49°C). ISO was maintained using a breath by breath end-tidal forcing system, and right middle cerebral artery velocity (MCAv) was measured continuously using transcranial Doppler at 400 Hz as an index of cerebral blood flow. Mental function was tested at baseline (36.5±1.3˚C) and at 38.5±0.4˚C. Working memory was tested with a Two-Back Test (TBT) while executive function was tested using the Set Shifting Task (SET)(CogState).

Results: Cerebral blood flow was successfully manipulated, with MCAv not different between ISO or PKC at baseline (ISO:57.4±10.4, PKC:58.5±10.4 cm·s^{-1}) but different at hyperthermia (ISO:51.7±5.2, PKC:45.1±7.8 cm·s^{-1}). TBT errors significantly (p=0.04) increased with hyperthermia, but with no significant differences between ISO or PKC at either baseline (ISO: 1.5±1.6, PKC: 1.1±0.7 errors) or hyperthermia (ISO:3.4±2.4, PKC:4.2±2.6 errors). SET errors (p=0.02) increased with hyperthermia, but with no significant differences between ISO and PKC at either baseline (ISO:20.3±6.3, PKC:22.4±8.2 errors) or hyperthermia (ISO:22.4±8.2, PKC:26.2±6.4 errors). SET speed did not change with hyperthermia (p=0.33).

Conclusions: The maintenance of MCAv was unable to counteract the hyperthermia-induced decrements in working memory and executive function, suggesting that altered cerebral blood flow is not the primary cause for mental decrements with hyperthermia.

The Effects of Acute Dopamine Re-Uptake Inhibition on Executive Function and Working Memory during Passive Hyperthermia

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Introduction: Passive hyperthermia ≥1.0˚C in core temperature (Tc) impairs executive function and working memory, potentially from hyperthermia-induced alterations in dopamine concentrations. The dopamine-reuptake inhibitor methylphenidate (MPD) increased time trial power output and final Tc while reducing perceived exertion in the heat, such that increased dopamine activity may alter mental function.

Method: 10 male participants completed a randomized, double-blinded study consisting of two experimental sessions where participants received either 20 mg MPD or placebo (PLA). Following 60 min wash-in, cognitive function was tested at baseline (37.1±0.6˚C) and after passive heating to 38.6±0.4˚C. Executive function was tested using the Groton Maze Learning Task (GMLT) and working memory by a Two-Back Test (TBT) (CogState, CT). Right middle cerebral artery velocity (MCAv) was measured continuously using transcranial Doppler at 400 Hz. Thermal perception was measured using the Thermal Comfort (TC, 1-4) and Thermal Sensation (TS, 1-7) scales (presented as quartile (q1-q3)).

Results: TBT errors significantly (p=0.006) increased with hyperthermia, but no significant differences between MPD or PLA at either baseline (MPD:1.0±1.4, PLA:1.0±0.8 errors) or hyperthermia (MPD:2.0±2.0, PLA:4.0±2.6 errors). GMLT errors (p=0.011) increased with no difference in speed (p=0.147) with hyperthermia, with no significant differences between MPD or PLA at either baseline (MPD:28.0±8.3, PLA:25.0±7.5 errors; MPD:125.3±19.5, PLA:124.2±21.1 s) or hyperthermia (MPD:33.0±6.7, PLA:31.0±8.4 errors; MPD:123.2±25.5, PLA:114.6±28.8 s). MCAv decreased with passive hyperthermia (p=0.009), with no significant differences between MPD or PLA at either baseline (MPD:56.0±11.2, PLA:61.0±11.8 $cm \cdot s^{-1}$) or hyperthermia (MPD:45.0±8.5, PLA:46.0±7.5 $cm \cdot s^{-1}$). TC (p<0.001) and TS (p<0.001) increased with hyperthermia with no difference between MPD or PLA at either baseline (TC: MPD: 1.0(1-1), PLA:1.0(1-1); TS: MPD:4.0(3-4), PLA: 4.0(3-4)) or hyperthermia (TC: MPD: 4.0(3-4), PLA: 4.0(3-4); TS: MPD: 7.0(7-7), PLA: 7.0(7-7)).

Conclusions: An acute 20 mg dose of a dopamine re-uptake inhibitor was unable to counteract the hyperthermia-induced (⊚+1.5˚C Tc) decrements in working memory or executive function.

Effects of pre-exercise voluntary hypocapnic hyperventilation on cardiovascular responses to simultaneous initiation of exercise and apnea

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Introduction: Apnea during exercise decreases arterial O2 pressure, whereas it substantially modulates cardiovascular responses including heart rate, arterial blood pressure, and cerebral blood flow responses. However, relatively unknown is that cardiovascular responses to simultaneous initiation of exercise and apnea, a situation that occurs when diving in the water. Also, to extend apnea duration, divers occasionally perform voluntary hyperventilation prior to exercise, which washes out CO2 from the blood, leading to reductions in arterial CO2 pressure (hypocapnia). Whether voluntary hypocapnic hyperventilation modulates cardiovascular responses to simultaneous initiation of exercise and apnea remains to be investigated.

Method: Fourteen young adults (7 men and 7 women) commenced a moderate- intensity cycling and maximal apnea at the same timing that was preceded by 1) 3-min spontaneous breathing or 2) 3-min voluntary hyperventilation resulting in a reduction in end-tidal CO2 pressure to 22±6 (SD) mmHg. 1) and 2) were also performed without apnea.

Results: Apnea duration was extended by voluntary hyperventilation relative to spontaneous breathing trial (62±7 vs 43±9 s). Arterial oxygen saturation estimated by pulse oximetry during apnea exercise was elevated by voluntary hyperventilation, whereas that measured at end-apnea was reduced by voluntary hyperventilation (87±10 vs 69±14% vs; $p < 0.01$, $d = 1.46$). Mean arterial pressure (84±26 vs. 98±17 mmHg, $P = 0.002$, $d = 0.61$) and middle cerebral artery mean blood flow velocity (56±18 vs 70±15 cm sec^{-1}, $P = 0.001$, $d = 0.84$) during apnea exercise in the hyperventilation trial were lower than the spontaneous breathing trial, albeit these cardiovascular variables at end-apnea were not different between the trials.

Conclusions: Our results suggest that when exercise and apnea are simultaneously initiated, pre-exercise voluntary hypocapnic hyperventilation blunts cardiovascular responses, but this effect is diminished at end-apnea.

Effect of cold intensity on cold-inducible RNA-binding protein release

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Introduction: Cold-inducible RNA-binding protein (CIRP) is an environmentally induced protein that upregulates during cold exposure. During moderate cold exposure (such as during cold-water immersion), decreased core temperature can lead to cellular injury and CIRP may assist with recovery. No previous studies have examined CIRP after cold exposure in humans *in vivo* and thus, the purpose of this study was to examine changes in plasma CIRP concentration in males after mild (no core temperature change) and moderate cold exposure.

Method: Six healthy, morphologically similar males (25.5±3.5y) participated in mild cold exposure and five males (25.6±3.6y) participated in moderate cold exposure. Participants completed a 30min habituation period followed by 60min of mild cold exposure wearing a liquid conditioned suit (LCS; 5°C) or 90min of moderate cold exposure using cold- water immersion (CWI; 20°C). Skin temperature was measured on 12-sites during the LCS and core temperature was measured using a telemetric pill. Plasma was collected pre-, post-, 4h post-, and 24h post-cold exposure. CIRP was analyzed via ELISA.

Results: Mean skin temperature at the end of mild cold exposure was 24.3±1.1°C (no change in core temperature) and core temperature at the end of moderate cold exposure was 36.2±0.9°C. During the mild cold exposure, there were no significant differences ($p>0.05$) in CIRP protein expression at any time point. In contrast, during the moderate cold exposure, 4h plasma CIRP was significantly higher ($p=0.019$) than post-exposure with no other significant differences ($p>0.05$) between any other time point.

Conclusions: CIRP was significantly upregulated only after cold exposure that elicited a decrease in core temperature (4hr post-CWI). The upregulation of CIRP seen in conjunction with an increase of cold intensity may indicate that CIRP can act as a cold stress marker at higher levels of cold stress even in the absence of hypothermia.

Commercially available cooling systems can extend work time in gas-tight protective clothing

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Introduction

Gas-tight protective clothing requires the use of self-contained breathing apparatus and are completely encapsulating. Extended work duration and/or working in a warm environment can result in the wearer developing heat strain; as the potential to lose heat through normal thermoregulatory mechanisms is diminished or completely removed. Commercially available cooling systems have been touted as a means to extend work durations without heat strain developing. The purpose of the present study was to evaluate internal, external, passive and active cooling systems' capabilities to extend work time in wearers of gas-tight protective clothing.

Methods

Eight males (24±3 yr, VO_2max 50.6±4.3 $ml \cdot min^{-1} \cdot kg^{-1}$) wore an encapsulating suit (Trellchem VPS, Ansell Protective Solutions, Sweden), respirator, safety helmet and a full gas cylinder. Combined ensemble weight 20.2 kg. Participants walked for a maximum of 120 minutes at 4.5 $km \cdot h^{-1}$, 1% gradient in 35 °C 50 % relative humidity. In a randomised order, participants completed the trial with: no cooling (CON); an ice-based cooling vest (IV); an ice slushy consumed before, combined with IV (SLIV); compressed air circulated through the suit at 2 $L \cdot min^{-1}$ (AIR); and a battery-operated water-perfused suit (WPS). Mean with 95 % confidence intervals are presented.

Results

Compared with CON (28.1 min [23.2, 33.1]), work time was improved with the addition of the WPS (+7.75 min [3.75-11.75], p=0.034), IV (+7.00 min [3.00-11.00], p=0.012) and SLIV (+9.63 min [5.63-13.62], p=0.002), but not with AIR (+1.25 min [-2.75-5.25], p=0.420). There was no difference in performance between the WS, IV, or SLIV.

Conclusion

Apart from the circulating of compressed air (AIR) all cooling systems extended work duration. The combination of internal slushy with the passive external ice-vest extended work duration but not more than the ice-vest alone, indicating the extra time required to administer the slushy may not be advantageous.

Requirements on microclimate cooling by enhanced evaporation in thermal insulating protective clothing

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Introduction: The need to wear thermal insulating protective clothing (firefighters, chemical industry, military etc.) is increasing. As sweat evaporation is restricted these garments cause heat stress resulting in reduced work performance and the risk of heat illnesses. A potential relief is the improvement of sweat evaporation via microclimate cooling. This paper focusses on the requirements for such a microclimate cooling method.

Method: In two studies (I+II) male volunteers in protective overalls performed balanced repeated measures within-subjects design tests in a climatic chamber (25°C, 50%RH, 0.2m/s wind speed). They were exposed to work-rest schedules (3 km/h, 5% incline) with insufflating dry air continuously (130min) into the microclimate of an additional air- diffusing garment layer (I: 600 l/min,<<5%RH, 25°C, n=10) or only during breaks (II: 105min of 205min, 600 l/min, <<3%RH, 30°C, n=12). Control conditions (I+II) contained no microclimate cooling.

Results: An essential thermal relief was achieved compared to the non-ventilated conditions: HRmax (M±SD): 123±12 vs. 149±24b/min, n=10, $p<0.01$ (I). HR in 205.min: 88.5±7.3 vs. 140.2±7.1 b/min, n=4, $p<0.01$ (II). Without ventilation in breaks (II, control) only 4 subjects tolerated the heat stress. The minima of mean skin temperatures (I: 33.4±1.0°C; II: 33.2±0.8°C) gave no evidence for a counterproductive peripheral vasoconstriction in consequence of ventilation.

Conclusions: Sweat evaporation is the most effective way of heat dissipation. A supporting microclimate cooling method can considerably reduce the disadvantages of commercial devices using ambient air (e.g. wet-hot climates) by optimizing the specific distribution (local sweat glands/rates) of a sufficient amount (600 l/min) of dry air for sweat evaporation in the microclimate of working man. While ventilation temperature has not only an effect on moisture absorption but also on peripheral vasoconstriction and heat transfer by convection a temperature of 25–30°C has proved to be appropriate. The application of this microclimate cooling method appears promising.

An Investigation of Temperature Sensing Textiles for Skin Temperature Measurement during Sub-maximal Exercise

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Introduction: Skin temperature (Tsk) is an important factor in understanding the complex nature of human thermoregulation, the effects of heat strain, and its impact on human performance. At present, most Tsk measures are impractical or unable to be used during competition. We have developed an advanced textile capable of measuring temperature that can be incorporated into clothing. The aim of this study was to validate these newly developed electronic yarns (e-Yarns) against a skin-mounted thermochron (iButtons).

Method: Data from 37 individual e-Yarns from 6 participants were analysed. iButtons were positioned using the ISO-standard 8-point method and 6 e-Yarns were embroidered into existing tri-suits at corresponding locations. Participants completed an incremental exercise test commencing at 95W, increasing by 35W every 3 minutes. Tsk was recorded throughout the test and e-Yarn temperature calculated in response to changes in electrical resistance. Additional experiments were conducted with the e-Yarns exposed to a sodium chloride solution (NaCl, range 0 – 342 mmol.L-1) to determine the impact of sweating on the resistance and conductivity.

Results: There was a weak correlation between temperature data from the e-Yarns and iButtons ($r = 0.345$; $p = <0.001$). Overall, there was a small positive bias with a large systematic error (0.148 ± 6.093, 95% LoA -11.8 to 12.1). There was no difference between the control and insulated eYarn temperatures at a NaCl concentration of 0 mmol@L-1 (24.8 ± 0.6; 24.6 ± 0; $F(7) = 0.0204$; $p = 0.667$, respectively) however, differences were apparent at all other NaCl concentrations ($p = <0.01$).

Conclusions: Tsk may be measured using current e-Yarns at rest if there is good contact between the e-Yarn and skin. However, their accuracy is limited when a sweating response is present. The appearance of NaCl has a clear impact on the resistance of the e-Yarns, rendering them inaccurate and highly variable.

Effects of moisture content on the dual thermal protective/ thermal hazardous performance of multilayer protective clothing under hot steam exposure

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Introduction: Thermal protective clothing (TPC) actually may have a dual impact on human skin because it not only resists heat transfer from environmental thermal threats, but also may impose thermal hazards on human skin due to the discharge of stored energy. The dual thermal-protective/ thermal-hazardous performance of TPC are rather complicated when it gets wet from internal and external sources (i.e. profuse perspiration and atmospheric water), and especially when it is exposed to a pressurized hot steam condition.

Method: A steam and hot fluid tester was employed to generate the saturated and superheated steam at a temperature of 133.7 °C and a pressure of 200 kPa. The outer shell and the thermal liner of a multilayer fabric system were chosen to be pre-wetted before the test, and each fabric layer had four moisture levels. Several indices were used to quantitatively assess the dual thermal-protective/thermal-hazardous performance of TPC. Empirical models were successfully established to predict the relationship between the moisture and the performance of TPC.

Results: The results showed that the increasing of external moisture enhanced thermal protective performance as it decreased heat absorption of the skin and increased skin burn injury time under direct steam exposure, but it did not have significant effect on the thermal hazardous performance through heat discharge. The increasing of internal moisture generally had a positive effect in reducing heat transfer during exposure, but during cooling it did the opposite, increasing heat discharge to the sensor. It demonstrated that thermal protective performance was more influenced by the external moisture; the thermal hazardous effect during cooling, however, was more affected by the internal moisture.

Conclusions: The results showed that moisture distribution was a key parameter to consider in the reliability of TPC since the moisture content and location have a complex influence on the dual thermal-protective/ thermal-hazardous performance.

Testing of Sleeping Bags per EN ISO 23537-1 with Different Chamber Air Temperatures

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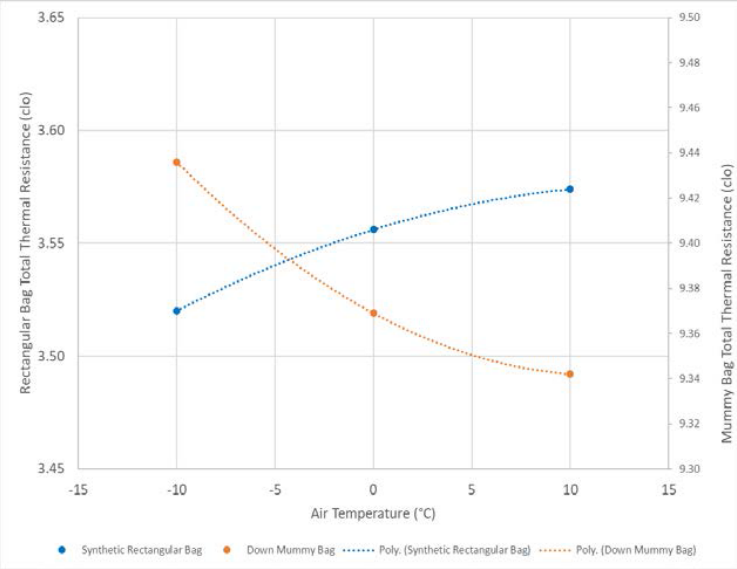
Introduction: ISO 23537-1:2016 provides a method to determine total thermal resistance and temperature rating predictions for sleeping bags using a thermal manikin. The total thermal resistance includes resistance of the sleeping bag system and the outer air layer. This outer air layer is a combination of convective heat transfer and radiation exchange. It is established that the radiation heat transfer decreases with chamber air temperature and bag insulation. Natural convection on the other hand is driven by temperature difference and increases with decreased environmental temperature. It is not known if the combined radiation and convective heat transfer in the air layer increases or decreases as environmental temperature changes. Furthermore, the ISO 23537 standard limits the air temperature of the test chamber to 10 ± 5 °C, but bags designed for environments to -20 C may be tested. The current study documents the change in measured bag insulation values for different bag types as chamber air temperature changes.

Method: ISO 23537-1:2016 test method is used in a controlled chamber. Bags of different construction types and insulation levels are tested at temperatures of 10 °C, 0 °C, and -10 °C.

Results: A plot of the insulation values for different air temperatures and bag types is shown in Figure 1. The graph shows an opposite response in measured total thermal resistance for a heavily insulated mummy bag vs. a lightly insulated rectangular bag as chamber temperature is changed.

Conclusions: Bag type influences how changes in chamber air temperature affect the measured total thermal resistance value. Changes in total thermal resistance were less than 0.15 clo for bags tested and calculated ISO 23537 temperature predictions were impacted by less than 0.6 °C.



Evaluation of Physiological Impact of Protective Clothing Fabrics for Firefighters by ISO 18640 Method

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Introduction: Continuation of an earlier study, the heat protection and the thermal and evaporative properties of 7 personal protection clothing (PPC) materials for the prediction of thermal physiological comfort (ISO 18640-1) have been evaluated. In this study, it was intended to focus on the investigation of physiological heat burden and work safety on firefighters. By coupling the Sweating Torso to a mathematical model for thermo-physiological responses, the thermo-physiological impact of protective clothing was estimated and the maximum allowable work duration (MAWD) for defined environmental conditions and a defined activity protocol were predicted by Thermal Human Simulator (THS) measurements (ISO 18640-2).

Method: The standard scenario for THS is defined as an ambient condition of 40 °C, 30% RH, wind speed of 1 m/s, and physical activity of 6 MET. The initial condition of the human body is assumed to be thermo-neutral (Tco = 36.8 °C; Tm,sk = 34.2 °C) and the onset of heat stress is defined at the core body temperature of 38.5 °C. The wicking layer was added next to the Torso skin and both MAWD with and without frame (simulating the air gap) between 7 PPC fabric assemblies were investigated.

Results: THS predicted the Tco and Tm,sk, and sweating water of the system, and MAWD was manually detected at the Tco of 38.5 °C. It was found that the highest total sweat water was 856.9g for PPC2 and the lowest of 797.9g for PPC1 among the 7 fabric assemblies. The MAWD results showed that the range was from 31 to 34 min with frame, and was 60.0 to 71.7 min without frame. The statistically significant correlations are between MAWD and Ret of ISO 11092 (p=.038), MAWD and IC, initial cooling, of ISO 18640-1 (p=.044), and MAWD and evaporated water of ISO 18640-2 (p=.000), respectively.

Conclusions: In previous study, all 7 PPCs meet the requirements of heat protection and Ret of EN 469:2005. In the case of ISO 18640-1 test standard, PPC6 revealed the best initial cooling efficiency, and PPC7 had the lowest Tm,sk during the later period of the exercise phase. On the other hand, PPC1 showed the highest Tm,sk during exercise, suggesting that lots of accumulated heat occurred. By ISO 18640-2 method, the MAWD with frame presented almost twice compared with that of no frame applied, indicating that the air gap was an important factor on it. With all of the indices relate to comfort, Ret seemed to be more critical than Rct and imt. It was found that ISO 18640-1 can give us some useful information in detection of cooler PPC, while ISO 18640-2 method can recommend a work safety index, despite the fact that it may need more detailed discussion of proceeding of the measurements including the setting of scenarios and comparison of different labs. These methods are all valuable for material tests. Both of ISO 18640-1 & -2 were studied by wear trials for validation, however, the future work should include either sweating thermal manikins or human subject evaluations.

Evaluation of radiative performance of equestrian helmets

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Introduction: Equestrianism is a popular activity that extends from amateur participation to international success. Studies show that 3.5 million people have ridden a horse in 2010 -11 (National Equestrian Survey) in Britain. There has been growing concern about the increase in horse riding related accidents. Among the injured equestrians admitted in hospitals, 60% are caused by head injuries which could be prevented by helmet usage. The aim of this study was to evaluate radiative heat loss characteristics of three equestrian helmets with the use of a thermal manikin head and to improve thermal performance using design guidelines to optimize bicycle helmets for cooling performance.

Method: Two commercial equestrian helmets and a equestrian helmet modified based upon design guidelines were tested using a thermal manikin head with 9 measurement zones and an external radiative heat source (150W infrared heat bulb placed at an angle of 60° with head) to simulate intermediate radiation condition. Surface temperature of manikin was 30°C and ambient temperature was 20°C. Power required to maintain the prescribed surface temperature was recorded as heat loss. The helmets were evaluated at 6m/s, an average prescribed by FEI. The cooling performance of bicycle helmets was modified using large inlets and larger outlets connected via internal channels to induce a low-pressure zone at the rear of the helmet

Results: The overall radiative heat gain of nude head was observed to be 9 W. The helmets as predicted shield the external radiation source from the head. The radiative heat gain observed with commercial helmet without vents was observed to be 0.72 W and the radiative heat gain with commercial helmet with vents was observed to be 0.93 W. The custom helmet showed a radiative gain of 2 W which is significantly comparable to the commercial helmets. This research shows that the cooling performance of equestrian helmets can be significantly improved.

The upper limits of allowed heat exposure for summer work uniform and vapor impermeable protective clothing estimated using PHS and TNM

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Introduction: The predicted Heat Strain model (PHS) and the Two Node Model (TNM) are widely used for predicting human responses to hot environments. Sweating in PHS is defined by the steady heat balance of the model. Sweating of TNM is based on body temperature deviation from its set point. In this study, we compared the core temperatures of these two models for workers wearing Summer Work Uniform (SWU) and Vapour Impermeable Protective Clothing (VIPC) focusing on the upper limits of the allowed heat exposure.

Method: We calculated core temperature changes of these models for gradually increasing environmental temperature at three relative humidity levels (20%, 50%, and 70%). We drew the core temperature curves against the environmental temperature for each clothing and relative humidity condition. Then, we estimated the inflection points of the environmental temperature at which the slope of the curves changed significantly. The determined inflection points were compared with the upper limits of the prescriptive zone for these conditions reported by Bernard et al. (2005).

Results: Inflection points for PHS appeared more clearly than for TNM. The Inflection points of PHS coincided well with the reported values for SWU while for VIPC the obtained values were higher than the reported ones for the lower relative humidity. Because of the more gradual changes of the core temperature slope for TNM, we could not determine the inflection points of TNM clearly. However the inflection points of TNM seem to be close to the reported values for both types of clothing.

Conclusions: The inflection points appear clearly for PHS. They coincided well with the reported values for SWU. While the inflection points of TNM were not determined clearly, they seemed to be close to the reported values for both types of clothing.

Required clothing insulation (IREQ - ISO 11079) and difference of thermal sensations between genders

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Introduction: The aim was to study if there are profound gender differences in thermal sensation during student laboratory exercise in an extreme cold environment. ISO 11079 (IREQ) was used to predict insulation.

Method: Ninety young healthy students with similar BMI, 45 males (24.7 ± 4.0 years; 180.2 ± 8.9 cm; 73.5 ± 7.8 kg) and 45 females (24.0 ± 3.0 years; 169.7 ± 6.3 cm; 63.6 ± 7.9 kg) were exposed to extreme cold in a climatic chamber at the temperature -35 ˚C and 0.4 m/s air velocity for 45 minutes. Average estimated metabolic rate for the exposure was 94 W/m^2 based on ISO 8996. The thermal sensation was recorded every 10 minutes on a scale -4 (very cold) to +4 (very warm) for feet, hands, whole body and face. Clothing insulation was estimated by ISO 9920. The students were asked to bring their own clothing.

Results: IREQ for 45 minutes' exposure was 3.2 clo for comfort (IREQneutral) and 2.9 clo for slight cooling (IREQminimal). The average available clothing insulation worn was 2.1 ± 0.4 clo for males and 2.3 ± 0.4 clo for females. Males experienced -1.5 ± 1.4 for feet, -1.0 ± 1.3 for hands, 0.2 ± 1.1 for whole body and -0.2 ± 1,3 for face. Females experienced -2.4 ± 1.5 for feet, -1.7 ± 1.5 for hands, -0.8 ± 1.4 for whole body and -0.8 ± 1.4 for face.

Conclusions: Female subjects recorded lower thermal sensations than male subjects, this may be partly explained by body differences between the genders. The females also report greater cold sensation in extremities than males which may be influenced by stronger general body cooling. The exposure time was relatively short making influence by initial thermal inertia somewhat high. Students tend to underestimate clothing need for low activity in extreme cold.

Development of a protocol to assess thermoregulatory impacts of multiple garments in a single, 90-minute trial

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Introduction: We sought to accelerate apparel thermoregulatory research studies (on humans) by developing a protocol to evaluate the impacts of multiple apparel conditions within a single experimental session.

Method: We selected a combination of exercise intensity and environmental conditions that could be sustained for 90 minutes by most participants and incorporated a 30 minute 'preload' in which steady state responses could be achieved, followed by four 15 min apparel conditions to be compared within the exercise trial. Accumulation of moisture (from sweat) in the apparel microclimate between shirt and skin was selected as the dependent variable and measured by assessment of microclimate water vapor pressure (MCvp). Study 1 was designed to assess variability in MCvp responses across four apparel conditions in which versions of the same shirt were worn. Study 2 was designed to assess variability in MCvp responses across four apparel conditions in which different garments were worn which varied widely in vapor permeability. A total of 12 subjects (6 males, 6 females) walked on a treadmill at a speed of 3.5 mph, 8% incline for 90 minutes in controlled environmental conditions of 20°C and 40% relative humidity. MCvp was measured at six locations over the torso using ibuttons taped to the skin, facing outward into the apparel microclimate (ANOVA between apparel conditions).

Results: MCvp was not different ($p=0.11$) across the four conditions in which subjects added/removed versions of the same shirt in study 1, nor were there differences between the increase in MCvp during each 15 minute condition ($p=0.20$). MCvp was higher in 'heavier' garment conditions than in 'light' garment conditions in study 2 ($p<0.001$), and was not different between duplicate conditions in the same garment (light or heavy; $p>0.40$ both comparisons).

Conclusions: We conclude this protocol is valid for thermoregulatory evaluation of multiple apparel conditions within a single, 90 minute experiment.

Comparison of different clothing area factor (fcl) calculations based on picture analysis in Adobe Photoshop

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Introduction: Clothing area factor (*f*cl) is an indicator of the increase in surface area relative to the nude body for calculation of heat loss from the clothed body to the environment. The aim was to calculate and compare the *f*cl values from two equations by the photographic method.

Method: Thirty-five modern western indoor clothing sets (19 male and 16 female) were tested on a thermal manikin Tore. In order to calculate *f*cl , front and side views of nude and dressed manikin were photographed against bright background. During analysis in Adobe Photoshop, colour information was discarded by selecting Grey scale mode. Then Curve was adjusted under Image to increase the manikin contrast against the background. The surrounding objects were eliminated by selecting black manikin silhouette, inversing the selection and deleting background residues. In the Histogram, Brightness and Contrast were adjusted to minimum and maximum levels, respectively. Then the black silhouette was selected with Magic wand tool and pixel number was recorded followed by deselecting the whole picture, percentile of pixels was taken, when cursor was left at level 100. The *f*cl-s were calculated based on both pixels and percentile by two equations and the comparison was made:

1. $f_{cl} = (Front_{clothed}+Side_{clothed}) / (Front_{nude}+Side_{nude})$
2. $f_{cl} = (Front_{clothed}/Front_{nude} + Side_{clothed}/Side_{nude}) / 2$

Results: The calculated *f*cl means (SDs) for Eq. 1 found similar for both pixels and percentile 1.17 (0.07), while those values for Eq. 2 appeared 1.19 (0.07) and 1.18 (0.07), respectively. The *f*cl means (SDs) differences equation wise for pixels and percentiles were 1.04 (0.57) % and 1.09 (0.57) %, respectively. The calculated basic means (SDs) insulation (*I*cl) did not differ when using the respective pixels and percentile *f*cl values.

Conclusions: Two equations provided the *f*cl values with a small difference based on either pixels or percentile of picture and did not affect the calculated intrinsic clothing insulation, *I*cl.

Applying immersion guidelines to military waterborne movements

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Introduction: Military waterborne activities include boat travel, river crossings, and navigating through wetlands, with risk for hypothermia due to cold air exposure (CAE) and cold water immersion (CWI). Immersion guidelines are intended to limit core temperature (Tc) from falling below 35.5°C. This study evaluated this guidance for Ranger School students conducting waterborne movements.

Methods: On two occasions (D1, D2), 17 Ranger School students moved from a start point (SP) through a swamp to a river crossing (CP), then through a swamp to high ground (HG). Location (GPS), Tc (ingested capsule), and skin temperatures (Chest, Thigh, Calf, Foot) were recorded. Air (Ta) and water (Tw) temperatures, respectively, were 10°C and 13°C, with waist-deep water on D1, and 14°C and 12°C, with knee to thigh deep water on D2.

Results: Duration was 2 h 10 min on D1 and 3 h 5 min on D2. On D1 and D2, respectively, Tc decreased ($p<0.05$) from SP (37.9 ± 0.3°C; 37.4 ± 0.3°C) to CP (37.2 ± 0.5°C; 37.0 ± 0.5°C) and from CP to HG (36.7°C ± 0.6°C; 36.7°C ± 0.5°C). Chest also decreased ($p<0.05$) from SP to CP and from CP to HG, while Thigh, Calf and Foot decreased ($p<0.05$) from SP to CP, with no further change to HG. The lowest Tc at HG was 35.6°C on D1, 35.7°C on D2.

Conclusions: Based on Tc response, risk assessments for these conditions were appropriate. Immersion tables currently have categories for knee and waist depths. On D1, Tw and depth suggested a limit of 2 h. On D2, Tw and depth suggested a limit of 1.5 to 2 h (waist-deep) or 5 to 7 h (knee-deep). An intermediate depth between knee and waist is recommended.

These are the private views of the authors and are not official US Army or DOD policy.

Physiological and Perceptual Markers of Performance During a Military Cold Water Immersion and Rewarming Exercise

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Introduction: Warfighter readiness is a fundamental component of an effective military force. In harsh environments, such as immersion in cold water, warfighter readiness can be undermined due to physiological and cognitive deterioration. Efforts to maintain readiness in such conditions, therefore, are of critical importance. The current work evaluates relationships between temperature perception, shivering sensation, and mean skin temperature (Tmsk) as markers of cognitive performance during cold water immersion and rewarming.

Method: Thirteen military personnel (age: 29 ± 5 yrs, ht: 172 ± 23 cm, wt: 81.8 ± 9.7 kg) participated in cognitive testing during a cold (1°C) water immersion and rewarming exercise. Cognitive testing consisted of tablet-based simple reaction time (SRT) and match-to-sample (MTS) memory tests, which were administered before, during, and after immersion, and at three time points during 60 minutes of rewarming. Prior to each cognitive assessment, temperature perception, shivering sensation, and Tmsk were obtained. Relationships between cognitive performance and physiological and perceptual measurements were analyzed using Pearson correlation coefficients (r) with a significance level set at $p < .05$.

Results: Colder temperature perception was associated with longer SRT ($r = -0.80$, $p < .05$) and a reduction in correct MTS responses ($r = 0.81$, $p < .05$). Greater shivering sensation was also associated with longer SRT ($r = 0.91$. $p < .05$), yet no relationship was observed between shivering sensation and MTS performance ($r = -0.48$, $p = .33$). Both SRT and MTS performance were not significantly correlated with Tmsk (SRT: $r = -0.73$, $p = .10$; MTS: $r = 0.79$, $p = .06$).

Conclusions: Findings suggest a possible link between cognitive performance and cold perception (temperature and shivering), which has relevance to warfighter readiness. Future work should focus on interventions that improve aspects of cold perception, which may enhance cognitive performance and improve warfighter readiness.

Use of a Portable Metabolic System to Revise Shipboard Work/Rest Guidance in the US Navy

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Introduction: Work/rest instructions have provided safety guidance from environmental or work load intensity in civilian and operational military scenarios for over 70 years with little revisions since their development. The US Navy uses the Physiological Heat Exposure Limits (PHEL Curves) developed in the 1960's and based on a predicted metabolic work load, to provide shipboard heat exposure guidance. Current technology is now available that allows metabolic data assessment in field settings.

Method: Twenty-five personnel (age: 23 ± 3 yrs, height: 169 ± 10 cm, weight: 79.4 ± 14 kg) had their VO_2 measured each minute while performing their actual shipboard duties for approximately three hours on two separate days (T1 and T2). T1 and T2 values were averaged to provide a single VO_2 value. Shipboard personnel from the following work spaces were evaluated in this pilot study: Flight Deck, Hangar Bay, Scullery, Galley, Waste Management, Catapult, and Reactor Room.

Results: Navy-predicted work rates (WR) of scullery personnel (n=8) were significantly higher from the measured WR (240 ± 22 vs 227 ± 28 watts; $p = .03$). The predicted versus measured WR of non-scullery personnel (n=17) followed the same trend to overestimate the WR (213 ± 36 vs 197 ± 17 watts, respectively). However, this difference was not statistically significant ($p = .06$), most likely due to a greater variability among the differing work space personnel.

Conclusions: Findings from this pilot study indicate that differences between predicted and actual WR exist. The ability to measure actual VO_2 data provides an opportunity to update guidance that may have become antiquated due to modern technology, protective clothing, and work place methodologies. This has implications for enhancing guidance in civilian and military work environments. Findings from this evaluation have resulted in further efforts to revise the U.S. Navy's shipboard PHEL curve guidance.

Air conditioning needs of workers in long-haul trucks can be substantially reduced with high-reflectivity paints, enabling important fuel savings in the European transportation sector

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Introduction: Transportation workers are often exposed to thermally challenging conditions while driving for long periods under high temperature and solar radiation. This is taxing for the workers, so air-conditioning (AC) is used to counter the external thermal loads and maintain comfortable temperatures inside the cabins. Yet, this increases fuel consumption and tailpipe emissions with clear detrimental environmental effects, thus it is crucial to consider alternative strategies to protect the workers while minimizing the AC loads needed.

Method: We have numerically investigated the thermal loads affecting the cabin of long-haul trucks, considering the environmental conditions prevailing across the different regions of Europe throughout the year. We studied the AC loads and related fuel consumption to maintain comfortable cabin temperatures during entire workdays. We analysed the potential reductions in AC loads and fuel consumption that can be obtained by using high-reflectivity paints on the cabin external surfaces.

Results: Southern Europe accounted for 38% of the European fuel costs related to AC cooling, despite representing only 26% of the trucks fleet. The yearly AC fuel costs of the southern European trucks are almost 12 times higher than those in the north, and 12-49% higher than those in the eastern/western regions. The use of high-reflectivity paints by the entire European long-haul fleet can substantially reduce the cooling AC loads. Paints reflecting 70% of the solar radiation instead of 32% (average value) can reduce the European transportation AC fuel costs by up to 39% or 1301 million euros per year, i.e. 0.6% of the yearly total fuel cost.

Conclusions: The optical properties of paints used in truck cabins have strong impact on the AC loads needed to maintain comfortable cabin temperatures. Important reductions in fuel consumption are possible by carefully choosing the paint properties, indicating potential for substantial savings by the European transportation sector.

Stress levels in simulation-based training of laparoscopic surgical skills: A pilot study

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Introduction: Stress in excess has negative effect on surgeon's performance during procedures in the clinic. Simulator training enables technical surgical training outside the operating room and allows surgeons to improve their technical skills in a low stressor environment, where they can perform targeted and repetitive exercises without fear of serious consequences. A question of interest relating to simulation- based training is whether the lack of real-life consequences and associated lack of stressors and low stress levels might affect the ability to transfer these technical skills to clinical settings. Little is known about stress levels of surgeons in training using simulation-based training and the transfer of skills. The objective of this study was to compare stress levels when using analogue and virtual reality (VR) simulators versus suture exercises on animal organs.

Method: In this pilot study, four test subjects who all were surgeons in training, underwent an experimental study, in which we applied both objective measurements: heart rate variability (HRV) and heart rate (HR), and subjective evaluations: Spielberger State-Trait Anxiety Inventory (STAI) to assess their stress levels. The data was obtained at rest and during the simulation exercises and the suture exercises.

Results: We found during rest that mean HRV was 2.4±2.3 (LF/HF), mean HR was 72.0±2.8 (beats/min) and mean STAI was 8.5±3.1 (score). During analogue simulation mean HRV was 8.5±6.4 (LF/HF), and mean HR was 84.4±8.7 (beats/min) and mean STAI was 11.9±2.2 (score), and during VR simulations mean HRV was 7.8±4.2 (LF/HF), mean HR was 83.6±8.7 (beats/min) and mean STAI was 11.8±2.8 (score). During suture mean HRV was 6.9±3.4 (LF/HF), and mean HR was 85.3±6.4 (beats/min) and mean STAI was 11.0 ± 0.0 (score).

Conclusion: The mean HRV measurements suggest a small elevation in stress levels when doing exercises on the analogue and VR data simulators compared to animal tissue suture exercises. The results from the subjective measurements suggest the same tendencies. In a future main study, these tendencies should be further assessed.

High-reflectivity paints reduce air conditioning needs of workers in long-haul trucks during the summer

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Introduction: Occupational heat exposure decreases productivity, causes discomfort and may lead to heat stroke. Due to climate change, occurrence and intensity of heat waves may increase in many regions of the world. Workers in the transportation sector are particularly vulnerable as they are inside vehicles when the temperature is high and the solar irradiance is substantial. Air conditioning is used to reduce the heating load on the vehicle cabins, but it impacts fuel efficiency and tailpipe emissions, which is detrimental for climate change mitigation. Therefore, one needs to minimize the air conditioning load while maintaining a comfortable environment inside vehicles.

Method: A virtual testing environment was developed to numerically investigate the thermal loads affecting the cabin of long-haul trucks. Using a lumped approach to represent the vehicle, the air temperature and loads in the cabin were calculated for a typical hot and sunny southern Europe summer day. Considering commercially- available paints used on the cabin external surfaces, we investigated the effect of high- reflectivity paints on the air conditioning load required to maintain comfortable cabin temperatures throughout an entire work day.

Results: High-reflectivity paints led to significant reduction on the thermal loads affecting the truck throughout the day. Using paints with optical reflectivity of 0.70 instead of 0.04 on the vehicle body reduced the heat absorbed and transferred to the cabin by 43 % when the sun was at its peak. This implied a 25 % decrease in the air conditioning power to maintain the cabin air at 23 °C.

Conclusions: The optical properties of the paint used in vehicles, specifically long-haul trucks, has a significant impact on the power consumption of the air conditioning. By carefully choosing the paint properties, one can passively improve the comfort of transportation workers during summer, but also improve fuel economy and reduce tailpipe emissions.

Effects of nitric oxide synthase with Ca^{2+}-activated and ATP-sensitive K^{+}-channels on local forearm sweat rate in older men during exercise in the heat

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Introduction: Nitric oxide synthase (NOS) inhibition attenuates sweating in young men. However, NOS-dependent sweating is diminished in older men. Calcium- activated and ATP-sensitive potassium (KCa and KATP) channels also modulate sweating in young men exercising in the heat, although their role in older men remains uncertain. Additionally, potential crosstalk between NOS and KCa and KATP channels on sweating in older men has not been previously evaluated under these conditions. Therefore, we examined the separate and combined effects of NOS with KCa and KATP channels on local sweat rate (LSR) in older men exercising in the heat.

Method: In thirteen habitually active men (61±4 years), LSR (ventilated capsule) was measured at six dorsal forearm skin sites receiving either: 1) lactated Ringer's (Control), 2) 10mM N^{G}-nitro-L-arginine methyl ester (L-NAME, NOS inhibitor), 3) 50mM Tetraethylammonium (TEA, KCa channel blocker), 4) 5mM Glybenclamide (GLY, KATP channel blocker), 5) GLY+L-NAME, or 6) TEA+L-NAME, via intradermal microdialysis. Participants rested in the heat (35°C) for 70-min, followed by 50-min of moderate intensity exercise (~55%VO2peak) and 30-min of recovery.

Results: During rest, LSR was not different between treatment sites (all P>0.05). End-exercise Control LSR Control (1.81±0.61 $mg \cdot min^{-1} \cdot cm^{-2}$) was not different from GLY (1.76±0.81 $mg \cdot min^{-1} \cdot cm^{-2}$), TEA (1.71±0.65 $mg \cdot min^{-1} \cdot cm^{-2}$), L-NAME (1.65±0.57 $mg \cdot min^{-1} \cdot cm^{-2}$) or GLY+L-NAME (1.78±0.56 $mg \cdot min^{-1} \cdot cm^{-2}$) (all P>0.05). However, combined TEA+L- NAME (1.49±0.56 $mg \cdot min^{-1} \cdot cm^{-2}$) was attenuated relative to Control (P<0.05).

Conclusions: While the independent effects of NOS inhibition or KCa or KATP channel blockade had no effects, a combination of NOS inhibition and KCa channel blockade attenuated sweating in older men exercising in the heat. The interactive effects of these mechanisms on regulating heat loss in older men at the level of the eccrine sweat gland requires further investigation.

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Upper body skin temperature during exercise in a warm environment: a sex comparison

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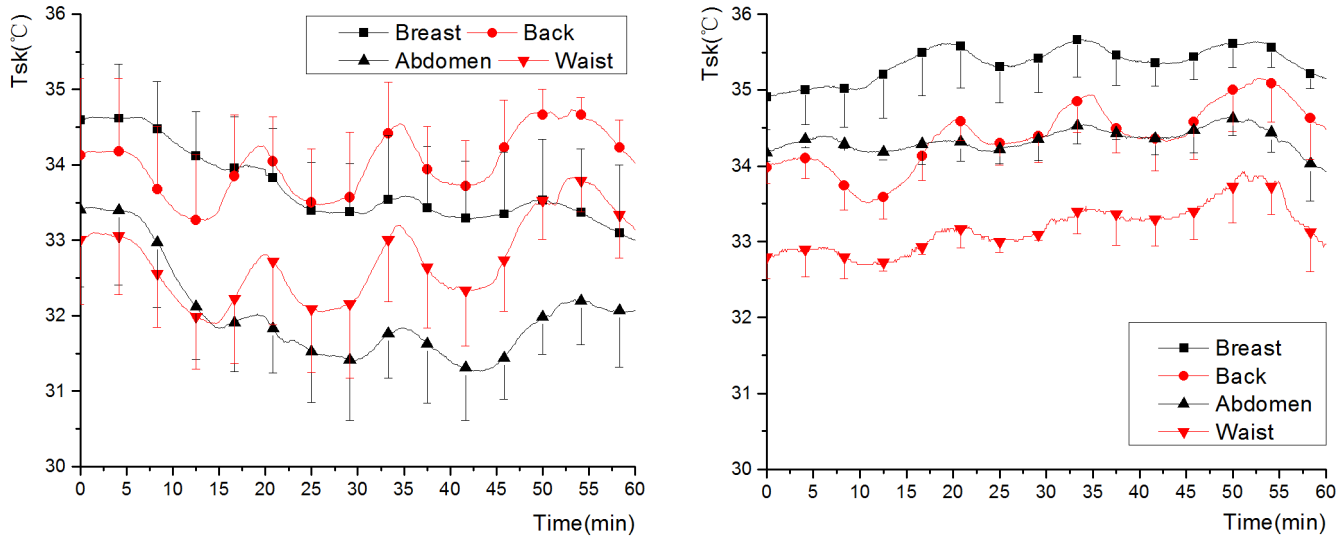
Introduction: Skin temperature is greatly affected by exercise. However, majority of researches that investigated skin temperature focused on males, which might not be applicable for females. This study aimed to investigate differences between female local skin temperature and male.

Method: Seven young females with B-cup breasts and three young males volunteered to participate in the experiment in a warm environment (30°C, 44%RH). Male subjects wore a T-shirt and shorts while female subjects wore an additional layer of a sports bra. The exercise protocol consisted of 5 min walking for warming up, three alternations between 10 min jogging and 5 min walking, followed by 10 min sitting rest to recover. Skin temperature was measured at breast/chest, abdomen, back and waist.

Results: Female breast and abdomen temperatures showed a stepped decrease along with the alternation between jogging and walking, while the temperature at back and waist increased. The four regional skin temperatures all showed an upward trend in males. It is speculated that the prominence of female breasts results in almost no air gap at breast and a bigger air gap at abdomen under the T-shirt. The decrease of skin temperature at breast might be due to the increased heat conductivity of the wet sports bra while the decrease of skin temperature at abdomen might be caused by the increased ventilation resulting from the pump effect during exercise.

Conclusions: Opposite change of local skin temperature was observed on the anterior between sexes during exercise. Such difference needs to be considered in sportswear design for females.



A. Female B. Male

Figure 1. Changes in local skin temperature

Observations of regional differences in finger skin blood flow fluctuations

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Introduction: Blood vessels of the finger skin play a vital role in regulating body temperature in humans. The rate of heat dissipation from hands depends on the blood flow of arterio-venous anastomoses (AVAs) which are able to change their diameter dramatically by dilating and constricting. Laser Doppler flowmetry (LDF) is widely used to observe skin blood flows (SBFs) including changes of blood flows in AVAs of fingers and toes as a representative value of the whole skin site, although its measurement area is quite small. This study aims to compare fluctuations of SBFs in some finger skin sites in order to confirm the synchronicity of SBFs measured by LDF in the different finger skin sites and explore the possibility of affecting the rate of heat dissipation, if asynchronous changes are observed.

Method: We examined healthy young females (N = 25) wearing only a T-shirt and short pants in a climatic chamber set at 32 ◎C. In each trial, after reaching thermal equilibrium, SBFs were measured by using LDF on the ventral and dorsal distal phalanx and the dorsal middle phalanx of the right index finger. Waveforms of SBFs were compared between the intra- and inter-skin sites of the finger to confirm synchronicity of fluctuations.

Results: In all sites of all participants, finger SBFs were around maximal levels with occasional spontaneous drops. While the SBF behaved synchronously between the three sites in almost all cases, SBFs measured in the ventral distal phalanx and the dorsal middle phalanx behaved asynchronously in some cases.

Conclusions: Observed asynchronous SBF fluctuations between different finger sites could be related with the location of probes and uneven blood distributions to vascular networks caused by different responses of AVAs to sympathetic activity. The impact of those discrepancies on the heat dissipation rate could be limited.

Thermal Burden of a Decontamination Protective Ensemble

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Introduction: Careful consideration should be given to the heat exchange properties of protective clothing when selecting appropriate systems for the anticipated operational threat. The aim of this study was to assess the thermal burden of a decontamination protective ensemble (DPE) and recommend limits to work duration.

Method: The thermal insulation (It), evaporative resistance (Ret), and evaporative potential (im/clo) of an individual protection ensemble (IPE) worn with or without a decontamination protective ensemble (DPE) were measured on a heated sweating manikin according to ASTM standards. The Heat Strain Decision Aid model was used to estimate work durations before a body core temperature of 38.5 °C was reached during personnel and equipment decontamination station activities (PDS 180 W and EDS 280 W) at a Wet-Bulb Globe Temperature of 26 °C. A recovery period of 60-min was modelled to investigate if doffing the DPE facilitated a reduction in body core temperature.

Results: Greater restrictions to heat exchange were measured in DPE+IPE (*It* 2.63 clo, *Ret* 0.43 kPa·m^2/W, *im/clo* 0.02) compared to IPE (*It* 2.21 clo, *Ret* 0.07 kPa·m^2/W, *im/clo* 0.13). The time to reach a body core temperature of 38.5 °C was most restricted during the EDS activity wearing DPE+IPE (PDS, 366 IPE *vs* 116 min DPE+IPE and EDS, 87 IPE *vs* 65 min DPE+IPE). During the recovery period the predicted body core temperature declined by 0.3 °C if the DPE was doffed.

Conclusions: Wearing DPE while performing decontamination is severley restrictive to heat loss thus limiting work durations. Work tables need to be adjusted for the added thermal burden of wearing DPE with considerations made for cooling strategies to reduce the risk of heat illness.

Infrared thermography technique for the assessment of footwear thermal comfort

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Introduction: Footwear thermal comfort is one of the relevant properties that are taken into account during the evaluation of footwear performance. However, it is difficult to quantify in that it is inherent to the subjective perception of each individual. This work is aimed to implement the infrared thermography technique as part of the protocol for the objective assessment of thermal comfort in footwear at different levels, from the evaluation of the materials by using standard methods to whole shoe assessment in real wearing conditions.

Method: Dynamic IR thermography is a rapid, non-contact and non-invasive technique; measurements are taken at a distance. To measure the surface temperature accurately, parameters such as the distance between the object and the IR camera, relative humidity, atmospheric temperature, apparent reflected temperature and the emissivity of the object must be provided to the camera. The emissivity varies between 0 and 1, according to the properties of the surface and the material and must be determined for each object. The emissivity value of human skin is 0.98. A thermal imaging camera ICI 8320 model P series and IR Flash Pro Image Analysis Software was used. Furthermore, IR thermogram results were correlated with the user's perception over use obtained by means of validated questionnaires based on a bipolar scale. The correlation obtained depends on the footwear model studied.

Results: A method consisting of several stages was set up. It was based on the dynamic IR thermography technique for the assessment of thermal comfort in different controlled environments. Qualitative results were obtained by checking the thermal images of the footwear and foot areas studied, which were taken right before and after the footwear trials. The overall quantifiable results were drawn by calculating the average temperature increase occurred in the areas under study of the user's feet and footwear while performing several activities that raise the thermal load.

Conclusions: Through this research, it was possible to appreciate the potential of infrared thermography and the benefits that this technique brings for footwear assessment, in that it is quite useful in identifying the areas that provide the greatest breathability and in choosing footwear that facilitates thermoregulation.

Modelling of conditioned automotive seats

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Introduction: Seats play a significant role in the thermal experience because of their large contact area with a human body. The occupant-seat contact area is exposed to the current thermal state of the seat as well as isolated from the ambient microclimate. This situation might be especially critical in vehicular cabins, where the operating conditions can temporarily reach extreme values. To enhance the thermal experience in such circumstances, seat conditioning technologies were developed. On the other hand, a method to calculate boundary conditions at seats for thermo-physiological modelling is not available. The aim of this study is to develop a physical model that realistically solves time-dependent heat exchange between the seat and the occupant.

Method: The model was developed using fundamental heat transfer principles simplified to a one-dimensional problem with dominant heat flux in a perpendicular direction to the seat plane. The computational nodes comprised human tissues as well as adjacent clothing and seat construction layers. The calculated heat fluxes were validated against our own measurements of heat flux by means of RMSD and bias. The tests were carried out in cool (tamb = 18 °C) and hot (tamb = 41 °C) conditions using unconditioned, heated, and ventilated seats and a pool of nine participants.

Results: The results showed good agreement between the experimental and calculated data with respect to the intended model application. The RMSD and bias were typically within two standard deviations of the experiment. Most importantly, the model captures the time-dependent development of the heat exchange, which is considerably different from the static approach – using thermal and evaporative resistances to represent the seat.

Conclusions: The proposed model was shown to realistically calculate heat transfer between the seat and the occupant. This tool can be coupled with thermo-physiological and thermal sensation models to enhance their applicability and accuracy for seated exposures.

New generation of thermal manikin with integrated surface heat flux sensor and active cooling system

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Introduction: Thermal manikins, as the most realistic devices for simulation of heat and mass transfer from the human body, are nowadays implemented in a wide range of disciplines including clothing research, the automobile industry and the building environment research. State-of-art manikins, however, cannot measure environmental heat gain due to lack of active cooling and low thermal capacity compared to humans. The recently developed manikin ANDI (Thermetrics, USA) with active cooling and integrated surface heat flux sensor can overcome these shortcomings.

Method: We have evaluated this new type of thermal manikin for its accuracy and applicability to simulate human heat exchange with the environment in steady state and transient conditions, including hot conditions.

Results: The evaluation results confirmed the relevance of the new technology for variety of standard and close-to-practice measurements. At the same time, we could demonstrate advantages of this novel manikin over state-of art manikins for simulation of human thermo-physiological response. The cooling system of the manikin enabled better accuracy of the simulations in hot environments.

Conclusions: This new generation thermal manikin significantly widens the application range of thermal manikins for not only static measurements (body heat gain in hot environments) but also dynamic simulations of human thermo- physiological response in realistic clothing and environmental scenarios.

Predict Human Physiological Response and Evaluate Thermal Properties for Multi-Temperature Adaptable Smart Clothing: Application of Physiology Model Controlled Manikin and Thermal Conductivity Analyzer in Various Ambient Temperatures

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Introduction: More and more functional smart textiles have been developed for the purpose of preventing people from suffering heat/cold impacts and fulfilling their needs in transient conditions. However, there are not so many proper test methods been available for these new textiles. The aim of this study is to establish test protocols by using various testing tools to determine the properties of temperature smart textiles and clothing systems.

Method: A Thermore® smart insulation jacket was selected for this study and normal outdoor apparel was chosen as the control sample. All the tests were carried out in a climatic chamber. The thermal effusivity and thermal conductivity of fabrics were determined by using a thermal conductivity analyser, MTPS, in different ambient temperatures (30℃ v.s. 10℃ and 20℃ v.s. 0℃). Furthermore, human thermal comfort was evaluated by using the physiological and comfort manikin (MPC) in static and dynamically changing environments. The test consisted of the following four periods: 1) 1 MET activity level at 20℃ (15 min), 2) increase activity level to 2 MET (15 min), 3) lower down ambient temperature to 10℃ (90 min), 4) decrease activity level to 1 MET at 10℃ (30 min). The major measurements include rectal temperature, skin temperatures (Tsk), perceived thermal sensation, comfort, and dynamic thermal sensation (DTS). The analysed items also include regional differences and cooling rates between ambient and skin temperature.

Results: The repeatability of all the tests was assessed by calculating the mean absolute deviation (MAD). The average MAD between the 6 parameters was in the range of 0.01 and 0.22. The maximum MAD was found in DTS, which was less than 0.75. On the other hand, the % Change of thermal effusivity of the test sample was analysed by comparing the results under different ambient temperatures, which were 12.33% and 9.25% respectively. The results showed that comfort rating was around 2 (comfortable) at temperature smart jacket covered segments, around -2 (uncomfortable) at control sample segments, and around -3 (very uncomfortable) at control segments, e.g. bare hand. Furthermore, the highest cooling rate of ambient temperature was 17.99 $°C.h^{-1}$ at the 3rd stage of MPC test, but instead, Tsk showed relatively stable through all the test periods.

Conclusions: In this study, several test protocols have been designed to determine the properties of functional smart textile materials, fabrics, semi-product, and clothing system. The established evaluation items include the thermal effusivity of fabrics and the physiological and comfort evaluation technology for temperature adaptable smart clothing systems. The results showed that MTPS and MPC can be used as testing tools to distinguish the thermal properties of temperature adaptable fabrics and the performance of temperature adaptable smart clothing systems in various ambient temperatures. Nevertheless, further validation study is needed to compare results of MPC with human subject trial for temperature smart clothing in these transient conditions.

Thermal Manikin Comparison of Cooling Methods

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Introduction: Military readiness depends on rigorous military training, however intense training can lead to exertional heat illnesses (EHI). The medical costs and long-term implications of EHI can force lost training days, impacting unit readiness and individual careers. Each year more than 2000 Soldiers experience an EHI serious enough to require medical attention and/or lost duty time. Though prevention of EHI remains a high priority, rapid and effective treatment remains key. Several field-expedient methods of rapid cooling to reduce EHI severity were tested.

Method: Total cooling power was measured using a Thermetrics (Seattle, WA), Newton 20 zone thermal manikin according to ASTM F2371-16, Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Heated Manikin. Environmental conditions were 35°C, 40% RH, and 0.4 m•s-1 wind speed. Performance of iced sheets and ice packs was compared with two commercial cooling products.

Results: When the thermal manikin was covered with bed sheets soaked in ice water the peak cooling was 369 W. Peak cooling for the iced sheet with ice packs on the armpits and groin was 427 W. Peak cooling for CAERvest® (BodyChillz LTD, Gatwick Sussex, UK) and Polar Skin ™ Comprehensive Cooling System (North American Rescue, Greer, SC USA) were 160 and 277 W respectively. Cooling durations of CAERvest® and Polar Skin ™ were 48 and 34 minutes, average heat extraction 55 and 28 W.

Conclusions: Of the methods examined, iced sheets with ice was most effective for rapid heat extraction. It is not always feasible to have coolers full of iced sheets nearby. This study quantified the potential for heat extraction by other methods which may be more appropriate for austere conditions. Since thermal manikin testing does not reflect human physiology, human studies are necessary to further assess cooling potential of various methods.

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U.S. Government.

Predicted Heat Strain (PHS) model predicts the evaporative water loss well in an extremely hot climate

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Introduction: The aim was to study if the evaporative water loss can be predicted enough accurately for hydration recommendations by ISO 7933 – Predicted Heat Strain (PHS) model during a student laboratory exercise in an extremely hot environment.

Method: Twelve young healthy students (8 males and 4 females), unacclimatized to heat, were exposed in a climatic chamber at 50˚C, 30% relative humidity and 0.4 $m \cdot s^{-1}$ air velocity for 45 minutes. They had a mean (SD) age of 25.1 (2.6) years, height 175.6 (6.9) cm, weight 72.3 (11.0) kg, VO2max 54.9 (6.5) $mL \cdot min^{-1} \cdot kg^{-1}$, and HRmax 194 (6) bpm. The men and women performed bicycling for 6-minutes at workloads of 150 and 100 Watts (W), when the metabolic rates (M) calculated found 363 and 290 $W \cdot m^{-2}$, respectively. Moreover, the students did step test at 60 $steps \cdot min^{-1}$ for 5-minutes with estimated M being 215 $W \cdot m^{-2}$. They were standing most of the time (34 min) (M = 80 $W \cdot m^{-2}$). Time weighted average M for males and females were 133 and 123 $W \cdot m^{-2}$, respectively, for the whole exposure duration. Clothing insulation, Icl = 0.4 clo and moisture permeability index, im = 0.42 were input to PHS model simulation. The actual water loss by evaporation was determined by subject's dressed body weight difference before and after exposure.

Results: The actual mean (SD) total water evaporated was 461.3 (176.7) g. The predicted total water loss was 427.4 (39.2) g by the PHS model. There was no significant (p = .514) difference between the actual and the predicted water loss.

Conclusions: PHS model appears to be reliable to foresee the evaporative water loss in short-term exposure at 50˚C in young healthy students. The results suggest that ISO 7933 – PHS model is a useful tool to predict the risk of dehydration and plan for drinking in extremely hot climates.

Realistic clothing model for heat and moisture transport through human skin-clothing-environment system

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Introduction: Heat and moisture transport from human skin to the environment is a critical aspect for protective and functional properties of clothing as well as thermal sensation and wearing comfort. The simulation of heat and moisture transport in clothing is a time-efficient and inexpensive approach to the virtual design of clothing and thermally comfortable and safe environment for human occupancy. The current models oversimplify enclosed air layers by assuming its homogeneous distribution which causes significant errors in simulated heat fluxes. In this study, we investigated the validity of heat and moisture transport through realistic heterogeneous air gaps, along with the effect of the body movement, ventilation through opening and porosity of the fabric.

Method: The newly developed model considers several heat and moisture transport mechanisms, such as conduction, forced and free convection, radiation, evaporation, condensation and wet conduction. It was systematically validated through more than 30 cases with an increasing level of complexity for the wide range of conditions including static and dynamic (caused by human movement) air gap distribution.

Results: The developed model is validated for the sensible and latent heat flux including effect of ventilation due to wind and movement as well as evaporation and condensation in clothing layers. The model showed good agreement with measured data with an average relative error of 12%.

Conclusions: The presented clothing model was proved to be accurate and robust and can be useful for several research fields, where the analysis of the interaction between thermal environment and the human body is in focus.

Evaporative resistance calculations analysis based on pre-wetted thermal manikin measurements

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Introduction: The aim of this study was to test previously published corrections for calculating clothing evaporative resistance (Ret) by heat loss method on dry thermal manikin using sweating system with pre-wetted skin. The main objective was to investigate to what extent are these corrections usable for this sweating system as many of them were proposed based on manikins with different sweating simulation systems.

Method: Dry thermal manikin TORE at Lund University with pre-wetted skin was used to measure 14 clothing ensembles composed of Taiga AB (Sweden) ambulance system garments covering range from 0.63 to 3.33 clo. Evaporative resistance (Ret) was measured in a standing posture with air velocity of 0.5±0.1 m/s to manikin´s back and ambient temperature with relative humidity controlled at 34.0±0.1 °C and below 40 % respectively. Evaporative resistance was simultaneously measured by both mass loss method using weighting scale (Mettler Toledo K240) and heat loss method using thermal manikin software. Paired two-tailed t-test was used to compare 8 different calculation methods using various corrections based on heat loss measurements with values calculated by mass loss method, which should be correct from physical point of view. Insulation-based analyses was also concluded, and the same t-test was done for insulation intervals of 0-2.0 clo, 0-2.5 clo and 2.0-3.5 clo.

Results: The statistical analysis with level of significance set at 0.05 for whole range of clothing insulation shows that there is no significant difference between the values calculated by mass loss method and 6 different calculating methods using various corrections for heat loss method. In insulation-based analyses, corrections with significant difference where changing with changing thermal insulation intervals. There is also a difference in results when the same analysis was conducted on basic evaporative resistance (Recl) instead of total evaporative resistance (Ret).

Conclusions: Some of the heat loss method corrections could be omitted from statistical perspective while using pre-wetted skin. Further research is needed to see if these results also apply to other sweating thermal manikins using pre-wetted skin method. Future objective is to see the impact on physiological modelling while using different evaporative resistance values from various calculations to keep good balance between accuracy of the model and complexity of the measurements.

Validation of ISO 9920 clothing item insulation summation method based on an ambulance clothing system

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Introduction: The aim of this study was to validate the summation method suggested by ISO 9920 based on the example of an available ambulance clothing system. Simultaneously, an objective was to evaluate this clothing system from the viewpoint of the standardized calculation paths for use in the standard models for prediction of human exposure to cold and heat.

Method: 28 items from the Taiga AB (Sweden) ambulance system, shoes and gloves were selected for this study. All items were tested individually on the thermal manikin Tore at Lund University according to ISO 9920 requirements (low air velocity), and basic insulation of each garment (Iclu) was calculated. More than 100 realistic clothing combinations were compiled and basic insulation (Icl) of these clothing ensembles was calculated according to ISO 9920. These were ranked after the calculated insulation, and 14 sets were selected to cover evenly a range of insulation values from 0.63 to 3.33 clo. Basic insulation (Icl) of the selected sets was calculated based on thermal manikin measurements. Photographic method was used to estimate clothing area factor (fcl) of the individual garments and the ensembles. Regression analysis was used to compare the estimated and measured basic clothing insulation values.

Results: The difference between measured and estimated basic insulation values varied from -18 to 12 %. The highest percentual difference was for the lightest clothing sets. However, when looking on absolute differences, then these were similar over the whole range of tested insulation values ranging between -0.17 to 0.18 clo with an average difference of 0.02 clo (-0.16 %). All basic insulation vales stayed very close to the line of identity ($R^2 = 0.9775$).

Conclusions: The equation to estimate basic clothing insulation (Icl) from individual items' insulation (Iclu) gave, in the case of this ambulance clothing system very close results to the measured values. This encourages evaluating and selecting protective clothing for ambulance personnel based on individual item measurements.

The physiological pathways to drowning

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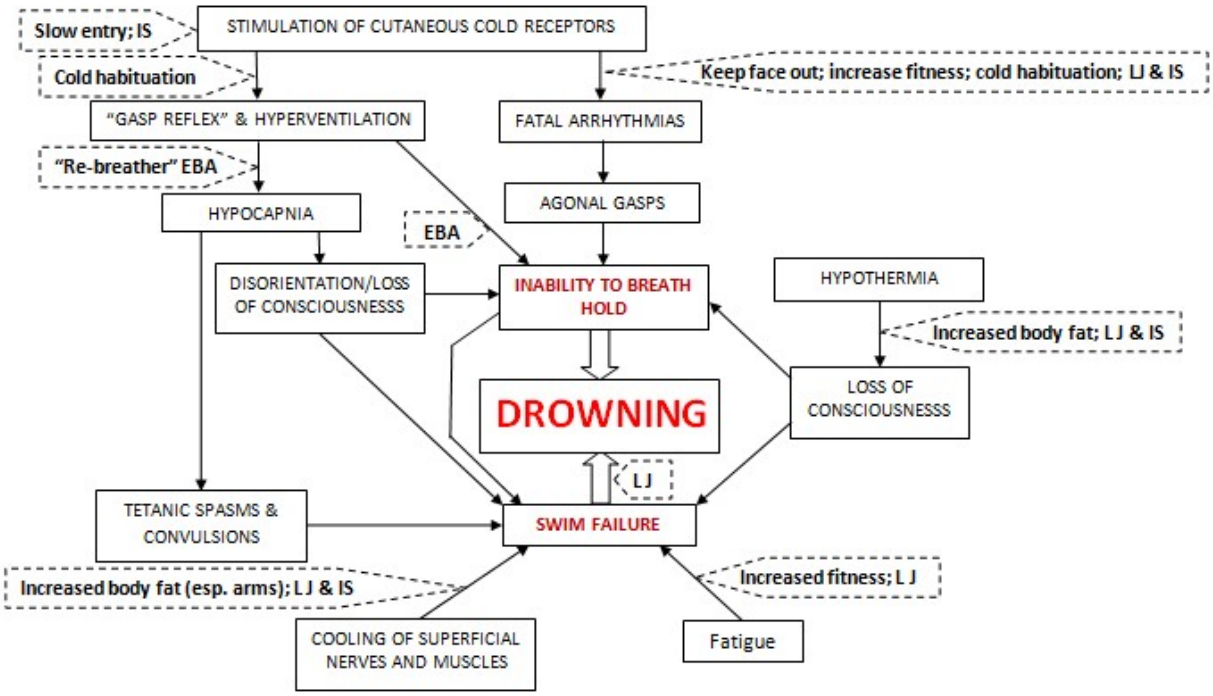
Immersion in cold water represents one of the greatest environmental stresses to which the body can be exposed, and immersion is the second most common cause of accidental death in many countries of the world. However, it is a relatively "hidden" killer with many of the 1,000+ immersion-related deaths that occur each day worldwide going unnoticed. Drowning is also a "disease of youth", 64% of deaths are < 30 years old; 25% are < 5years old.

In this presentation the physiological responses to cold water immersion, particularly those hazardous responses that can be a precursor to pathophysiological consequences such as drowning and sudden cardiac arrest will be briefly reviewed. The importance of understanding these physiological responses lies in the insight it gives to "the cause of the cause of death"; this can help target and promote interventions such as training, equipment and treatment protocols that reduce immersion deaths. These will be explored in the rest of the symposium.



The "Physiological Pathways to Drowning" following immersion/submersion in cold water, with possible interventions for partial mitigation (dashed lines). IS = Immersion suit; LJ = lifejacket; EBA = emergency breathing aid (From Tipton [2016] The Science of Beach Lifeguarding. CRC Press)

Immersion suits for Arctic waters

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Introduction: The harsh arctic environment with low sea and air temperatures, strong winds and waves represent a challenge to protection and survival in emergency situations. The aim of this study was to evaluate whether a immersion suit provided enough protection in accordance with the thermal and functional requirements described in ISO 15027, and identify possible weaknesses during exposure to more extreme conditions.

Method: The immersion suit was tested in a controlled laboratory study at SINTEF SeaLab in Norway. Six subjects were exposed to cold air (-11.3°C) and seawater (-0.1°C) wind (5 $m \cdot s^{-1}$) and 40-50 cm waves. Every 10^{th} minute the subjects were overflowed with water. Test subjects were recruited in accordance with the criteria described in ISO 15027-3. Core- and skin temperatures, heart rate and heat flux were measured continuously during the test. Oxygen uptake was measured every 20 minutes through the test period and the subject's perceived thermal sensation and comfort were assessed.

Results: Only one of five subjects were able to complete the defined three-hour test period. For four of the subjects, the tests were stopped because they reached one of the termination criteria: skin temperatures fell to 10°C at for more than 15 minutes or one of the temperatures dropped to 8°C. Core temperature dropped only 0.5 ± 0.3°C and none of the subjects reached the termination criterion. The requirements for the temperature in the neck and the back were satisfied. The temperatures of the fingers and toes reached the termination criteria for four of the five subjects. The subjects voted the temperature of their body, feet and hands as "cold" at the end of the test. Ice clotted on the splash hood and buddy line, resulting in reduced visibility and difficulties in hold of, pull out, attach and release these items when wearing gloves. Heat flux increased up to seven times and metabolic heat production increased 1.5-3 times due to increased heat production by shivering.

Conclusions: More extreme weather conditions than those described in existing international standards reduced the mean exposure time of the volunteer subjects to 120 minutes (65 to 180 minutes). The mean drop in core temperature was only 0.5°C, however the hands and feet reached the termination criteria in four of the five subjects. It is recommended that standards for immersion suits that is to be used in Arctic waters should be revised to meet the requirements for a harsher environment.

Initial responses to cold water immersion in men and women

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Introduction: Sudden immersion into cold water evokes an inspiratory gasp followed by uncontrollable hyperventilation and tachycardia. Given the large individual variation in the response, it was hypothesised that the difference between men and women would be minimal. Data collected over the last 20 years have been reanalysed to examine this.

Method: 15 women (mean [SD]: 21 [4] years; 163 [6] cm; 65 [11] kg) and 66 men (22 [2] years; 179 [6] cm; 80 [13] kg) undertook a head-out seated immersion into stirred water at 15.6 (0.5) °C wearing swimwear. Inspiratory minute volume (VI), respiratory frequency (fR), tidal volume (VT) and heart rate (HR) were recorded at rest in 23.2 (6.2) °C air and during the first 30 seconds of immersion. The inspiratory gasp (largest breath within the first 10 seconds of immersion) was also recorded.

Results: fR, VT, VI and HR were all increased on immersion ($P<0.0001$). fR and HR increased similarly in men and women (from 15 [4] to 35 [13] breaths.min^{-1} and 90 [17] to 113 [20] bpm). VT and the gasp were greater in men than women (Rest: 1.08 [0.40] L v 0.77 [0.21] L; $P=0.0032$. Immersion: 1.78 [0.55] L v 1.41 [0.29] L; $P=0.0104$; Gasp: 2.48 [0.58] v 1.84 [0.45] L; $P=0.0004$). VI was also greater in men, but only during immersion (58.3 [22.7] L.min^{-1} v 43.3 [15.4] L.min^{-1}; $P=0.0049$). In both men and women, fR increased more than VT on immersion (142 [102] % v 80 [56] %; $P=0.001$). VT and gasp were correlated with stature ($P<0.05$).

Conclusions: Although men had a greater VT than women, the increase from resting was similar and probably related to larger lung volumes rather than sensitivity to cold water**.** fR appears to be a better indicator of ventilatory drive on immersion than VT in both men and women.

Resuscitation in drowning: theoretical aspects

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Introduction: The majority of resuscitations take place after a primarily cardiac arrest. Public training programs are aimed at this situation. Resuscitation of drowning represents a minority of all resuscitations that take place around the world. Resuscitation after drowning includes several physiological, technical and practical elements that do not occur under common circumstances, but are typical for the environments near by water or on the water.

Method: Narrative review

Results: A cardiac arrest after drowning is the result of cardiac hypoxia. The sequence of events under water is: tachycardia; bradycardia; pulseless electrical activity; asystole. Ventricular fibrillation is rare in a drowned person. At the same time, most of the drowning victims are young, which means that the hypoxic heart has the opportunity to regenerate and to function as a healthy heart after resuscitation. At the same time, hypoxic brain damage can remain, resulting in survivors with long-term severe brain damage. Many drowning victims have aspirated a volume of water sufficient to cause lung damage and an acute respiratory distress syndrome. Another element of drowning is hypothermia caused by rapid cooling of the deep body tissues by the aspiration of water. This hypothermia can prolong hypoxic survival time and thereby protect the brain under extreme circumstances. Not only is the physiology of drowning complex and poorly understood. Also resuscitation measures in drowning are complex and differ to what is commonly taught for other scenarios. In drowning, the emphasis is on ventilation, while the AED should not interfere in such a way that any hypoxic period is prolonged. Ventilation can be extremely different as result of pulmonary oedema. Often resuscitations of drowning victims have to occur under extreme circumstances including noise, cold, rain and waves. Protective clothing and the limited space to perform the resuscitations are other problems that will influence the efficacy of resuscitation.

Conclusions: The common way that people are trained to resuscitate does not take into account the physiological and ergonomic challenges that are typical for drowned victims.

"Should I stay or should I go?" Evidenced based triage for pre-hospital resuscitation and extracorporeal life support in a profoundly hypothermic patient post drowning.

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Introduction: Pre-hospital decision making for victims with profound hypothermia following a drowning event is complex and idiosyncratic, with resulting limited relevant guidance in the literature. This case presentation examines the evidence-base for pre-hospital triaging of such patients including the commencement, or withholding, of resuscitation and extracorporeal life support (ECLS).

Method: Case presentation and literature review. Medline, Embase, and Cochrane databases were searched for pre-hospital triage, specifically with respect to ECLS, in severe accidental hypothermia after drowning.

Results: The case: Young adult body found adjacent to an estuary's edge on a cold, winters day (10°C air temperature) following an unwitnessed immersion/submersion, they were assumed to be deceased. They were in cardiac arrest (asystolic), oesophageal temperature of 18.8°C, fixed dilated pupils, and an end-tidal CO2 of 1.0 kPa with initial ventilation. Cardiopulmonary resuscitation (CPR) was commenced based on the presence of end-tidal CO2 and core temperature greater than that of air. Following in- hospital ECLS they were discharged home neurologically intact.

38 publications specific to ECLS were identified, 3 related to drowning but none to the pre-hospital phase. The following can be extrapolated to this phase as indicators of survival:

- Submersion duration less than 90 minutes
- No cardiac arrest (71.4%), survival less in those who received CPR before ECLS (57%) and worst if CPR ongoing when ECLS commenced (23.4%)
- Reasonable prognosis if no asphyxia (immersion) has occurred, compared to poor outcome in cases with asphyxia (submersion)
- Hypothermia before cardiac arrest

Conclusions: Little specific guidance exists for pre-hospital triage of profoundly hypothermic patients following a drowning event. Key factors that may aid decision making include: immersion versus submersion; requirement for CPR; and initial core temperature. The suggested default position is to delay the decision to cease resuscitation attempts until further diagnostic tests can be performed e.g. in hospital.

An Artificial Neural Network to predict Divers' Sensation of Cold Based on Survey Data

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Introduction: Cold sensation leading to thermal discomfort is a major issue while practicing scuba diving. EN 14 225 standard classifies diving suits in regards of their foam thickness and proposes water temperatures ranges. But, some important parameters are not taken into account, especially duration, depth and local body discomfort. Decathlon's Thermal Laboratory decided to build a model predicting whereas divers are cold or not, according to several diving scenarii and features. A large customer campaign was organized to get thermal sensations after a multitude of diving sessions. The resulting database was used to develop this predictive model using machine learning.

Method: After cleaning, our data set consists of 709 examples with 211 positives (cold) and 498 negatives (not cold) split into training, cross-validation and test set with a ratio of 0.6 / 0.2 / 0.2. We optimized a feedforward neural network with 100 units embedded within one hidden layer. The negative log-likelihood cost function has been used as a cost function $-logP(y|x)$, where (x,y) is the (features, target class) pair.

Results: Evaluating our model on test set, we obtained an accuracy of 75.52% and a precision of 80,26% which is a good result given the amount of data. In our knowledge no such model with this accuracy is publically available for this specific application.

Conclusions: This work is a first attempt on the use of Artificial neural network to predict divers' cold sensation. The precision reached is encouraging for further studies such as local cold sensations. However, we are aware that a larger data set would be of great help to enrich our experimental database and hopefully improve the accuracy.

The effect of shivering on whole-body glucose tolerance and insulin sensitivity

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Introduction: Impaired glucose tolerance is predominately the result of skeletal muscle insulin resistance. Exercise is one method of increasing skeletal muscle insulin sensitivity and glucose tolerance. Additionally, we previously showed for the first time that mild cold exposure also increased insulin sensitivity. During more intense cold exposure, with evident shivering, plasma glucose turnover and carbohydrate oxidation are increased. Specifically, during cold stress, muscle glycogen is utilised at lower metabolic rates than compared to exercising, which may prove beneficial for inducing lasting improvements to glucose metabolism. Therefore, the aim of this study is to determine the effects of shivering on oral glucose tolerance and insulin sensitivity.

Method: Sixteen healthy, non-cold acclimated, males will complete two test days, one with cold exposure (CE, 10°C) to induce ~1 h of shivering and the other test day resting at a thermoneutral temperature (TN, 32°C). Both conditions utilise a water-perfused suit, which is removed after CE/TN and then participants passively rewarm/rest on a bed for 90 min. Energy expenditure (EE), core temperature (Tcore) and mean skin temperature (Tmeanskin) are measured during 1 h CE/TN. Next, participants consume 75 g of glucose for an oral glucose tolerance test (OGTT). After the glucose load, blood is frequently sampled for 3 h to determine glucose tolerance and estimate insulin sensitivity.

Results: Preliminary results show that EE during 1 h of shivering was greater than during 1 h at thermoneutral (11±1 kJ/min versus 5.5±0.5 kJ/min). Tmeanskin decreased from 33.8±0.2°C at the start of CE to 27.2±0.3°C at the end. Prior to CE, Tcore was 36.9±0.1°C and remained stable during CE (36.8±0.1°C).

Conclusions: The cold exposure was sufficient to approximately double energy expenditure. Moreover, during the cold exposure Tmeanskin decreased notably whereas Tcore remained stable. The complete dataset, along with data from the OGTT, will be presented during the conference.

Mental fatigue independent of boredom and sleepiness does not impact self-paced physical or cognitive performance in normoxia or hypoxia.

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Introduction: Altitude exposes humans to stressors including hypobaric hypoxia, cold, solar radiation and prolonged cognitive effort. This study aimed to explore the individual and combined effects of mental fatigue and hypoxia on physical and cognitive performance.

Method: Following ethical approval from Loughborough University, 15 healthy males (mean ± SD; 24.2 ± 3.27 years) completed one familiarisation session and six experimental trials, including: 1) normoxia (0.209 FiO2) and no mental fatigue; 2) normoxia (0.209 FiO2) with mental fatigue; 3) low normobaric hypoxia (0.13 FiO2) and no mental fatigue; 4) low normobaric hypoxia (0.13 FiO2) with mental fatigue; 5) high normobaric hypoxia (0.10 FiO2) and no mental fatigue; 6) high normobaric hypoxia (0.10 FiO2) with mental fatigue. All conditions were completed at 21°C with 50% relative humidity. Mental fatigue was induced using a 16-min individualised cognitive test. Each condition included a 15-min self-paced time trial on an arm bike, followed by a 60-s isometric maximal voluntary contraction (MVC) of the biceps brachii. Supramaximal nerve stimulation was used to quantify central and peripheral fatigue with voluntary activation (VA%) calculated using the twitch interpolation method. Following each time trial, participants performed the Tower of Hanoi (TOH) cognitive test. Subjective measures of mental fatigue (VASF) and mood (BRUMS) were assessed.

Results: A main effect of hypoxia was observed on average power output, oxygen consumption and muscle oxygenation ($P \leq 0.004$), with no effect of mental fatigue, ($P \geq 0.599$). VA% of the biceps brachii was reduced in hypoxia, (68.42 ± 5.64%, $P = 0.039$). Time to completion in the TOH was significantly increased in all conditions (+14.74 ± 6.99-s, $P \leq 0.041$) however no effect of mental fatigue or hypoxia was observed on cognitive performance, ($P \geq 0.138$).

Conclusions: Hypoxia impacted physical performance whilst mental fatigue had no effect on physical or cognitive performance.

The roles of arterial CO_2 pressure on cardiovascular responses to apnea during dynamic two-legged knee extension exercise

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Introduction: During aquatic exercise, breathing can be restricted (apnea). Apnea during exercise can cause reductions in heart rate (HR) and active muscle blood flow with concomitant elevations in blood pressure and cerebral blood flow, though mechanisms underpinning these cardiovascular responses remain to be elucidated. Apnea leads to elevations in arterial CO2 pressure (i.e., hypercapnia). Hypercapnia is known to modulate HR, blood pressures, and muscle and cerebral blood flows. Thus hypercapnia may in part or in whole mediate the apnea induced modulation of cardiovascular responses during exercise. In this study, we assessed the roles of arterial CO2 pressure on cardiovascular responses to apnea during dynamic exercise.

Method: Ten young adults (nine men and one women) performed maximum apnea during a dynamic two-legged knee extension exercise at a workload that elicits a HR of approximately 100 beats min^{-1}. This apneic exercise was preceded by 3-min voluntary hyperventilation that reduced end-tidal CO2 pressure to 23.0 ± 1.6 (SD) mmHg (pre-apnea hypocapnia trial). As a control trial, the above protocol was performed while keeping end-tidal CO2 pressure at normocapnic level, which was achieved by CO2 inhalation.

Results: Pre-apnea hypocapnia resulted in longer apnea duration relative to the control trial. In parallel, end-apnea arterial O2 saturation was reduced by pre-apnea hypocapnia in comparison to the control trial. At the time point wherein apnea ended in the control trial, mean arterial pressure and middle cerebral artery mean blood velocity were lower, whereas HR and leg blood flow were higher in pre-apnea hypocapnia than the control trial.

Conclusions: Our results suggest that hypercapnia contributes to apnea mediated modulation of cardiovascular responses including elevations in blood pressures and active muscle and cerebral blood flows and a reduction in HR during dynamic exercise.

Cognitive performance is associated with cerebral oxygenation and peripheral oxygen saturation, but not plasma catecholamines, during graded normobaric hypoxia

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Introduction: The physiological mechanisms responsible for cognitive decline following exposure to hypoxia have received little attention. This study examined the effects of graded reductions in fraction of inspired oxygen (FiO2) on oxygen saturation (SpO2), cerebral oxygenation, cardiorespiratory variables, activity of the sympathoadrenal system (adrenaline, noradrenaline) and hypothalamic-pituitary-adrenal axis (cortisol, copeptin), and cognitive performance.

Method: Twelve healthy males (mean [SD], age: 22 [4] yrs, height: 178 [5] cm, mass: 75 [9] kg, FEV1/FVC ratio: 85 [5] %) completed a 4-task battery of cognitive tests to examine inhibition, selective attention (Eriksen Flanker), working memory (n-back) and simple and choice reaction time (Deary- Liewald). Tests were completed before and following 60 minutes of exposure to FiO2 0.2093, 0.17, 0.145, and 0.12.

Results: Following 60 minutes of exposure response accuracy in the n-back task was significantly reduced in FiO2 0.12 compared to baseline (82 [9] vs. 93 [5] %; $p < 0.001$) and compared to all other conditions at the same time point (FiO2 0.2093: 92 [3] %, FiO2 0.17: 91 [6] %, FiO2 0.145: 85 [10] %, FiO2 12: 82 [9] %; all $p < 0.05$). The performance of the other tasks was maintained. Δ accuracy and Δ reaction time of the n-back task was correlated with both Δ SpO2 ($r(9) = 0.66$; $p < 0.001$ and $r(9) = -0.36$; $p = 0.037$ respectively) and Δ cerebral oxygenation ($r(7) = 0.55$; $p < 0.001$ and $r(7) = -0.38$; $p = 0.045$ respectively). Plasma biomarkers were not elevated in any condition or correlated with cognitive performance.

Conclusions: These findings suggest that reductions in peripheral oxygen saturation and cerebral oxygenation, and not increased activity of the sympathoadrenal system and hypothalamic-pituitary-adrenal axis, as previously speculated, are responsible for a decrease in cognitive performance during normobaric hypoxia.

Human brown adipose tissue and skeletal muscle contribution for resting, non-shivering and shivering thermogenesis during gradual cold exposure

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Introduction: Human brown adipose tissue (BAT) has been reconfirmed as a major organ for non-shivering thermogenesis (NST). Based on the previous studies, Asians showed less active BAT compared to Europeans. The skeletal muscle (SM), which is the major effector for resting and shivering thermogenesis, might contribute to the NST. We hypothesized that human with less BAT activity would have more contribution of SM to NST, and/or induce earlier shivering onset for compensating the less thermogenesis.

Method: Nineteen males participated in this study. Their percentages of body fat and SM mass were estimated by electrical impedance method. The BAT activity and detectable volume was investigated using fluorodeoxyglucose (FDG)-PET/CT. They conducted cold exposure test in a climatic chamber. After baseline measurement in thermoneutral condition, ambient temperature was gradually decreased in 20 min and maintained at 18°C for 90 min for inducing NST. Then, ambient temperature was decreased to 12°C in 30 min for initiating minimal shivering. Oxygen uptake (VO2), rectal and skin temperature were measured.

Results: BAT volume was significantly correlated with change in VO2 relative to baseline (ΔVO2 NST) during the final 10 min of mild cold exposure ($r=0.60$, $P<0.01$). The SM mass was correlated with VO2 at baseline ($r=0.82$, $P<0.01$) but not with ΔVO2 NST. The BAT volume was not correlated with ΔVO2 at the final 10 min of minimal shivering (ΔVO2 Shiv+NST) nor shivering component (ΔVO2 Shiv = ΔVO2 Shiv+NST - ΔVO2 NST). The ΔVO2 Shiv+NST was negatively correlated with SM mass and VO2 base ($r=-0.46$, $P<0.05$; $r=-0.46$, $P<0.05$).

Conclusions: The hypothesis of metabolic compensation between BAT and SM was rejected. It was confirmed that BAT was a major effector of NST, with no direct association of the SM. Participants with less resting metabolism (i.e. less SM mass) induced greater cold-induced thermogenesis including NST and minimal shivering (ΔVO2 Shiv+NST).

Thermal variety and health

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Introduction: As with many upper latitude countries, the UK experiences a higher rate of deaths in winter than in summer months. The consensus is that dangerous cold exposure contributes to these excess winter deaths. However, determining when, where and for whom this dangerous exposure occurs is challenging. Rather than using static domestic measures of ambient temperature or local weather stations, this paper reports a novel method which makes use of the experienced temperature – that is, a characterisation of the immediate thermal environment of a participant. Using data from the UK Biobank - a large longitudinal observational health study of over 100,000 participants - we report the demographic, housing and health covariates of experienced temperature.

Method: The experienced temperature was derived from a wrist worn monitor worn by each participant for a week in everyday life. Following an extensive data processing exercise, the temperature time-series were summarised in a variety of measures, such as minimum, mean and the standard deviation. The standard deviation is used as a characterisation of participants 'thermal variety'.

Results: The thermal variety experienced by participants increases with increasing health satisfaction and separately with activity levels. It decreases with age, body mass index and the external temperature.

Conclusions: While no causal claims can be made, the results suggest that increased thermal diversity correlates with health and activity levels. These results complicate the picture that mild cold exposure is necessarily linked with ill-health.

Protection of face against cooling while using powered respirators in the cold environment

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Introduction: Respiratory protective equipment (RPE) is required in several outdoor professions in the cold, e.g. mining, steel and construction work. Powered air purifying respirators (PAPRs) decrease breathing resistance and thus psychophysiological strain, but facial cooling occurs in the cold. The aim was to prevent facial cooling while using PARP in the cold and determine the influence of the cold protection on protective efficiency of the PARPs.

Method: Thermal insulation (Icl) of two PARPs with and without air flow and with and without thin (1.0 mm) and thick (3.0 mm) balaclavas were measured by using thermal head model in climatic chamber at air temperature (Tair) of +10°C. Also two half face masks and one full face mask were tested. Facial cooling was measured (N=7) wearing two PARPs at -20°C. Experimental protocol (40 min) included standing, stepping (20-cm high step), lifting a dumbbell and standing. Face skin temperatures (Tfs) and Tair inside the facemask were measured. Thermal sensation on the face was asked according to ISO 10551.

Results: Half and full face masks without air flow are protecting the face against cooling, but when PARPs with air flow were used, Icl dropped on an average 62%. Thin balaclava increased the Icl on the face by 29 and 81% without and with air flow, respectively. Whereas thick balaclava increased the Icl on the face by 73 and 144% without and with air flow, respectively. Tfs was 5.4±2.4°C and 7.7±2.6°C higher with thin and thick balaclava under PARPs, respectively. Thermal sensation was experienced warm with the balaclavas. The balaclavas didn't have any influence on protective efficiency of the PARPs.

Conclusions: Cold protection of the face is recommended when PAPRs are used in the cold (<-10°C). Skin cooling can be prevented by using a thin balaclava under PARP. This study was supported by The Finnish Work Environment Fund.

Characteristic of human behavioural thermoregulation of clothing removal during and after exercise: effect of thermal perceptions and autonomic function

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Introduction: The effect of unventilated clothing can significantly impair our thermoregulatory function and thermal perceptions during and following exercise recovery in temperate environment. Therefore, the ability to perceive and to select appropriate thermoregulatory behaviour by removing some part of the clothing is necessary to attenuate both thermoregulatory and perceptual strains. However, limited studies are available and therefore we examined whether partial clothing removal is aneffective tbhermoregulatory behaviour to attenuate both thermoregulatory and perceptual strains in thermal neutral environment (23°C, 65% RH) during and after the recovery of exercise.

Method: Ten healthy males (age: 21.9 (0.3) years; height: 173.9 (2.0) cm; mass: 62.3(2.6) kg; VO_2max: 51.8 (4.2) $mL.kg^{-1}.min^{-1}$) wore long sleeve T-shirt and performed two randomized counterbalance cycling trials for 40 minutes at 40% VO_2max and with 20 minutes on recovery. In one trial, they were permitted to roll up their sleeve at any time they want (Roll) whereas in the other trial they were instructed to remain in long sleeve (Long) until the end of the recovery. Thermal perceptions (local SW, TD, TS and whole body SW) were measured at every 10 minutes whereas thermoregulatory variables were measured continuously throughout the trial.

Result: All subjects behaved by rolling up their sleeve (Roll up time: 21.4 ± 1.3 min) and Tskin (32.2(0.2) °C vs 31.9(0.2) °C, $p = 0.03$) ,LSR (0.24(0.03) $mg.cm^{-2}.min^{-1}$ vs 0.2(0.02) $mg.cm^{-2}.min^{-1}$, $p = 0.05$), local SW, TD, TS and whole body SW were all lower in Roll than in Long (all $p < 0.05$) whilst Tcore and SKBF remained similar throughout the entire trial.

Conclusions: We conclude that partial clothing removal is an effective thermoregulatory behaviour to modulate local thermal perceptions, whole body skin wetness and sudomotor function during exercise and may persist after the recovery of exercise in temperate environment.

Whole-body thermal sensation is independently modulated by local changes in foot skin temperature

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Introduction: Skin temperature is an important physiological parameter in thermal comfort evaluation. Variations in skin temperature are often greatest at the feet, thus it is suggested that the feet modulate and dominate whole-body thermal sensation and perceptions of comfort, especially in the cold. However, the thermal state of the whole- body and feet tend to change together. This study investigated whole-body and foot thermal sensations and comfort by independently changing the thermal state of the feet from that of the whole-body.

Method: Trials were performed in a climatic chamber at 23°C, 50% relative humidity. 10 females, on three separate occasions rested seated on a medical bed, positioning their feet at hip level within a custom-built climate system. Three environmental conditions (neutral-23°C, heating-38°C and cooling-15°C) were applied to both feet for 30-minutes. Mean skin temperature (T_{sk_body}) was estimated from five sites. Mean (left) foot skin temperature (T_{sk_foot}) was determined from seven sites. Thermal sensation and thermal comfort were recorded every 5-minutes for the whole-body and left foot.

Results: While T_{sk_body} remained stable, T_{sk_foot} significantly changed during 30- minutes of foot conditioning (heating +1.9°C, neutral -0.3°C, cooling -4.5°C, $p<0.01$). Foot thermal sensation remained *neutral* with neutral conditioning ($p=0.92$) but increased from *neutral* to *warm* with heating ($p=0.01$) and decreased from *neutral* to *cold* with cooling ($p=0.01$).

Discussion: The literature indicates that typically a ±1.0-1.5°C increase respectively decrease in T_{sk_body} from *neutral* is required to elicit *slightly warm* or *slightly cool* whole- body thermal sensations. In our data, regression analysis indicated a +0.9°C and -0.2°C change in T_{sk_body}, mainly caused by the foot, was enough to elicit *slightly warm*, respectively *slightly cool*, whole-body thermal sensations. This apparent increased sensitivity to T_{sk_body} with local cold exposure, indicates a larger role of the feet in modulating whole-body sensations compared to the rest of the body.

The effects of low-intensity exercise on local and whole-body thermal sensations in hypothermic resting humans

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Introduction: Thermal sensation is modulated by both skin and core temperatures, and is an important controller of the thermoregulatory behaviour. Previous studies suggested that thermal sensation to locally-applied cold stimulus is blunted during exercise compared to rest. However, whether exercise also modulates thermal sensation to whole-body cold stress has not been investigated. Furthermore, the effects of hypothermia on local thermal sensation at rest and during exercise need to be established. We investigated therefore the effects of low-intensity exercise on local and whole-body thermal sensations in hypothermic humans during cold water immersion.

Method: Nine healthy young males (24 ± 2 years) were cooled through cold water immersion (18°C) up to their abdomen while resting (rest trial) or during low-intensity cycling (30-60 W, 30 rpm) (exercise trial). Esophageal and skin temperatures, oxygen uptake, heart rate, mean arterial pressure, and skin and whole body thermal sensations were measured at normothermic baseline, during cold water immersion with 0.5 and 1.0°C decrements in esophageal temperature from baseline. Skin thermal sensations to thermal stimuli were measured by applying Peltier element thermode to the chest.

Results: Esophageal and mean skin temperatures did not differ between the trials. Oxygen uptake and heart rate were higher in the exercise than rest trials throughout cold water immersion. Whole-body thermal sensation tended to be higher (participants felt less cold) in the exercise than rest trial at esophageal temperatures of -0.5 and - 1.0°C from baseline (P=0.051 and 0.092, respectively). On the other hand, thermal sensations to locally-applied cool (29.5 ± 1.0°C) and warm (33.8 ± 0.6°C) stimuli did not differ between the trials throughout cold water immersion.

Conclusions: These results suggest that whole-body but not local thermal sensation is blunted by low-intensity exercise during cold water immersion resulting in < 1.0°C decrease in core temperature.

Connected Helmets: piloting the big data era using continuous field evaluation of Thermal Comfort

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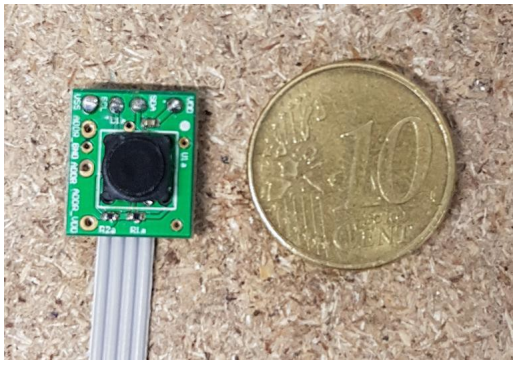
Introduction: The area of thermal comfort in helmets has mainly been investigated using either laboratory testing or modelling. Subjective ratings are often used with a limited number of participants, rarely in the field. The aim of this exploration is to create a complete approach starting from large scale field data collection with newly designed embedded systems towards a big data analysis for a better understanding of thermal comfort changes associated with helmet design parameters.

Method: The first phase of the study was dedicated to finding the optimal solution for the measurements of both physical and subjective data regarding thermal comfort in helmets. The second phase will correspond to a pilot test in real life situations (skiing and cycling) to evaluate the robustness of the solution. The third phase will take place on a larger scale with around 200 users.

Results: The challenge of the first phase was to find the right sensors (locations, technical specifications) for the measurements of thermal parameters (temperature and relative humidity) and the ability to integrate them in different types of helmets. Hygrocron (Maxim) were tested but ruled out due to their size, sampling frequency and response time. STH35 (Sensirion) represented the right compromise with fine wires connected to a small acquisition pad attached to the helmet, transmitting data via Low Energy Bluetooth to a mobile application. The system can dynamically track physical changes within the helmets. A watch (Geonaute onMove500) is currently modified in order to track subjective ratings.



Conclusions: This ongoing study will deliver a large dataset in a wide range of situations which will enhance our understanding of thermal comfort in real life contexts. Big data analysis will help in the prediction of discomfort and therefore suggest product adaptations in connection with personal parameters (e.g: exercise intensity) and environmental parameters (e.g wind speed).

Thermal Comfort Assessment of an Automotive Cabin Environment in a Transient Cooldown Scenario

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Introduction: Objective assessment of automobile cabin thermal environments can be challenging since evaluators must rely on subjective reports. Consequently, test devices that incorporate human thermal models are being used more often to improve consistency and reduce time and effort in vehicle testing.

Methods: A test protocol was developed to investigate the effectiveness of a test device to predict the thermal comfort reported by humans in an automobile undergoing a transient cool down. A vehicle was exposed to a 40°C a hot soak, after which a human entered and reported subjective responses as the climate system was manipulated from the control room. The climate system set points were 22°C for the first 40 minutes, 18°C for the next 10 minutes, and 26°C for the final 10 minutes. This protocol was repeated 9 times: Once for each of the 7 participants, who were wearing light summer clothing (0.34 CLO); and, twice for a Thermetrics HVAC (passive sensor) Manikin, which measured environmental conditions for processing by the TAITherm human thermal model. The manikin-model results were compared quantitatively (using RMSD and bias) to the average of the human subjects.

Results: The mean skin temperature, overall thermal sensation, and overall thermal comfort obtained from the manikin-model were generally within one standard deviation of the human subjects.

Conclusions: Despite the good agreement between the manikin-model and the human averages, the relatively large standard deviations in the human subjective responses indicate that variability among human subjects should be more fully considered. In the future, the manikin-model should perform multiple simulations that vary individual characteristics (e.g., clothing insulation/fit, sex, physical fitness, activity) to obtain a range of potential comfort states. More broadly, this study demonstrates the unsuitability of a "one-size- fits-all" vehicle climate control system, and consequently, that some level of personalization should always be considered in product design.

Thermal comfort range of Perceived Temperature based on Thermal Sensation Votes in Korea

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Introduction: The Perceived Temperature (PT) is an equivalent temperature based on Klima-Michel Model which considers the complete heat budget of the human body. The PT is based on Predicted Mean Vote (PMV). Actual Thermal Sensation Votes (TSV) reflects subjective deviations from the regional climate, culture, socioeconomics, and recent experiences of outdoor conditions. Thermal assessment for the equivalent temperatures may be replaced using surveyed TSV for the local climate. In this study, we optimized the thermal comfort range of PT for Korean climate based on TSV.

Method: The TSV was obtained from heat-stress experiments in a climate chamber (chamber study) conducted in the summer of 2017 and 2018. The chamber environment was set to 30℃ and 35℃ in 2017, and 28℃, 33℃, and 38℃ in 2018. As for exercise, walking by 4 km h^{-1} speed was chosen. The experimental protocol consists of two periods; 10 minutes resting and 60 minutes for exercise. Thermal sensations differ among individuals even when they are exposed to the same environment. To reduce these differences, Mean TSV (MTSV) was used. The PT was calculated using environmental conditions and anthropometric characteristics of subjects.

Results: The fitted linear regression for the relationship between MTSV and PT is MTSV=0.13PT-2.66. The obtained PT range from MTSV "slightly warm (1)", "warm (2)", "hot (3)", and “very hot (4)” are increased by 8℃. The comparison of the two PT thermal scales shows that the PT range of Koreans is larger than that of Germans for each thermal sensation level. It means that the Koreans have higher thermal tolerance than PMV.

Conclusions: This chamber study was conducted only for the high-temperature condition to improve information about heat waves in Korea. This method can be applied for any other climate regions where the PT range is unknown by modifying experimental conditions.

Thermosensory mapping of skin wetness sensitivity across the body of young males and females at rest and following maximal incremental running

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Introduction: Humans lack skin hygroreceptors and we rely on integrating cold and tactile inputs from A-type skin nerve fibres to sense skin wetness. Yet, it is unknown whether sex and exercise independently modulate skin wetness sensitivity across the body. The aim of this study was to map regional sensitivity to cold, neutral and warm wetness at rest and post maximal incremental running in young males and females.

Method: 10 males (27.8±2.7y; BSA: 1.92±0.1m^2) and 10 females (25.4±3.9y; BSA 1.68 ± 0.1m^2) underwent a quantitative sensory test where they reported the magnitude of thermal and wetness perceptions (Visual Analogue Scales) resulting from the application of a cold (5°C below skin temperature) wet (0.8ml water), neutral wet, and warm wet (5°C above skin temperature) thermal probe (1.32cm^2) to the forehead, neck, underarm, lower back, and dorsal foot, at rest and following a maximal incremental running test.

Results: We found that: 1) females were ~14 to ~17% more sensitive to cold-wetness than males ($p=0.029$), yet both sexes were as sensitive to neutral- and warm-wetness ($p>0.05$); 2) regional differences were present for cold-wetness only, and these followed a cranio-caudal increase that was more pronounced in males (i.e. the foot was ~31% more sensitive than the forehead; $p=0.002$); 3) maximal exercise reduced cold-wetness sensitivity over specific regions in males (i.e. ~40% decrease in foot sensitivity; $p=0.003$), and it also induced a generalised reduction in warm-wetness sensitivity in both sexes (i.e. ~4 to ~6% ; $p=0.015$).

Conclusions: For the first time, we show that females are more sensitive to cold wetness than males, and that maximal exercise induce a reduction in local skin wetness sensitivity, i.e. hygro-hypoesthesia. These novel findings expand our fundamental and applied knowledge on sex differences in thermoregulatory physiology.

Principles of Radiant Heat Exchange between Humans and their Environment – a model study

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Introduction: Radiant heat exchange between humans and their environment has not received a lot of attention. Some basic models have been developed, such as by Lotens, and a major EU research project was conducted to study effects of color and heat reflective clothing. Yet, recently new technologies have emerged that would allow engineering of emissive, reflective and even transmissive properties of clothing.

Method: In this paper an overview of the basic equations and principles of radiant heat exchange will be discussed and the application of these to clothing and fabric engineering will be discussed. Basic heat exchange theory will be applied and equations derived and then the predictions will be compared to some fabric studies and other data from the literature.

Results: The results will show from a theoretical perspective how engineering of radiant properties will help heat loss increase or reduction and under what conditions it may have unintended consequences. Novel emissive, reflective and transmissive properties will be judged on their expected added value. Furthermore, the data will show how thermal infrared cameras can be used for analysis of clothing insulation and human heat exchange.

Conclusions: The development of this model will further support specific fabric engineering to attenuate radiant heat exchange as well as serve as a theoretical framework to help understand the relevance of radiant heat exchange for humans, and measure it, in a variety of environments.

Comfort rating for Upholstery Systems

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Introduction: Nowadays long-distance drives or sitting workplaces are normal. As consequence a human sit up to 7.5 h per day. Therefore, the comfort while seating is getting more and more important. The comfort of upholstery systems such as car seats, office chairs or upholstered furniture is influenced by different ergonomic properties in particular thermophysiological comfort.

Method: There are different methods for rating the comfort of upholstery systems: Thermophysiological comfort of an upholstery can be characterized by Hohenstein Skin Model (sweating guarded hot plate) according to ISO 11092. With the Skin Model the specific thermophysiological quantities of textiles as layers are determined. Under stationary measurement of the Skin Model the water vapor resistance Ret is determined, which characterizes the insensible sweating. Higher sweating rates (sensible sweating) can be described by buffering capacity of water vapor Fd and buffering capacity of liquid sweat kf. In the next step a sitting human can be simulated by the sweating buttocks model or thermal, sweating manikin "Sherlock" (Newton type by Thermetrics). By combining these measurement systems with humidity sensors within in the upholstery the moisture management of an upholstery system can be determined. Further pressure distribution of a sitting person can be qualified by measurements with a pressure pad. Handheld scanner systems like Artec Eva, Creaform Revscan and or low-cost devices as the Kinect sensor offer the opportunity to scan objects like seats. The 3D information of seats, chairs or furniture can be compared with 3D data of target groups. As a result, the contact area can be identified in regard of size and shape.

Conclusions: Comfort of upholstery systems depends on different aspects: thermophysiological rating, skin sensory behaviour, ergonomic fitting and e.g. pressure distribution of a sitting person. For good comfort ratings of upholstery systems it is recommendable to characterize several of these aspects.

The influence of mechanical cues and friction coefficients on the wetness perception of the human index fingerpad.

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Introduction: Despite not possessing skin wetness receptors, humans often experience wet stimuli (eg. holding a drink, touching a damp cloth). We now know that our brains instead form a comprehensive perception of wetness by integrating a range of external stimuli, such as thermal (eg. evaporative cooling) and mechanical (eg. adhesion). However, little research exists on how mechanical cues and perceived surface roughness influence skin wetness perception. We therefore aimed to quantitatively assess the impact of roughness across a range of wet stimuli on perceived roughness and skin wetness in static and dynamic interactions.

Method: Five adult females (29.6 ± 4.6y; BMI 24.0 ± 1.7) performed blind perceptual tests consisting of static and dynamic interactions with stimuli varying in volume (ie. 0 ml, 10 ml, 25 ml) and roughness (ie. low, medium and high friction coefficients; 0.43, 0.45 and 0.49 respectively). We recorded wetness and roughness perceptions during contact using a dichotomy of choice method (wet/dry; smooth/rough) and 100 mm visual analogue scales (very wet/very dry; smooth/rough).

Results: Participants discriminated between different wetness levels with larger volumes eliciting greater wetness sensations ($P<0.001$). However, we found that participants could not discriminate between the different friction coefficients ($P=0.743$). Despite this, we found that participants tended to associate greater wetnesses with smoother sensations ($P<0.001$). No distinct relationship was observed in either roughness ($P=0.687$) or wetness ($P=0.609$) perceptions between static and dynamic interactions.

Conclusions: We conclude that there is correlation between friction coefficients and perceived roughness, which is influenced by applied volume. Although different friction coefficients could not be differentiated, the associated mechanical cues play a role in the magnitude estimations of different wet stimuli. These fundamental insights are relevant to optimise the feel of absorbent products.

Investigation on the effects of moisture management boots' linings in improving feet thermal comfort in moderate temperature environments

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ABSTRACT WITHDRAWN

On using a smart local heating blanket to improve body thermal comfort in a cold environment

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Introduction: The bedding system plays an important role in regulating the bed micro- environment, which significantly affects the sleep quality of human body, even more than room environment. Survey results indicate that most rural residents in North and Northwest China prefer improving their bed climate instead of increasing the whole room temperature in winter. Using a heating blanket is a common strategy to improve their sleeping thermal comfort and quality. However, the heating blankets currently available cannot ensure body thermal comfort, because they were developed without considering body thermal physiological characteristics.

Methods: A smart local heating blanket was designed in this study. The carbon fibre heating elements are embedded in the blanket. A temperature controller is installed to control the surface temperature of the blanket steady in feet, buttocks and shoulder regions, and the respective temperature setpoints, i.e., 42, 37, 32°C, were used in this test. Two polyester quilts, foam mattress and the smart heating blanket were used as the bedding items. The experimental condition was set as 4.9 °C, 57% RH, and air velocity of 0.17 m/s. Eight female subjects were involved in two test scenarios: no heating condition (CON) and heating condition (HEAT). The experiment duration was set as 8 h; the mean skin temperature, core temperature, heart rate, local and whole thermal sensation and comfort sensation were recorded.

Results: The results showed that HEAT increased local skin temperatures at heated body parts and mean skin temperature, whereas there was no significant difference in core temperature and heart rate. Besides, thermal and comfort sensations in both the local and the whole body were all greatly improved in HEAT, and the ratings are near 'thermal neutral'.

Conclusions: The research findings demonstrated that the smart heating blanket could improve both the local and whole body thermal comfort in cold environments.

Evaluation of Teq method for thermal comfort prediction in automotive cabins

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Introduction: A thermal comfort evaluation based on the Equivalent temperature and Comfort zone diagram is the well known method defined by standard ISO 14505-2, where principles, measurement procedure, measurement equipment, and evaluation of thermal comfort are described**.** The aim of the contribution is to show how this method could be applied in testing processes of air distribution system for ventilation of automotive cabin and which steps are necessary for successful application.

Method: The equivalent temperature method is typically base on using of measurement system with actively heated surfaces and calculation of equivalent temperature**.** Above mentioned measurement systems are typically thermal manikins or special sensors. Then Comfort Zone Diagram (CZD) is used for thermal sensation and thermal comfort evaluation. This is standard description of method for laboratory environment but for application in testing process of specific customer the situation is much more complicated. At the beginning the method has to be adopted by the company employees and they should be familiar with the method at the end of this phase. Then the next step is pilot measurement to proof that thermal comfort evaluated by method (thermal manikin + Teq + CZD) is correlated with sensation of real test subjects (environment and setting typical for customer's tests are used) and the method could be really helpful for customer's purposes. If this is successfully pass, next step is to design and perform the tests based on customer's demands to test features of air distribution system or tuning the control algorithms of other HVAC technologies.

Results: The results from pilot evaluation of thermal comfort prediction (measurement by Newton manikin system) against test subjects' data are presented. Three different environments (+10, +25 and +32 °C) and two different middle class car cabin were tested. Important parameters of the tests were setting of air distribution system as well. The thermal sensation vote from ten main body parts and overall thermal comfort were collected via questionnaire and compared with prediction from Teq method. The typical deviation between averaged subjects data and thermal manikin prediction was less than one standard deviation.

Conclusions: The evaluation of local thermal sensation prediction based on Teq and Comfort zone diagram method versus test subject data was made. The accuracy of prediction was sufficient and discrepancy was within one standard deviation. We can concluded that Teq method is applicable for prediction of thermal comfort in environment of automotive car cabin and could be helpful tool for testing of air distribution system, HVAC technologies and their control algorithms.

Menthol application on the skin modulates thermal perceptions but not heat loss, ventilatory, and cerebrovascular responses in resting heated humans

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Introduction: Menthol activates transient receptor potential melastatin 8 (TRPM8), providing cool sensation. Previous studies reported that menthol application on the skin leads to cool sensation and improves thermal comfort, whereas it might attenuate heat loss responses of cutaneous vasodilatation and sweating in exercising humans. However, whether menthol application on the skin modulates thermal perceptions and the heat loss responses in passively-heated resting humans is unknown. Also, hyperthermia causes hyperventilation (so called hyperthermia-induced hyperventilation) and cerebral hypoperfusion in resting heated humans. However, whether these responses during severe hyperthermia at rest are modulated by menthol application on the skin remains to be determined.

Method: In thirteen healthy young males, 3% menthol solution (menthol trial) or control solution (control trial) was applied to the trunk and arm skin (pre-heating only), then lower-body hot water immersion (42°C, 34 ± 8 min) was conducted in a room temperature of 25°C. Body temperatures, skin blood flow, sweat rate, minute ventilation, middle cerebral artery mean blood velocity, and thermal sensation and comfort were assessed throughout.

Results: Heating time was longer in the menthol than control trials (32 ± 8 vs. 37 ± 6 min), but oesophageal and mean skin temperatures similarly increased to ~38.6°C and ~37.5°C, respectively, in both trials. Thermal sensation was lower in the menthol trial (i.e., felt cooler) at ≥5 min of heating. Also, thermal comfort was lower in the menthol trial (felt more comfortable) at 20-25 min into heating. Passive heating increased skin blood flow, sweat rate, and minute ventilation, whereas it decreased middle cerebral artery mean blood velocity. However, these responses did not differ between the trials.

Conclusions: Our results suggest that 3% menthol application on trunk and arm skin improves thermal sensation and comfort, but it does not affect heat loss, ventilatory, and cerebrovascular responses during severe hyperthermia at rest.

Experimental study of the thermal comfort in car cabin

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Introduction: Standard ISO 14505-2 describes thermal comfort evaluation based on the Equivalent temperature (Teq) and Comfort Zone Diagram (CZD). The standard describes principles, measurement procedure and examples of measurement equipment. The aim of the contribution is to show how the method (Teq + CZD) was applied in testing of air distribution system for ventilation of middle-class car cabin.

Method: The tests for comparison of thermal sensation of test subjects and thermal manikin prediction were performed. The middle-class car with HVAC unit set to AUTO 22 °C was used and three different environments were tested: +10 °C no sun, +25 °C with 900 W/m^2 and +32 °C with 900 W/m^2 all in climatic chamber with wind simulator set to 80 km/h. The group of 10 test subjects acted as driver and the thermal manikin (Newton type) was the co-driver. Newton's control mode was set to constant surface temperature mode 34 °C, the test subjects were stabilized 1 hour before test in thermal neutral environment. The thermal sensation votes from ten main body parts and overall thermal comfort were collected via questionnaire and compared with data from the thermal manikin.

Results: The results of test subjects thermal sensation and thermal manikin prediction were compared. The lowest discrepancy was reached in the seat contact parts and in legs and feet; the highest discrepancy was found in the arms. But the accuracy of prediction was within one standard deviation. The discrepancy in measurements in arms region can be explained by different position of manikin's and test subject's arms because manikin is rigid but test subject can adjust the position based on his/her driving habits.

Conclusions: The evaluation of local thermal sensation prediction based on Teq and Comfort zone diagram method versus test subject data was made. The accuracy of prediction was sufficient and discrepancy was within one standard deviation. We can conclude based on authors experiences that method is sufficient for scoring of HVAC technologies in the early stages of their development.

Human Thermal Comfort Model in Electric Vehicle with Infrared Warmers

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Introduction: There is significant interest in electric vehicles (EVs) due to their capability to reduce CO2 emissions compared with internal combustion engine vehicles. There is demand for a new technology that can provide low energy consumption and reasonable thermal comfort for passengers in electric vehicles (EVs). We aim to develop human thermal comfort model for local radiant heating in EV and verify its effectiveness.

Method: Experiments were conducted in an environmental chamber containing a real operable vehicle. The temperatures inside the environmental chamber were kept at
−20°C and −7°C. The infrared (IR) warmer control component was installed separately outside the dashboard. The EV in the environmental chamber was soaked for 1.5 hrs. The subjects first spent 20−30 min inside the EV without heating. Subsequently, heating (IR warmer, HVAC or heating wire for vehicle seat) was applied according to the experimental conditions and subjects recorded their thermal sensation every 2 min for 0.5 hrs.

Results: Radiant heaters placed on the wall of the vehicle cabin interior may offer a solution to reduce heating energy consumption. Partial heating allows the energy consumption to be reduced while the passengers can feel an increased heating effect due to radiation heat transfer characteristics. The combination of low HVAC and IR warmer was more energy efficient than using only strong HVAC. Local thermal sensation increases after IR warmer surface temperature reaches the steady state, indicating that the IR warmer is not effective until it reaches the target temperature after which it affects the local thermal sensation of the lower body.

Conclusions: The effect of a new energy saving heating method called local radiant heating was investigated using real EV experiments. It was confirmed that using the IR warmer and HVAC together to attain the same level of overall thermal sensation (in equivalent time) is more energy efficient than with a conventional HVAC. Good thermal environment with less energy can be achieved by interworking with the simulations of internal environment and human body temperature.

Optimizing safety by customization in conjunction with whole-body cryotherapy

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Introduction: Whole-body cryotherapy (WBC) is associated with significant drops in skin temperature. General skin temperature drops are in the range between 10-20°C. Recent findings illustrate that at specific body locations, local skin temperature drops might even be larger, implying drops that might cause harm to the individual. This study investigated the skin temperature responses as the derivative from the treatment dose, specific body location and personal characteristics. Next, we aimed to develop and validate an algorithm to a priori correct the WBC treatment dose to ensure a safe exposure for each individual.

Methods: 20 volunteers, 10 male and 10 female, were exposed to 2 different WBC protocols (one at -110°C for 2,5 minutes and one at -130°C for 3 minutes) while assessing skin- and core temperature, thermal comfort and sensation at 15 minutes prior to 45 minutes after exposure. The Fiala thermal Physiology and Comfort (FPC) numerical simulation model (Fiala et al. 1999, 2016) adapted for cryotherapy applications was used to assess the impact of personal characteristics on the stimulation settings in relation to safety.

Results: The results show that skin response is always rapid though very sensitive to variations in personal anthropometric settings. The body fat content (BF) and the so-called fat free mass index (FFMI) were found to a significantly affect the personal skin temperature response and thus the protocol settings. Following the validation tests, parametric simulation for different personal configurations will be performed to study the influence of personal characteristics on local skin cooling responses. The influence of each parameter on predicted local skin response will be assessed using the goodness-of-fit of linear regression analysis with stepwise variable selection.

Conclusions: Local skin responses to WBC are very sensitive to variations in personal characteristics. Results of the parametric simulation and linear regression analysis are expected in the coming months.

A gender difference in acute recovery following strenuous exercise caused by cold-water immersion

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Introduction: Almost all cold-water immersion (CWI) research focusses on male athletes, while Stephens et al. (2017) recently concluded that male and female athletes likely require different protocols due to a difference in cooling rate. Therefore, the purpose of this study is to examine if a gender difference exists in acute recovery after strenuous exercise caused by a standard CWI protocol.

Methods: Twenty healthy recreational athletes, including ten men and ten women, performed a multistage 20-meter shuttle run test and 50 drop jumps followed by a standard CWI protocol (14 minutes immersion in 12℃ water). Power (squat jump height), strength (maximum voluntary isometric contraction) and acute muscle soreness (questionnaire) were tested before exercise and directly following CWI.

Results: CWI led to a higher power recovery (0.97 [0.41; 1.54]) for women compared to men and unclear differences for strength (0.12 [-0.06; 0.30] and muscle soreness (0.37 [-0.85; 1.59]). Additionally, a moderate correlation between body surface area to lean body mass ratio (Ad/LBM) and acute power recovery ($r = 0,42$; $p<0.05$) was found.

Conclusions: A standard CWI protocol was more effective in the recovery of power for women compared to men. This gender difference is partly attributable to a higher Ad/LBM for women compared to men. The standard CWI protocol intensity (duration*temperature) concerning power recovery should accordingly be shorter for women compared to men.

Prediction of thermal variables during exercise in cold, wet, and windy conditions using a six-cylinder thermoregulatory model

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Introduction: Thermoregulatory models predict deep body (Tdeep) and skin (Tskin) temperatures under various cold-weather conditions. These models have not been validated against data during cold-air exposure while wearing wet clothing.

Purpose: Compare the six-cylinder thermoregulatory model (SCTM, Xu and Werner, 1997) to data collected during exercise in wet clothing in cold and windy conditions.

Methods: The data set used for model comparison was from Castellani et al. (2001). Thirteen volunteers completed rest/walk cycles for up to 6 hours in 5°C air while wearing an Army uniform (1.1 clo dry insulation, estimated at 35% of this with wet clothing manikin evaluation). For the first 10 min of every hour, the clothing was saturated during 10 min of simulated rain (5.4 cm/hour); this was followed by 45 minutes of walking at 1.34 m/s at a 5.4 m/s wind velocity. Tdeep, mean Tsk, local Tskin (Tthigh and Tcalf = Tleg; Tforearm and Ttricep = Tarm, Tsubscap = Ttorso), and metabolic rate (MR) between actual and predicted values were compared to each other using root mean square deviation (RMSD) statistic vs. the standard deviation (SD).

Results: The RMSD and SD, respectively, were 0.37 and 0.32 for Tdeep, 3.82 and 2.27 for mean Tsk, 6.33 and 2.75 for Tleg, 4.03 and 2.14 for Tarm, 3.72 and 4.36 for Ttorso, and 83.5 and 46.8 for MR. SCTM over predicted Tdeep by 0.08°C, mean Tskin by 3.28°C, Tleg by 5.89°C, Tarm by 3.73°C, and Ttorso by 2.30°C. MR was under predicted by 77 W.

Conclusion: During exercise in cold, wet, and windy conditions, the bias across time for Tdeep was within ±0.1°C. Higher model predictions of Tskin were likely due to the fact that evaporative heat loss caused by water absorption in clothing was not taken into account.

Author views not official U.S. Army or DOD policy

Does practice make perfect in the cold? A study of motor skill training for cold performance.

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Introduction: Little is known about how to best prepare persons for motor performance in cold conditions. It is unclear if principles of training specificity would apply because cold exposure reduces sensorimotor feedback and cognitive function. The current study investigates the effect of cold or thermoneutral training on performance of the Grooved Pegboard task.

Methods: Twenty persons (11M, 9F, mean age 31.2 ± 5.44) were randomly assigned to either a cold (5M, 5F) or thermoneutral (6M, 4F) training group. Prior to each repetition of the task during training, the cold training group immersed their hand in cold water (2 ◎C) while the thermoneutral group immersed their hand in thermoneutral water (34 ◎C). Participants were tested at baseline, at retention after training, and at a delayed retention period of 24hrs. During baseline and retention testing, participants performed the task twice; once after immersing their hands in cold water and once after immersing their hands in thermoneutral water. On day one, participants were tested at baseline and then performed 20 repetitions of the task according to their respective group assignment. Following this, participants were tested once again in an immediate retention test. On day two, delayed retention tests were performed. Time to completion and number of errors were recorded during testing. Errors were defined as the number of times a peg was dropped or when subjects picked up multiple pegs at once.

Results: There were no differences in time to completion during the delayed retention test between thermoneutral and cold-trained groups ($T(18) = 0.80$, $p = 0.434$). The cold trained group however made fewer errors than the thermoneutral training group during delayed retention testing ($p < 0.05$).

Conclusion: The main finding of this study was that dexterity but not speed in cold conditions was improved by cold training.

Predicting Core Temperature during Exercise in Arctic Conditions using Observed Heart Rate

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Introduction: ECTemp uses observed heart rate (HR) to predict core temperature (Tc) changes. However, it has only been validated in moderate to hot ambient temperatures (Tamb, 18- 45°C). It has not been validated during work in Arctic environments where Tamb often falls below 0°C.

Purpose: Assess ECTemp using HR and Tc data from two Arctic field training exercises (FTX) and evaluate its ability to accurately predict Tc using HR.

Method: HR and Tc data from two FTXs were used. In FTX 1, 8 men performed 46 hours of intermittent ski marches (ISM; Tamb: -18 to -6°C, wind speed: 5-13m/s). In FTX 2, 9 men performed 43 hours of ISM (Tamb: -17 to -3°C, wind speed: 0.3-19m/s). The baseline observed Tc was used as the starting point for the model prediction. Minute-by-minute HR values were input into the model which predicted the corresponding Tc. Hourly data points were used to evaluate the model over the 40+ hours of ISM. The root mean square deviation (RMSD) was calculated for each data set. Predictions were considered valid if the RMSD fell below the standard deviation (SD) of the observed Tc values. Non-parametric Bland-Altman plots were used to determine the level of agreement between the observed and predicted temperatures for the ECTemp model using ±0.4°C as a qualitative physiological threshold for Tc assessment.

Results: Model predicted Tc across time was higher than observed Tc. In FTX 1, RMSD was 0.83 with a corresponding SD of 0.31 and 17% of values falling within the ±0.4°C threshold. In FTX 2, RMSD was 0.56 with a corresponding SD of 0.42 and 63% of values falling within the ±0.4°C threshold.

Conclusions: ECTemp over-predicts Tc when using observed HR as a predictor during 40+ hours of intermittent work in Arctic environments.

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Physiological and Subjective Responses from Wearing a Winter Cap on Elderly Males in a Cold Environment

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Introduction: The rate of hat wearing for elderly Korean males in winter is high. This seems to be related to hair loss in elderly males. However, there have been few studies on the head and a hat in terms of heat loss under cold stress. We examined the physiological and psychological effects of wearing a winter cap at rest in a cold environment.

Method: Seven older males (76.2±4.0 yr) participated in the two seperate trials: with a winter cap (CAP) and without a winter cap (CON). The experiment was conducted in a climatic chamber (an air temperature 7.8±0.3℃ with 43±2 %RH) for 60 min in a sitting position. The cap consisted of 50 % wool and 50 % polyester and its insulation (Icl) measured on a thermal manikin was 0.02 clo. Besides the cap, all subjects wore the same experimental clothes (estimated clothing insulation excluding sneakers: 1.50 clo). Microclimates at the vertex of the head, rectal and skin temperatures, heart rate, as well as subjective perceptions were measured.

Results: Microclimate temperature at the vertex was 6.9^{o}C higher in CAP than that in CON (p<0.01). Microclimate humidity at the vertex was lower in CAP only during the last 5 min than that in CON (p<0.01). Forehead skin temperature in CAP was higher than that in CON (p<0.01). Also, during the last 5 min, rectal temperature was higher in CAP than that in CON (p<0.05). Unlike CAP, heart rate in CON during the last 5 min decreased significantly compared to that during the initial 5 min. There were no statistical differences in thermal comfort and humidity sensation between CAP and CON. Subjects felt less cold only on the head/face in CAP than in CON (p<0.01).

Conclusions: Wearing a cap for elderly males positively affected body temperature regulation in cold environments.

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Two-minute hand immersion test for estimating finger skin temperature and manual dexterity during and after whole-body sub-zero cold air exposure

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Introduction: The impairment of manual dexterity could be a potential risk factor for occupational accident in cold environment. It is well known that manual dexterity is correlated with finger skin temperature (Tfing), and there are wide individual variations in cold-induced vasomotor response in their extremities. This study investigated the validity of two-minute hand immersion test for estimating individual Tfing response and impairment of manual dexterity during and after whole-body cold exposure to sub-zero air.

Method: Eleven males participated in this study. At first, they conducted a simple skin temperature recovery test using a hand cold immersion for 2 min in 10°C water followed by 20-min rewarming in 20°C air. Second, they exposed to -20°C ambient air for 20 min with wearing cold protective clothes and gloves (around 2.2 clo), and then removed the protective clothes and rewarmed in 20°C for 40 min. During the whole- body exposure test, they repeated pegboard tasks with gloves every 4 min and finger Tfing was continuously measured.

Results: There were wide individual variations in their Tfing response to the short time hand immersion test and whole-body sub-zero cold exposure. Tfing rewarming rate (°C/min) from 1 to 3 min after the hand immersion was significantly correlated with the rewarming rate after whole-body cold exposure ($r=0.74$, $P<0.05$) and the recovery time taken for rewarming Tfing to 20°C ($r=-0.63$, $P<0.05$). The manual dexterity was impaired during whole-body cold exposure and gradually recovered with rewarming, but it was not correlated with recovery of Tfing. The manual dexterity test with gloves might not be sensitive enough to assess the correlation with Tfing.

Conclusions: The validity of the two-minute hand immersion test was confirmed for predicting recovery of Tfing after whole-body cold exposure. This simple test could be used for assessing cold workers' individual risk of cold injury in their extremities.

Investigation into the risk of injury in workers setting cables in place during construction in cold conditions

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Introduction: Present research investigated the risk of work-related musculoskeletal injury in work crews setting cables in place along the rail corridor for new signalling equipment in cold conditions. This work involved feeding cables from large, vehicle- mounted reels through underground conduits on a point-to-point basis.

Method: Applied experimental design was combined with using wearable sensors to capture objective measurement of body movement patterns (that is, joint motion and posture) and muscle activity. Trunk and lumbar forward flexion and the muscle activity of the back musculature were measured during two methods of cable pulling: using a conventional method and using a specially constructed trestle to elevate the cable above ground level.

Results: The trunk inclination and lumbar flexion demonstrates that cable pullers use high levels of trunk inclination and lumbar flexion, as demonstrated by the mean and peak values. Higher levels of trunk inclination and lumbar flexion occur at the start of a rope or cable pulling cycle where the worker reaches to a position slightly higher than ground level to obtain their grasp. In addition to adopting these high levels of back movement, force exertion for cable pulling is most likely highest at this point of the cycle. This was demonstrated with analysis of EMG data. Force exertion to pull the rope or cable along, once the participant was upright, was also identified as problematic.

Conclusions: The investigation demonstrated and quantified trunk inclination, lumbar flexion (L5/S1) movement and EMG values for the usual method of cable pulling in cold conditions. It also provided preliminary evidence on the likely impact of a novel trestle device to raise the cable when pulling it close to a pit, thus improving operator back postures and movements in these conditions.

Exercise Ice Maiden: Physiological responses to incremental exercise in normoxia and hypoxia before and after an Antarctic expedition

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Introduction: The purpose of this study was to characterise the physiological adaptation to chronic prolonged arduous exercise under Antarctic conditions in females (http://exicemaiden.com/). Submaximal and peak physiological responses to exercise were measured in normoxic and hypoxic conditions before and after the expedition.

Method: Within three weeks of expedition departure (Pre) and return (Post) all six members team members (aged 33(3) years) undertook incremental exercise tests to volitional exhaustion on a treadmill in normoxia (N) and hypoxia (H) equivalent to 3000m. After an initial 3 min at 5.0 $km \cdot hr^{-1}$ at a 1% gradient speed was increased to 7.5 $km \cdot hr^{-1}$. Thereafter, speed was increased by 1 $km \cdot hr^{-1}$ every 3 min until an RER of 1 was exceeded. Subsequently speed remained constant, and the gradient was increased by 1% every 1 min until volitional exhaustion. Data are expressed as median and interquartile range. When Friedman's test returned significance at $P<0.1$ post hoc Wilcoxon signed rank tests identified differences between trials.

Results: Peak oxygen consumption ($L \cdot min^{-1}$) declined pre to post expedition in both N -7(9)% and H -9(3)% ($P<0.05$). However when changes in body mass (Pre 73.6(5.0) vs. Post 65.6(5.3) kg) were accounted for no difference was observed (Pre 44(1) and 36(3), Post 45(4) and 35(4) $ml \cdot kg^{-1} \cdot min^{-1}$ for N and H respectively). Post expedition participants reached volitional exhaustion at a steeper gradient in both N and H trials. Although not affected in N maximal fat oxidation (MFO) was seemingly reduced in H post compared to pre expedition (0.24(0.10) versus 0.34(0.09) $g \cdot min^{-1}$; $P<0.05$), however running economy ($ml \cdot kg^{-1} \cdot km^{-1}$) at MFO did not vary.

Conclusions: The reduced fat oxidation in H at a given level of work alongside the participant's ability to exercise at higher gradients post expedition is indicative of greater dependency on carbohydrate metabolism and improved anaerobic capacity.

Effects of a 1-week cold-water acclimation protocol on oxygen consumption during moderate aerobic bike exercise in normothermia after 48-h recovery period.

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It has recently been observed an increase in muscular UCP-3 content, an uncoupling protein linked to mitochondrial expression, after cold-acclimation period. Whether or not these observations are sustained once back in warm conditions and impact oxygen consumption at exercise has never been investigated. Therefore, the present study aimed to investigate if a 1-week cold acclimation protocol led to modification of cycling VO2 after 48-h recovery period that could be explained from a rise in UCP-3 content.

Six (6) participants underwent the protocol consisting of two 30 minutes standardized bike tests (*Neo Smart*, TACX) sustained at 50% maximal aerobic power (MAP) at room temperature before and after a cold-acclimation week (1-h daily cold bath at 16°C). Oxygen consumption at exercise (VO2), at rest before (VO2before) and after (VO2after), heart rate (HR), heart rate recovery (HRr) mean skin temperature (TSK), thermal comfort (TCex) and rating of perceived exertion (RPE) were measured during the two tests. Core temperature (Tcore) and thermal comfort (TCacc) were measured to control the intervention.

Initials results demonstrated a trend for VO2 to increase post *vs* pre-acclimation (0.13±0.08 LO2.min^{-1} p=.173) parallel to a significant increase of RPE (0.43±0.13 p=.043), while others parameters did not change (VO2before: 0.01±0.02 L.min^{-1} p=.833; VO2after: 0.00±0.02 L.min^{-1} p=.599; HR: 1.29±1.01 bpm p=.249; HRr: -1.15±2.18 bpm p=.600; TSK: -0.18±0.27°C p=.345; TCex: 0.24±0.16 p=.225). Significant decrease in Tcore (-1.08±0.19 °C p=.028) and TCacc (-3.75±0.25 p=.020) alongside no changes in power (-0.52±1.01 W, p=.753) and cadence (0.09±0.45 rpm, p=.753) demonstrate the control we exerted. Data expressed as average difference Post – Pre ± SE.

These observations suggest changes in mitochondrial complex that could be UCP-3 related, explaining why no changes were observed in VO2 at rest before and after exercise, while an increase can be observed when cycling at 50 % MAP in normothermia after 48-h recovery period.

Iron deficiency anemia impairs cardiovascular responses after graded exercise to exhaustion in the cold

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Introduction. Blood pressure recovery after incremental exercise is considered as a prognostic tool for various cardiovascular diseases. Iron deficiency anemia (IDA) forces the heart to work harder in order to provide tissues with oxygen, thus causing serious heart problems, such as arrhythmias and an enlarged heart. Moreover, exposure to a cold environment can augment vasoconstriction, even more so in an anemic population, since cold exposure potentiates the catecholamine response. Thus, the aim of this study was to examine the cardiovascular responses following incremental exercise to exhaustion in thermoneutral and cold conditions across a wide range of hematocrit values.

Methods. Eight normotensive young males, four diagnosed with chronic mild IDA and four healthy individuals (Hct: 38.4±0.91% and 46.0±0.82%, respectively, range: 37.1-47.0%) were tested on two separate occasions, in neutral (22.5^{o}C, 45%rh) and cold (11^{o}C, 45%rh) conditions, in a randomized order. In both environments, following a 20-min rest, the participants performed a graded test to exhaustion on a cycle ergometer followed by a 5-min recovery. Systolic pressure (SP), diastolic pressure (SP), mean arterial pressure (MAP), and heart rate (HR) were monitored with finger plethysmography. Pearson r correlation was used to investigate the relationship between baseline Hct and Δ values of cardiovascular parameters (peak exercise–5min recovery).

Results. In the thermoneutral condition, a non-significant correlation between Hct and ΔSP, ΔDP, ΔMAP (r=0.60, 0.43, 0.48, p>0.05) and ΔHR (r=-0.15, p>0.05) was observed. However, in the cold condition, Hct was significantly correlated with ΔSP and ΔMAP (r=0.85, p=0.01) as well as with ΔDP (r=0.76, p=0.05) whereas there was a tendency for correlation between Hct and HR (r=0.66, p=0.07).

Conclusion. In summary, IDA impaired blood pressure recovery after maximal exercise in the cold. This may be attributed to an exacerbated catecholamine response, which could pose a health concern in an anemic population.

Compensable and non---compensable cold exposure: Effects of body morphology and body composition

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Introduction: Cold exposure (CE) in humans can be categorized as compensable (C--- CE) or non---compensable (NC---CE), leading to preserved or decreased core temperature (Tcore), respectively. Responses to a decrease in skin temperature (Tskin) or Tcore have been seen to be quantitatively different among individuals with varying body morphology and body composition. The purpose of this study was to examine the relationship between body morphology and composition on changes in Tskin and Tcore in men during C---CE and NC---CE.

Methods: Five males (27.7±4 y) participated in the C---CE and five males (26.5±5.3 y) participated in the NC---CE. Height and weight were taken and body composition was measured using DEXA. Skeletal muscle mass (SM), body surface area (BSA), body fat (BF) and body volume (BV) were calculated. Participants were either exposed to CE for 60 min using a liquid conditioned suit (LCS; 5°C) or NC---CE for 60 min using cold--- water immersion (CWI; 20°C). Tskin was measured using 12 site thermocouples during LCS and Tcore using a telemetric pill during CWI.

Results: For C---CE, a relationship was found between final Tskin and BF (r^2=---0.937, p=0.019), but not with BSA (r^2=---0.672, p>0.05), BV (r^2=---0.863, p>0.05) and SM (r^2=--- 0.655, p>0.05). In contrast, during NC---CE, changes in Tcore were correlated to BSA (r^2=0.994, p=0.001), BV (r^2=0.943, p=0.016) and BF (r^2=0.91, p=0.032), but not to SM (r^2=0.643, p=0.242).

Conclusion: This preliminary study indicates that while changes in Tcore are related to interindividual differences in BSA and BV during NC---CE, these individual body characteristics are not linked to changes in Tskin during C---CE. Even though this finding was expected for NC---CE, it remains that this assumption is not confirmed during compensable CE as it relates to changes in Tskin. Consequently, more research is needed to establish the exact parameters that dictate cold response during compensable cold exposure.

Hand sweating magnitude during Alpine skiing in sub-zero ambient conditions

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Introduction: The aim of the present study was to assess the magnitude of sweating in gloved hands during Alpine skiing in sub-zero conditions.

Methods: The field study was carried out at the Nassfeld Ski Resort. Male (N=31) and female (N=27) participants took part in this study: age (male 32(13); female 27(7) yrs), weight (male 80(8); female 60(7) kg) and height (male 181(6); female 167(4) cm). The subjects participated in two trials, each repeated and conducted over 4 consecutive days: 1) (Impermeable) ski gloves worn with a water-impermeable membrane; 2: (Permeable) ski gloves worn without a water-impermeable membrane. Glove weight was recorded before and after skiing. The difference in the gloves' mass in the Permeable and Impermeable conditions provided an index of the amount of sweat that was evaporated.

Results: Ambient temperature varied from -5.1 to -1.5 ◎C throughout each day. The average (SD) daily distance skied was 54 (5) km, with no significant difference in the distance skied between the 4 days of skiing. The sweat production was greater for males (32.2 g) than females (24.5 g) and with greater sweating noted in the morning compared to afternoon skiing.

Conclusions: Substantial sweating of gloved hands may be anticipated during downhill skiing in sub- zero ambient temperatures. Increased moisture in the glove may affect the thermal insulation characteristics and contribute to thermal discomfort.

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Greater vasodilation in hypoxia compared to normoxia following dynamic exercise

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Introduction: After a single bout of exercise, mean arterial pressure (MAP) drops below pre-exercise values. This phenomenon, called post-exercise hypotension (PEH), is commonly observed following long bouts (30–60 min) of moderate intensity (50–60%VO2peak) dynamic exercise. Hypoxia affects blood pressure homeostasis in humans, since hypoxemia induces vasodilation and therefore hypotension. However, studies examining hypotension following dynamic exercise in hypoxia are scarce. Therefore, the aim of the present study was to compare normoxic with hypoxic post-cycling hemodynamic responses.

Methods: Seven young healthy normotensive male subjects were tested in thermoneutral conditions (23^{o}C, 50%rh) on two occasions, under hypoxia (FiO2: 13.5%) and normoxia (FiO2: 20.9%), in a randomized order. After a 2-min resting period, the participants exercised on a cycle ergometer at 40% of their normoxic peak power output for 30 min immediately followed by an incremental test to exhaustion; thereafter, they were monitored during a 30-min seated recovery period. Blood pressure, cardiac output (CO), total peripheral resistance (TPR), heart rate and stroke volume were recorded by finger plethysmography (Finometer). Data analysis was conducted using one- and two-way ANOVA for repeated measures with Tukey post-hoc tests.

Results: During recovery, TPR was lower ($p=0.002$) and CO tended to be higher ($p=0.075$) in hypoxia than in normoxia. Post-exercise TPR dropped below resting values in both conditions ($p<0.01$). Post-exercise MAP values were consistently, although non-significantly, lower in hypoxia compared to normoxia across the recovery period (91.7±1.8 vs. 95.7±3.1 mmHg; $p>0.05$). At the 30th min of recovery there was a strong tendency for PEH in normoxia ($p=0.057$), whereas PEH was profoundly exhibited in hypoxia ($p=0.001$).

Conclusions: These findings suggest an enhanced peripheral vasodilation which offsets the slightly higher cardiac output after cycling in hypoxia. As a result, post-exercise hypotension seems to be further augmented in hypoxia compared to normoxia.

Reduced post-exercise vasodilatory response after combined acclimation to hypoxia and heat

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Introduction: Baroreflex sensitivity seems attenuated in acute hypoxia and exacerbated in chronic hypoxia. Arterial blood pressure (MAP) drop below pre- exercise values after a single exercise bout appears accentuated with acute hypoxia due to a pronounced increase in peripheral vasodilation. The elevated sympathetic response in chronic hypoxia attenuates vasodilatory response and augments MAP in healthy humans at rest and during exercise. On the other hand heat acclimation increases skin vasodilation and sweating that challenge blood pressure regulation. However, no study has examined the adaptive post-exercise blood pressure responses after hypoxia and heat acclimation in humans.

Methods: Seven young normotensive males underwent a 10-day normobaric hypoxic confinement (FiO2:13.5%) interspersed with daily 90-min normoxic controlled-hyperthermia (target Tre:38.5°C) exercise sessions in warm conditions (35°C,50%RH). Prior to and after confinement, the participants were tested under normoxia (FiO2:20.9%, 23°C, 50%RH) and hypoxia (FiO2:13.5%, 23°C, 50%RH) in a randomized and counterbalanced order. The initial workload was set at 40% of normoxic PPO for 30min and was immediately followed by 20W/min increments until exhaustion. During the 30-min seated recovery cardiovascular parameters were recorded by finger plethysmography. Data were analysed using one- and two-way ANOVA for repeated measures with Tukey post-hoc tests pre and post confinement. For technical reasons 6 subjects were included in the post-confinement analysis.

Results: After hypoxic confinement, post-exercise total peripheral resistance (TPR) and cardiac output were not different between normoxia and hypoxia ($p=0.20$ and $p=0.37$, respectively) and no TPR drop from resting values was observed in any condition. The profound post-exercise hypotension manifested in hypoxia pre-acclimation was not evident post-acclimation, since MAP was not reduced compared to rest in either normoxia or hypoxia.

Conclusion: A 10-day combined acclimation to hypoxia and heat attenuated the vasodilatory response during recovery in normoxia and hypoxia and abolished the profound post-exercise hypotension observed after cycling in acute hypoxic conditions.

Individual and combined impact of hypoxia and acute inorganic nitrate ingestion on autonomic thermoregulatory responses to the cold

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Introduction: This study assessed the impact of normobaric hypoxia and dietary nitrate ($NO3^{-}$) ingestion on shivering thermogenesis and vascular control in response to acute whole-body cooling.

M**ethod:** Ten male volunteers underwent supine passive cooling at 10°C air temperature across four conditions; NORM_PLAC: 20.9% fraction of inspired oxygen (FiO2) with ~0.003 mmol $NO3^{-}$ ingestion, NORM_NTR: 20.9% FiO2 with ~13 mmol $NO3^{-}$ ingestion, HYP_PLAC: 12.6% FiO2 with ~0.003 mmol $NO3^{-}$ ingestion, HYP_NTR: 12.6% FiO2 with ~13 mmol $NO3^{-}$ ingestion. Shivering thermogenesis via mechanomyography (MMG) and pulmonary oxygen uptake ($\dot{V}O2$) were continuously assessed to determine shivering onset. Vascular activity, via laser doppler flowmetry (LDF) at the forearm and mean arterial pressure (MAP), in addition to rectal and skin temperature (Tre and Tsk), were continuously assessed and analysed across a 30 min time window during passive cooling. Preliminary data from 7 participants is presented.

Results: Hypoxia significantly reduced (earlier) shivering onset time assessed via MMG and $\dot{V}O2$ (mean of NORM condition minus HYP conditions; MMG, 500 ± 140 s, P=0.02; $\dot{V}O2$, 337 ± 158 s, P=0.04) and increased microvascular perfusion (NORM minus HYP; LDF, -18 ± 7 PU, P=0.03). Hypoxia reduced MAP, reduced Tre and increased Tsk (NORM minus HYP; MAP, 3 ± 2 mmHg, P=0.2; Tre, 0.06 ± 0.06 °C, P=0.3; Tsk, -0.24 ± 0.19 °C, P=0.3), though these differences were not significant. No significant main effects were found for nitrate ingestion (mean of PLAC conditions minus NTR conditions; MMG, -430 ± 220 s, $\dot{V}O2$, -532 ± 326 s; LDF, 21 ± 16 PU; MAP, 4 ± 2 mmHg; Tre, -0.06 ± 0.07 °C; Tsk, -0.21 ± 0.29°C).

Conclusions: Initial findings suggest increased heat loss with hypoxic exposure, leading to earlier onset of shivering thermogenesis. No differences were seen with nitrate ingestion. Interactions between hypoxia and nitrate ingestion requires further investigation.

Hypobaric normoxic exercise

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ABSTRACT WITHDRAWN

Glomerular proteinuria increases as bicarbonate and carbon dioxide decrease at altitude.

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Introduction: Glomerular leak, characterised by increases in urinary orosomucoid (uORM) occurs with ascent (and decreasing pO2) inferring renal (mal)adaptation. Hypothesised mechanism(s) include hypoxia and disturbances in acid-base balance although uncoupling the relative effects of each at altitude is difficult. Simultaneous examinations of uORM and arterial measures other than pO2 - such as changes in bicarbonate (HCO_3^-), carbon dioxide (pCO2), base excess (BE), and pH may help provide a better understanding of the underlying glomerular mechanism(s). The purpose of the present study was to examine uORM excretion in conjunction with blood gas components during ascent to high altitude.

Methods: Twenty-three individuals ascended to Whymper Hut (5035m), Mt Chimborazo, Ecuador over the course of 6 days (Day 1, 2800m to Day 6, 5035m). Arterialised ear lobe blood gases were obtained each morning and analysed using the Abbott iStat. Twenty-four hour urine samples were collected daily with aliquots frozen (dry ice) and transported back to Birmingham (140m) where they remained at - 80◎C until analysed for uORM by radial immunodiffusion. Statistical analyses were performed on complete data sets from Days 1-6 (n=17) using IBM SPPS. Repeated measures ANOVA (with Bonferroni correction), Pearson's rank, and Spearman's rho were used where appropriate with significance set to $p<0.05$.

Results: 24-hour uORM excretion (◎g/min) progressively increased with ascent (by days, $p<0.01$), while arterial pO2, pCO2, HCO_3^-, and BE decreased with ascent (all $p<0.01$). pH showed no significant changes during ascent (Day 1, 7.436±0.020 thru Day 6, 7.432±0.022). With ascent, 24-hour uORM excretion was correlated with decreasing mean daily: pO2 ($p = 0.017$; $r=-0.891$), pCO2 ($p<0.01$; $r=-0.966$), and HCO_3^- ($p=0.029$; $r = -0.857$) but not pH ($p=0.753$) or BE ($p=0.095$).

Conclusion: Increasing glomerular leak of uORM with ascent is negatively correlated with changes in pO2, pCO2 and HCO_3^-, although the precise underlying mechanism(s) remain unclear.

Music enhances self-paced maximal exertion in normoxia and hypoxia

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Introduction: High altitude is characteristic of a combination of environmental stressors which inhibit performance. Music has ergogenic effects through enhancing psychological factors such as mood and cognition. This study aimed to explore the impact of music as a tool for mitigating the performance decrements observed at altitude.

Method: Following ethical approval from Loughborough University, 13 healthy males (mean ± SD; 23.9 ± 4.01 years) completed one familiarisation session and four experimental trials: 1) normoxia (0.209 FiO_2) and no music; 2) normoxia (0.209 FiO_2) with music; 3) normobaric hypoxia (0.13 FiO_2) and no music; 4) normobaric hypoxia (0.13 FiO_2) with music. All conditions were completed at 21°C with 50% relative humidity. Music was self-selected by each participant prior to the familiarisation session. The songs were assessed for their motivational qualities using the Brunel Music Scale Inventory (BMRI-2). Each experimental trial included a 15-min self-paced time trial on an arm bike, followed by a 60-s isometric maximal voluntary contraction (MVC) of the biceps brachii. Supramaximal nerve stimulation was used to quantify central and peripheral fatigue with voluntary activation (VA%) calculated using the twitch interpolation method. Subjective measures included motivation (MS) and mood using the Brunel Mood Scale (BRUMS).

Results: Average power output (W) was reduced in hypoxia ($p = 0.02$) but increased with music ($p = 0.001$) indicating a non-interactive effect. MVC force (N) was reduced in hypoxia ($p \leq 0.026$) whilst VA% of the biceps brachii was increased with music ($p = 0.022$). MS and BRUMS remained unchanged across all conditions ($p \geq 0.065$). Music reduced subjective scores of mental effort, breathing discomfort, and arm discomfort in hypoxia ($p < 0.001$).

Conclusions: Music increased self-paced and maximal physical exertion through enhancing neural drive and diminishing detrimental mental processes. Therefore, music is a viable tool for enhancing performance at altitude.

Effect of hypoxia on thermal sensation and thermoregulatory response during exercise

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Introduction: Hypoxia reduces sweating and cutaneous vasodilatory responses during exercise as reflected by reduced sensitivity of the responses in response to increased core temperature (Kolka et al. 1987; Miyagawa et al. 2010). In addition, hypoxia at rest reportedly decreases cold sensation of the toes but not warmth (Golja et al. 2004). However, it remains unclear whether hypoxia decreases thermal sensation during and after exercise, and whether the effect of hypoxia varies at different body sites. We therefore examined the effect of hypoxia on thermal sensation and thermoregulatory response during exercise.

Method: Thirteen healthy subjects (three men and ten women) performed cycle exercise at 30% of peak oxygen uptake in normoxia for 35 min under hypoxic (12%O2) and normoxic (20.9%O2) conditions. During resting, exercise and post-exercise, cutaneous thresholds for warm and cold sensation on three regions (forehead, chest and forearm) were measured by the method of limits (±0.3 °C/s). Esophageal temperature (n=9), skin temperature at seven sites, heart rate, arterial blood pressure, respiratory gases, forearm sweat rate and forearm skin blood flow were continuously measured.

Results: Cutaneous threshold for warmth at forehead was significantly increased during exercise (3.2±2.1 vs. 2.3±1.5°C, P=0.013) and post-exercise (3.2±2.4 vs. 2.3±1.7°C, P=0.045) in hypoxia than in normoxia. The threshold for cold at forehead was significantly decreased during post-exercise resting (-2.3±1.6 vs. -1.6±0.8°C, P=0.025) and tended to be lower during pre-exercise (-2.0±1.3 vs. -1.5±0.8°C, P=0.061) in hypoxia than in normoxia. The thresholds for warmth and cold at chest and forearm did not differ between conditions. Esophageal temperature thresholds for sweating and cutaneous vasodilation were increased in hypoxia than in normoxia (n=9, both P<0.05).

Conclusions: Present results suggest that exercise in hypoxia diminishes the sensation of warm and cold at forehead, but not at chest and forearm.

Health over wealth: formalised feedback concerning occupational heat stress across multiple European industries

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Introduction: The European Commission Heat-Shield Project exists to minimize the impact of occupational heat stress (OHS) on five key European industries (agriculture, construction, manufacturing, transportation and tourism). Often, scientific recommendations are produced without input from the real-world end-users. Therefore, to counteract this oversight, the purpose of this investigation was to host meetings with European stakeholders from the aforementioned industries to identify their current state of knowledge and attitudes towards OHS.

Method: Five workshops were held in Florence, Italy; Tønder, Denmark; Rome, Italy; Nicosia, Cyprus; and Ljubiana; Slovenia. Mixed qualitative and quantitative standardized questionnaires and focus group discussions were used to obtain attendee feedback. Notes from the focus groups and questionnaires were collated, and relevant themes were identified.

Results: Feedback was collected from 72 people representing a variety of occupations, including: extrusion workers, manufacturers, farmers, shop stewards, company doctors, employers, policy makers and legislators. On average (range), workers had 15 (1-33) years of industry-experience and reported that heat stress moderately affected their work-performance [score of 3 (1-4) on a four-point scale] for 3 (0-12) months per year. On a scale out of 10, worker safety (9; 2-10) scored higher than preventing company productivity losses (7; 1-10) for combatting OHS. A prominent discussion theme that emerged was feeling under-informed concerning OHS. Further, differences in company resources necessitate prioritizing effective, feasible and low-cost cooling interventions in dissemination materials. Interventions best-regarded by stakeholders included: having a pre-made heat mitigation plan, utilizing hot weather notification services, adding pre-planned rest breaks in cool areas, changing work hours, ensuring hydration and optimizing clothing.

Conclusions: Protecting worker-health is prioritized over productivity in the five selected European industries, regardless of occupation; however, knowledge and attitudes toward OHS vary widely. Several interventions (highlighted above) were agreed to be best suited to combat OHS from both a scientific and real-world perspective.

The independent and interactive effect of thermal stress and mental fatigue on fine and gross manipulative tasks

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Introduction: Many occupations (e.g. military) require performance of fine and gross manipulative tasks (e.g. operating equipment or vehicles) under thermal and mental stress. We aimed to quantify the effects of thermal stress and mental fatigue on fine and gross manipulation.

Method: Seven healthy males (21.1±1.3y) partook in 6 separate 40-min trials characterised by a different combination of 3 ambient temperatures (HOT: 37°C, 40%RH; NEUTRAL: 21°C, 40%RH; COLD: 7°C, 40%RH) and 2 mental fatigue states (mental fatigue, MF; no mental fatigue, No-MF). Participants performed a fine (O'Connor dexterity test) and a gross (Hand-Tool test) manipulation task at the start and end of trials. Performance changes (%) were determined. To induce mental fatigue, participants performed 35 minutes of arithmetic problems during MF trials only. We monitored participants' rectal temperature (Trec) and hand skin temperature (Tsk_hand) continuously and assessed reaction time (Hand-Click test) and subjective mental fatigue (5-point scale) prior to the tasks.

Results: Trec remained stable during trials. Thermal stress ($p<0.001$), but not mental fatigue ($p=0.290$), modulated Tsk_hand (+3.3°C [95%CI +0.2, +6.5] during HEAT trials; - 7.5°C [-10.7, -4.4] during COLD trials). Mental fatigue ($p=0.022$), but not thermal stress ($p=0.646$), decreased reaction time (~9%) and increased subjective fatigue (~50%). Thermal stress and mental fatigue had an interactive effect on fine manipulation ($p=0.040$), with HEAT-No-MF and COLD-No-MF decreasing performance by 15.7% [- 1.4, 32.7] and 21.8% [4.7, 38.9], while HEAT-MF, COLD-MF, and NEUTRAL-MF by 36.0% [18.9, 53.0], 34.5% [17.5, 51.6], 36.4% [19.4, 53.4], respectively. Gross manipulation was affected by mental fatigue only (i.e. 29.8% [16.2, 43.4] performance decrement across all thermal conditions; $p=0.002$).

Conclusions: Thermal stress-induced impairments in fine manipulation are increased by mental fatigue; yet combined stressors' effects are no greater than that of mental fatigue alone, which also impairs gross manipulation. Mental fatigue poses a greater challenge to manipulative tasks than thermal stress.

Extreme heat policies for sport and physical activity – an international review

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Introduction: Evidence-based extreme heat policies are needed for the management and mitigation of heat stress risk in sport and physical activity (PA). Our aim was to determine the quality of publically available sport and PA heat-protection advice from government and sport organisations internationally.

Method: We combined "weather", "guidelines" and "physical activity" terms to systematically search websites for advice from: major international sporting event organisations; government, sports medicine and Olympic summer games organisations in Anglosphere countries and former and future countries hosting major international sporting events; and the six most popular outdoor club sport organisations in each Anglosphere country. We included English advice only. Quality was the presence(1) or absence(0) of 13 components considered crucial for the management and mitigation of heat stress risk and covered the areas of vulnerable populations, measurement and use of environmental parameters, prevention and treatment of heat-illness, ease-of-use and evidence-base. A quality score was given from 0-13 based on the total number of components present, with high scores denoting high quality; data presented as mean.

Results: 133 documents (score:4) were retrieved from 52 (26%) of 198 organisations in 37 countries. Short documents e.g. PA fact sheet (n=122, score:4), had ease-of-use with mostly well presented, lay terminology but lacked evidence-based prevention, treatment and environmental cut-offs. Sport heat-policies (n=7, score:5) prioritised game cancellation often without apparent evidence and other prevention strategies or treatments. Position statements (n=4, score:9) were evidence-based but were unclear how environmental parameters should be measured and lacked ease-of-use and prioritisation of prevention strategies.

Conclusions: We found low online accessibility to sport and PA heat-protection advice. Predominantly, advice was either good quality with poor ease-of-use, or vice-versa. The general public and sporting communities need greater access to usable, good quality sport and PA heat-protection advice in policy form to guard against heat illness.

Implication of drop in footwear comfort for the physiological needs of obese users

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Introduction: It has been shown that obesity is a factor that alters: the gait pattern, the foot structure and the loads. In general, overweight and obese people, with respect to normal-weight people, show feet with larger dimensions, lower arch, greater plantar pressures and balance deficiencies. Epidemiological research indicates there is a higher rate of falling among those who are obese. This work is aimed at analysing the functional effect of two casual footwear models, one flat and the other with some *Drop**, in the distribution of the plantar pressures of obese users. (**Drop: height difference between the heel and the forefoot of the shoe*)

Methodology: Two models of comparable casual shoes were selected with different *Drop*: flat =0cm and *Drop*=1cm. The participants in the study were a total of 20 subjects with BMI 29±5Kg/m2 with shoe size 42±2EU. The distribution of the plantar pressures in dynamic conditions was recorded and analysed with the Pedar® Insoles system that included the Pedar-X Expert software (Novel GMBH, Munich, Germany). Data were recorded for 60 seconds with a frequency of 50 Hz. 3 areas of the foot were established: the forefoot, the midfoot and the hindfoot. The normalised absolute maximum pressures (kPa/kg) and the contact area (cm2) were calculated in the midstance phase of the tread. Data were analysed with the SPSS Software v. 20 for Windows® (IBM, Chicago, USA), with significance level $P < 0.05$ and a t-test for related samples.

Results: The footwear model with some drop significantly decreased pressures in both the forefoot and hindfoot areas, indicating a shock absorbing effect.

Conclusions: In response to the functional health, safety and comfort needs of overweight and obese users, the use of shoe models with some drop is recommended as opposed to flat shoe models. Footwear designs that reduce the pressures and improve balance will be positive for the user. It would be necessary to conduct further research to assess the effect of different footwear models in the movement pattern, including stability.

The influence of ethnicity on thermal sensation responses in British and Chinese Individuals

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Introduction: Thermal comfort models have largely been developed using data acquired from studies conducted using participants of Western European and North American ancestry. Consequently, these models have been used to inform the design of indoor climate systems installed worldwide. Little is known of the impact of other factors such as ethnicity (encompassing geographical, social and cultural issues), on a person's level of thermal comfort and sensation. Some data suggest a warmer preference temperature in Asians. It is unclear whether this would be due to a sensitivity difference.

Method: This study aimed to investigate whether ethnicity influences cutaneous thermal sensation responses in British and Chinese individuals. Thirty-two participants, (16 British [age 25.4±3.45] and 16 Chinese [26.3±1.75 years; mean ± SD) were body-matched to within ±1kg/m^2 of Body Mass Index. Local Thermal sensation responses across thirty-three body locations were examined using a conductive thermal probe set to a warm (40 ^{0}C) and a cool (20 ^{0}C) stimulus in a thermoneutral environment (25°C air temperature, 50% relative humidity). Thermal sensation ratings were obtained immediately prior to the stimulus being applied, on initial contact with the skin and after 10-seconds of contact. Perceptual ratings of whole-body thermal sensation, thermal comfort and thermal preference were measured at 5- minute intervals to monitor overall thermal state.

Results: Chinese individuals reported slightly greater thermal sensation responses to the warm stimulus though this was only statistically significant for some areas on the front torso. No significant differences were observed for the cool stimulus between the ethnic groups ($p = 0.11$).

Conclusions: The thermal sensitivity maps obtained in the present study are consistent with earlier observations. However, the data indicate that there is only a minor difference in the thermal sensation responses to a warm stimulus between the tested British and Chinese groups.