Effects of Local Cooling on Tissue Viability in Compressed Soft Tissue

A review of the literature

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Outline

- Theoretical basis of skin temperature as a risk factor—current literature
- Support surface's effect on skin temperature

Theoretical Basis of Skin Temperature as a Risk Factor

Factors to consider

- Heat increases metabolic demands
  - Metabolic rate increase 10% per degree Celsius *(Brown & Brengelmann, 1965)*
- Heat stimulates increased blood flow
- Cooling decreases metabolic demands
- Externally applied pressure reduces blood flow
- Heat results in increased tissue stiffness

Clinical Research on Skin Temperature as a Risk Factor

- Increased histological changes in sites with higher temperature *(Kokate et al., 1995)*
- Cutaneous and subdermal tissue damage reduced by focal cooling ≤ 30 ºC *(Iaizzo et al., 1995)*
- Temperature ≥ 35 ºC causes deep tissue damage *(Iaizzo, 2004)*
- Perfusion increases with heat; no perfusion increase under vessel occlusion *(Patel et al., 1999)*
- Elevated pressure ulcer risk associated with elevated skin temperature in hospitalized neurologically impaired patients *(Sae-Sia, 2005)*

Examining the effects of age and disability on temperature response

Int J Biometeorol (2003) 47:139–147
DOI 10.1007/s00484-003-0158-2

ORIGINAL ARTICLE

Yoshinao Nagashima · Yukihiro Yada ·
Toshiyuki Suzuki · Akio Sakai

Evaluation of the use of an integration-type laser-Doppler flowmeter with a temperature-loading instrument for measuring skin blood flow in elderly subjects during cooling load: comparison with younger subjects

Received: 22 April 2002 / Revised: 1 October 2002 / Accepted: 6 December 2002 / Published online: 8 April 2003

Diminished Physiological Response in Elder Subjects Toward Cooling

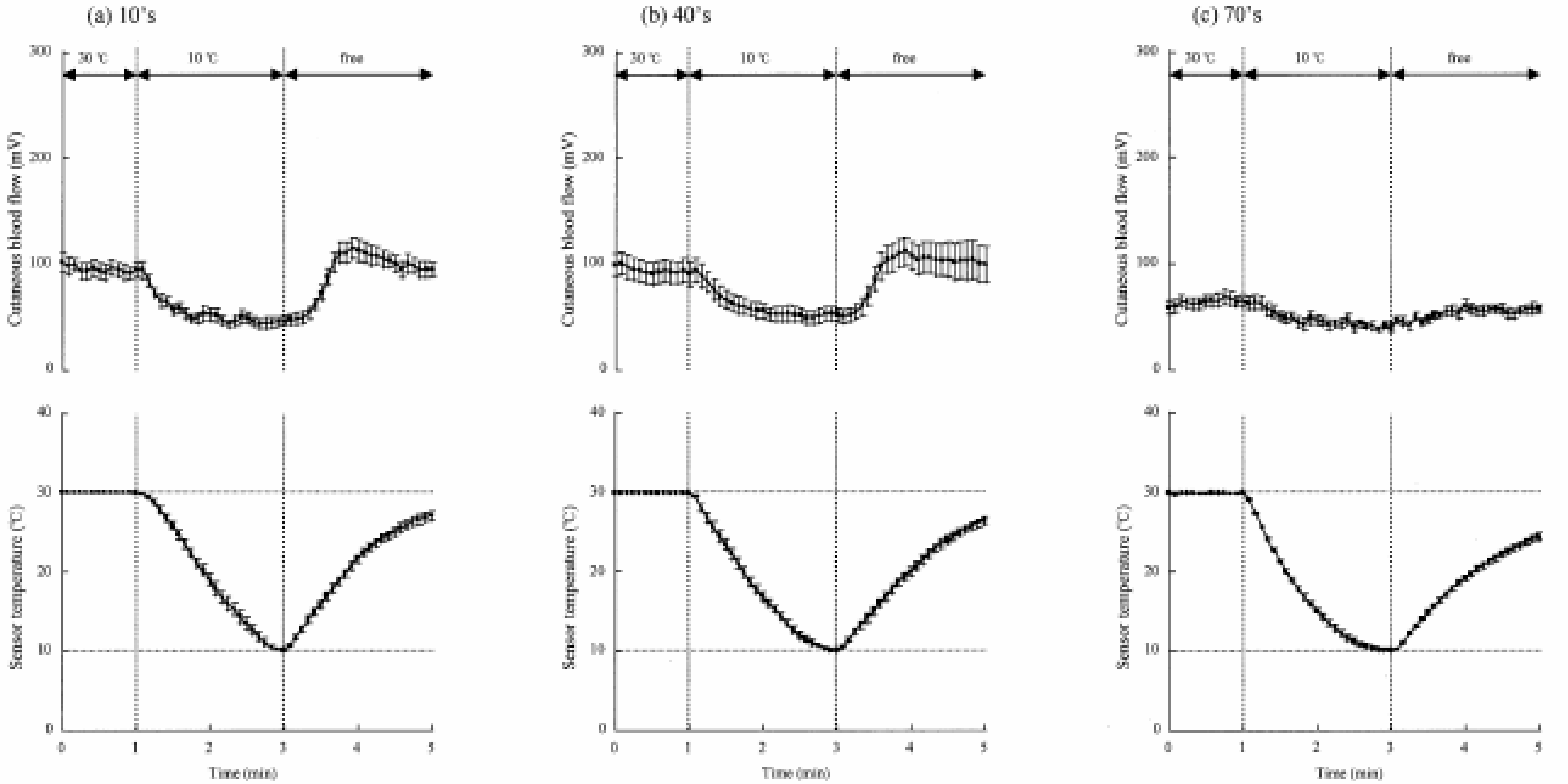


Fig. 2a–c Comparison among age groups of the skin blood flow and sensor temperature with a 10 °C cooling load applied to the forehead. **a** 10s ($n = 10$), **b** 40s ($n = 10$), **c** 70s ($n = 11$). The blood flow was measured for 1 min at a sensor temperature of 30 °C, for 2 min at 10 °C, and for 2 min after the temperature setting had been cancelled. Blood flow values: mean ± SE; sensor temperature values: mean ± SD

(Nagashima et al., 2003)

Diminished Physiological Response in Elder Subjects to Cooling (con't)

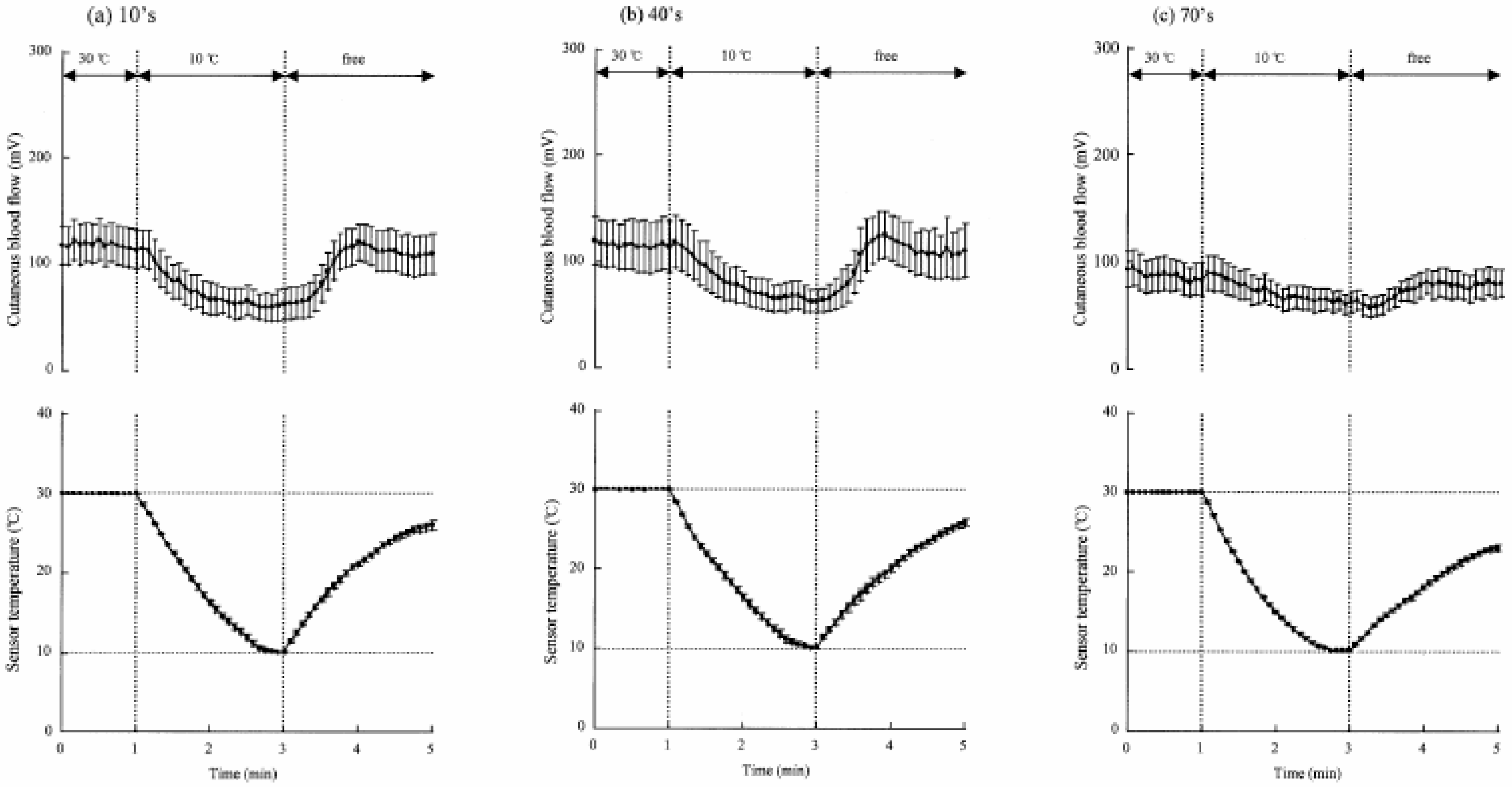
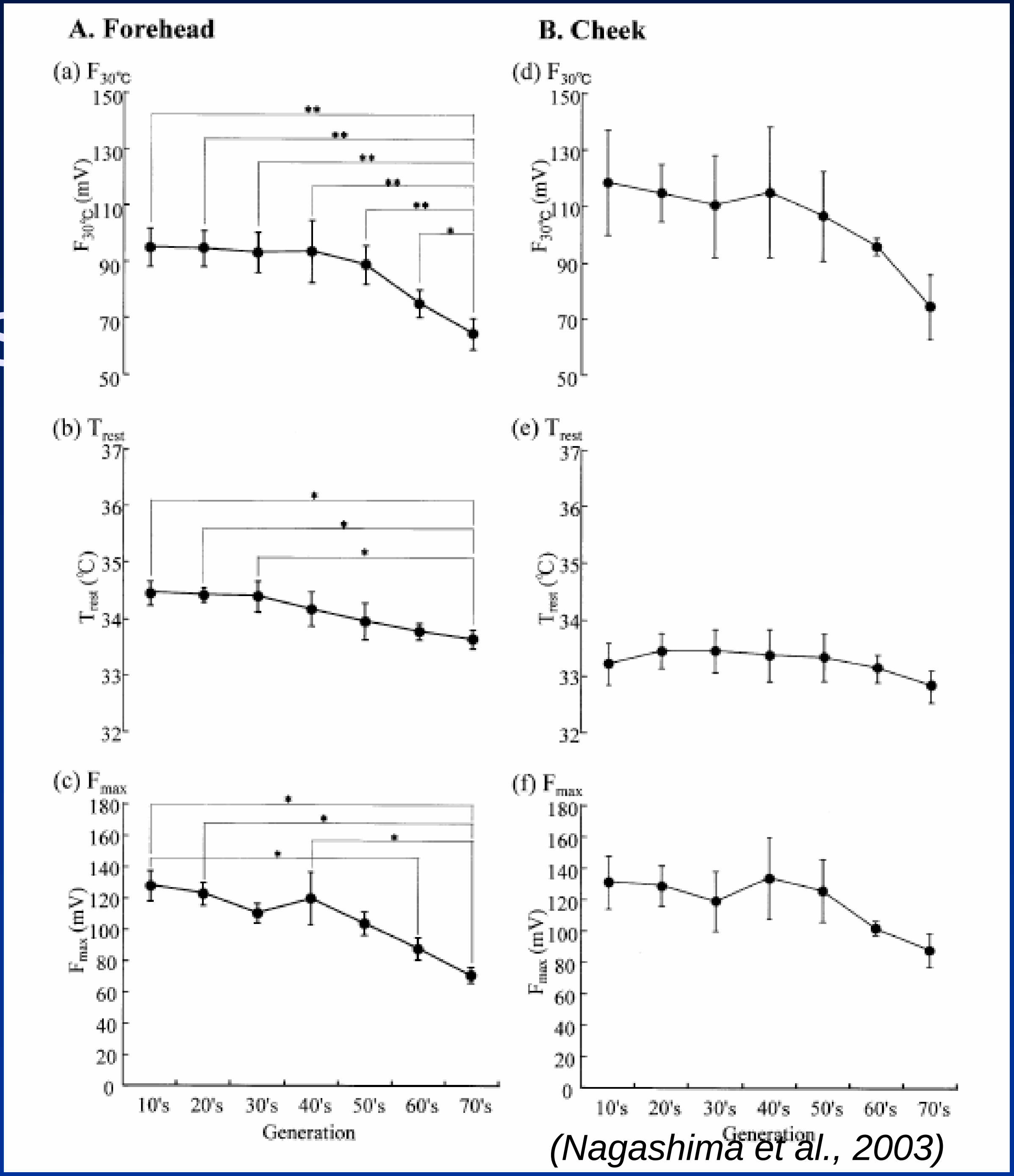


Fig. 3a–c Comparison among age groups of the skin blood flow and sensor temperature with a 10 °C cooling load applied to the cheek. **a** 10s ($n = 10$), **b** 40s ($n = 10$), **c** 70s ($n = 11$). The blood flow was measured for 1 min at a sensor temperature of 30 °C, for 2 min at 10 °C, and for 2 min after the temperature setting had been cancelled. Blood flow values: mean ± SE; sensor temperature values: mean ± SD

(Nagashima et al., 2003)

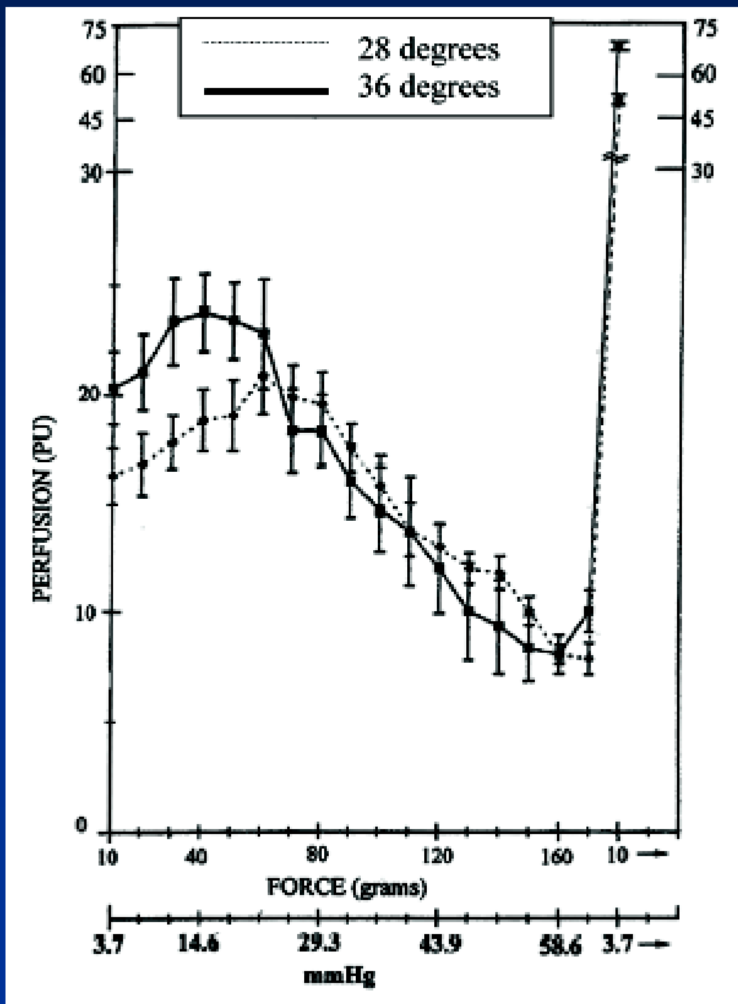
Post-coolin response differences

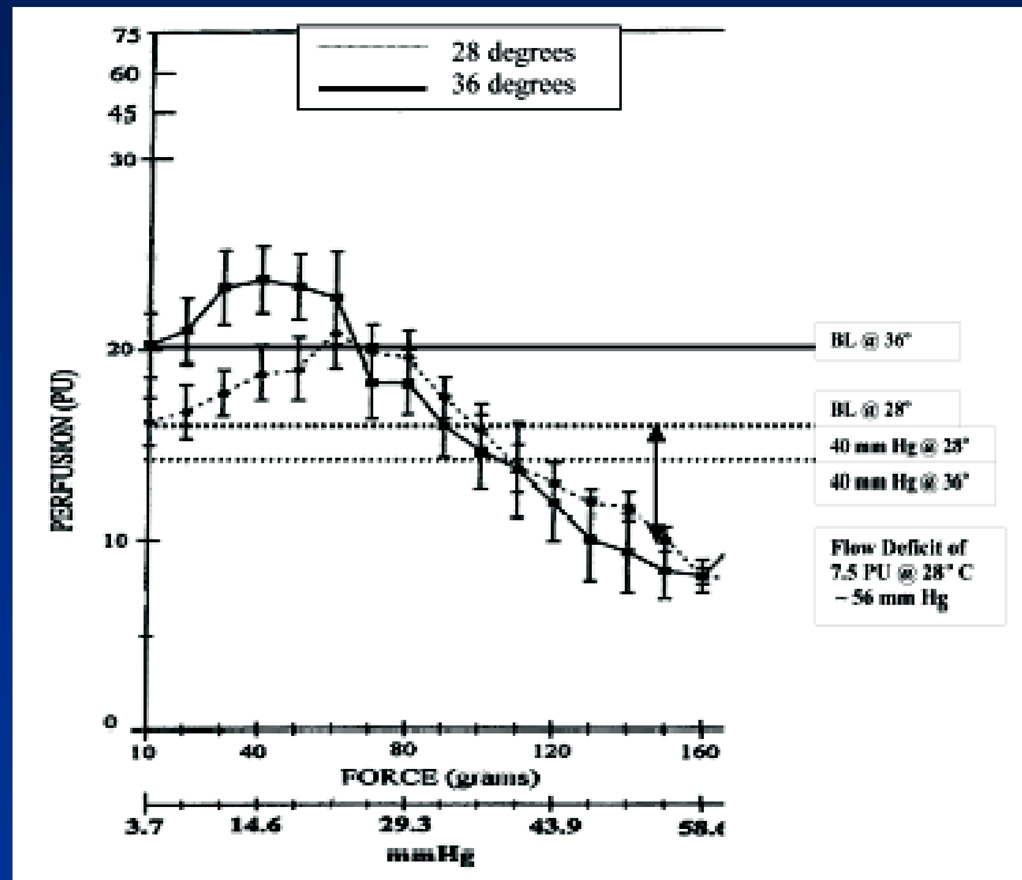
- Differences in flow reduction response with site (fig. a)
- Differences in hyperemic response with age (fig. c)



(Nagashima et al., 2003)

Skin Perfusion response to pressure, with and without Heat





(Patel et al., 1999)

Heat increases pressure ulcer susceptibility in swine

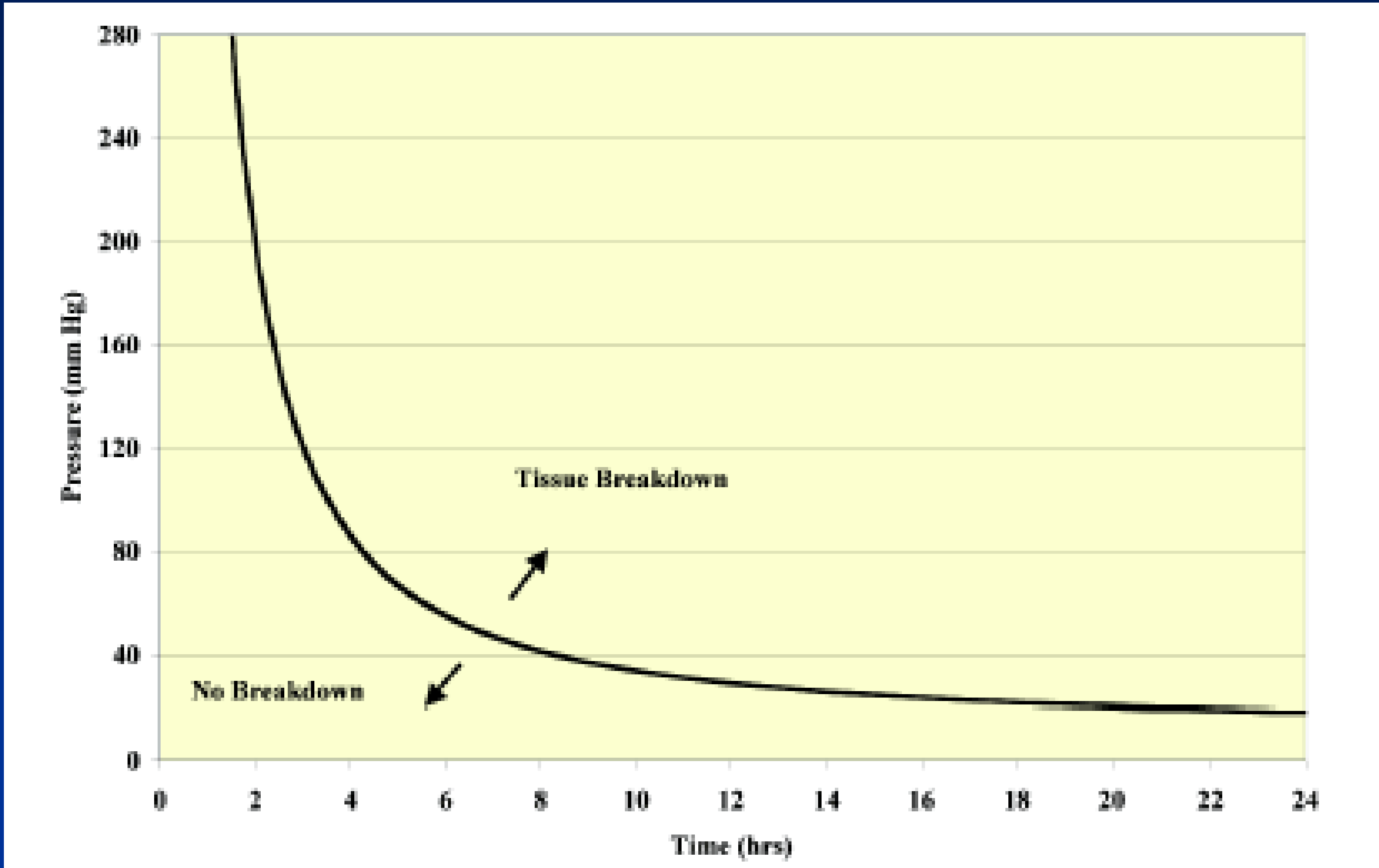
- Pressure (100 mmHg) was applied for 5-hour periods at 4 different temperatures (25°C, 35°C, 40°C, 45°C) on 16 swine
- Pressure damage after 7 days was found to be related to damage severity
  - 25°C - no damage
  - 35°C - deep tissue damage
  - 40°C - deep and superficial damage
  - 45°C - more severe deep and superficial damage

Kokate,et. Al. 1995; Iaizzo, et. Al. 1995

The combined effect of cooling and pressure

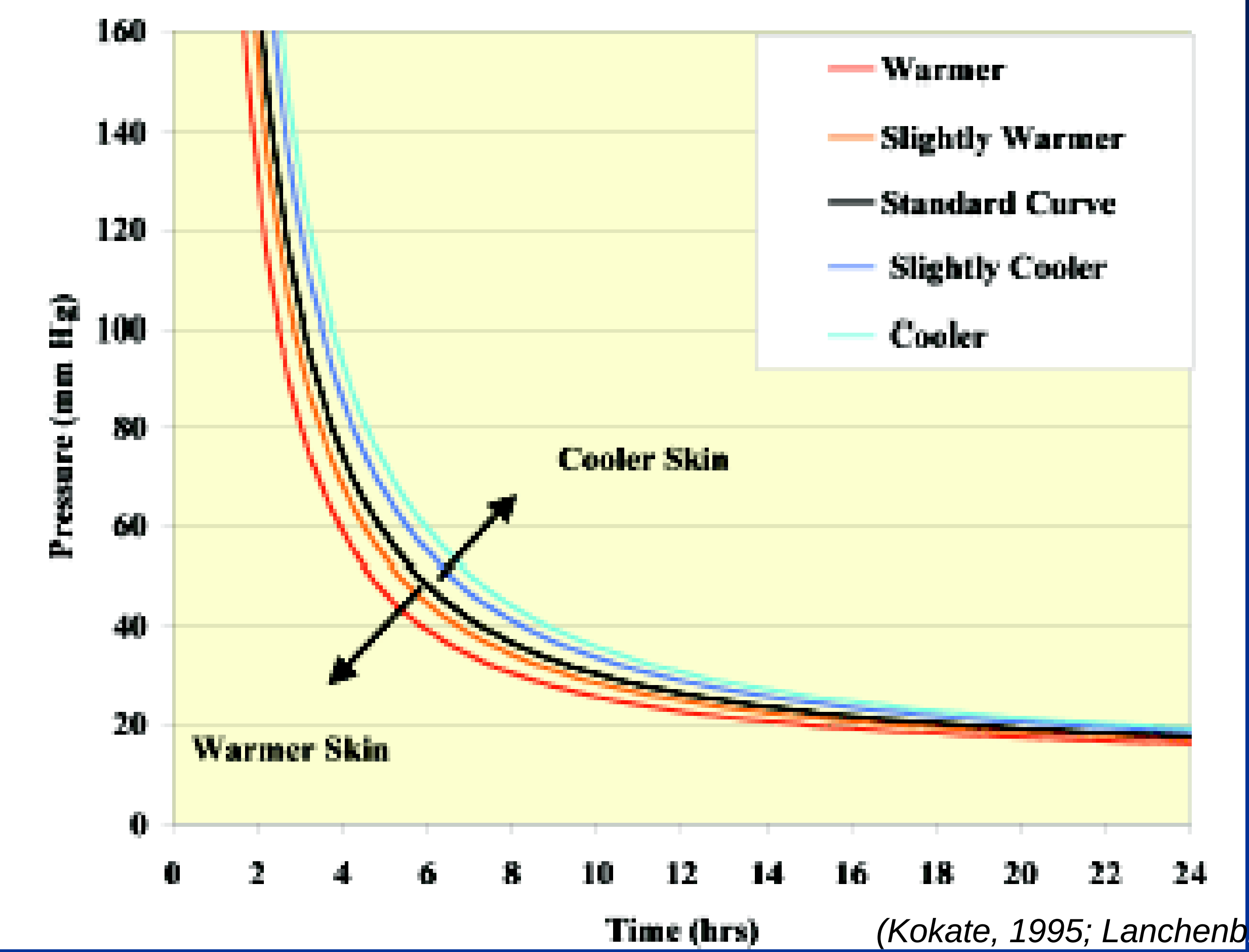
- Lachenbruch, 2005 - an analysis of the evidence to estimate the protective effect of cooling
- Used skin perfusion and oxygenation data from the literature to estimate the equivalence between pressure reduction and cooling relative to pressure ulcer risk
  - Blood flow data - 8°C reduction equivalent to 29% reduction in pressure
  - Tissue oxygenation data - 3°C reduction equivalent to 14% reduction in pressure

Pressure vs. Time Curve



(Reswick & Rogers, 1976; Lanchenbruch, 2005)

Pressure vs. Time Curve with Different Temperature



(Kokate, 1995; Lanchenbruch, 2005)

Support Surface Effect on Skin Temperature

Potential effects of support surfaces on temperature

- The body generates heat
- Skin exposed to room temperature air (~23°C) would normally be in the 32 to 33°C temperature range
- Applying a support surface can:
  - Increase temperature if it insulates and traps heat
  - Maintain temperature in normal range if is neutral
  - Decrease temperature if has an enhanced ability to conduct heat away from the body (compared to the ability air)

Variables

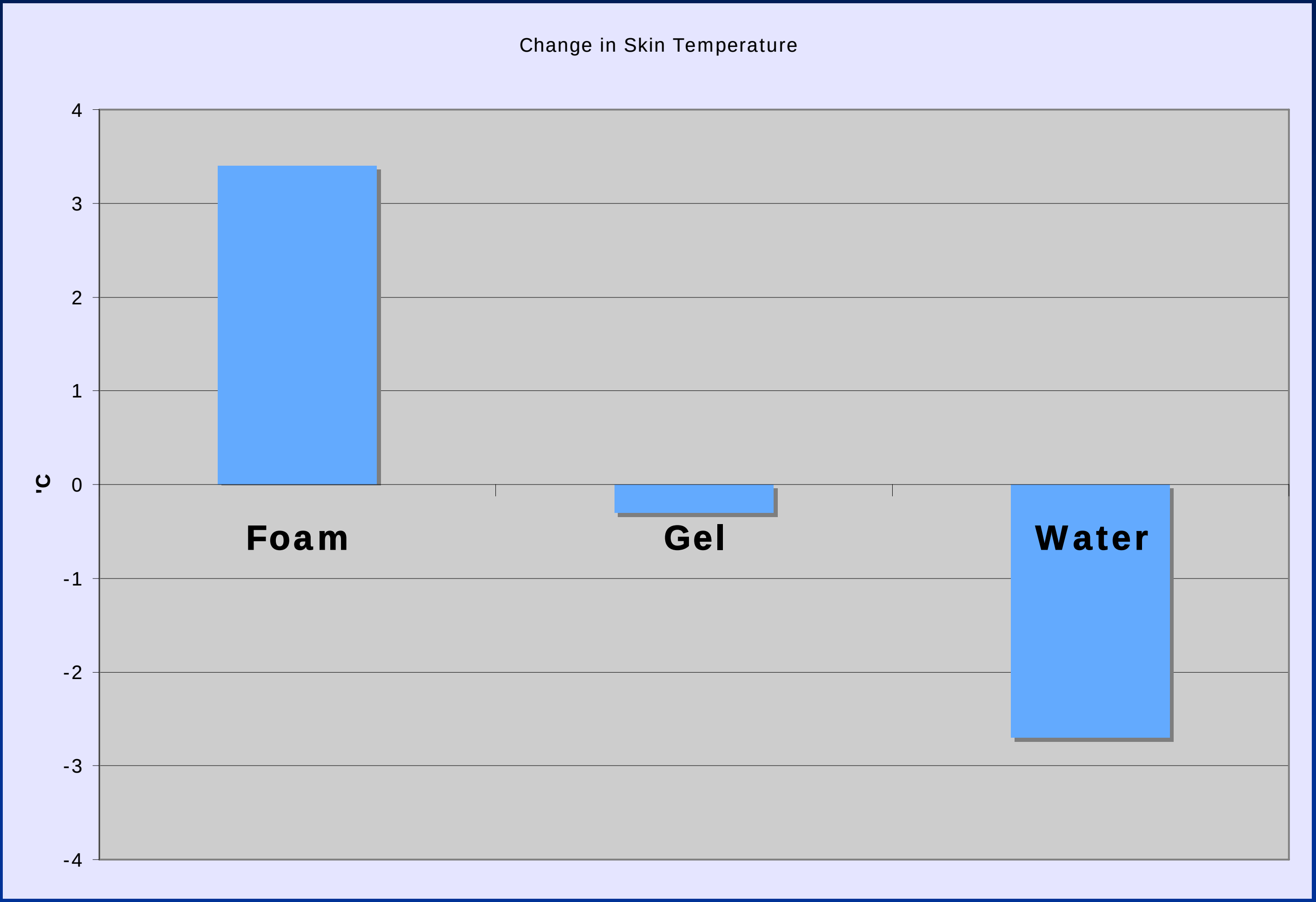
- Temperature
- Heat flux - flow of heat from one place to another

Foam, Gel, and Water Pad Comparison
(Stewart, Palmieri & Cochran, 1980)

- Stewart et al, tested 24 commercially available cushions on a 24-year-old male subject on a 1-hour period.
- Compared changes in thermal parameters for foam, gel, and water pad cushions after 1 hour f sitting.

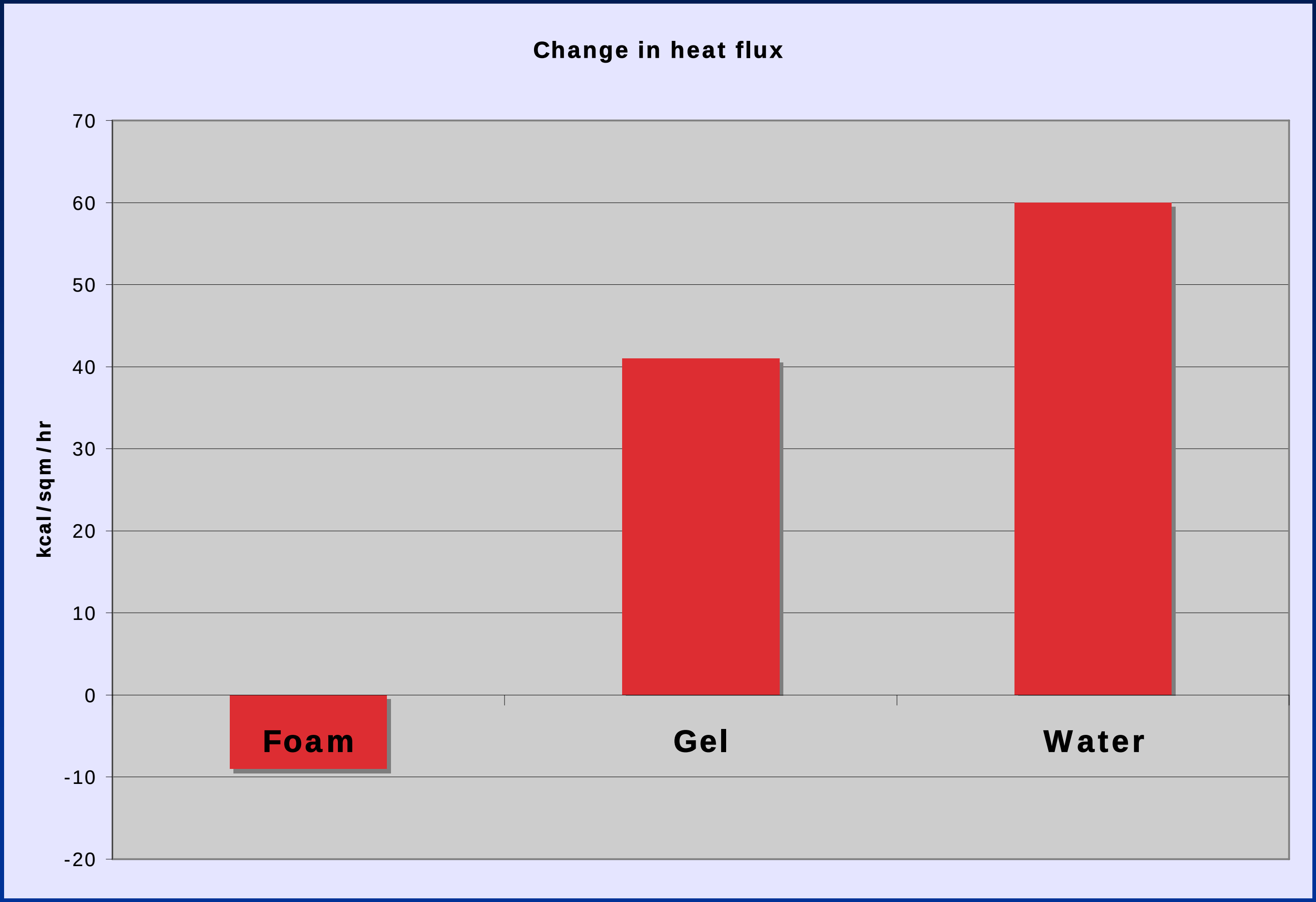
Change in Skin Temperature **Change in Heat Flux** **Increase in Relative Humidity**

Change in Skin Temperature
(Stewart, Palmieri & Cochran, 1980)

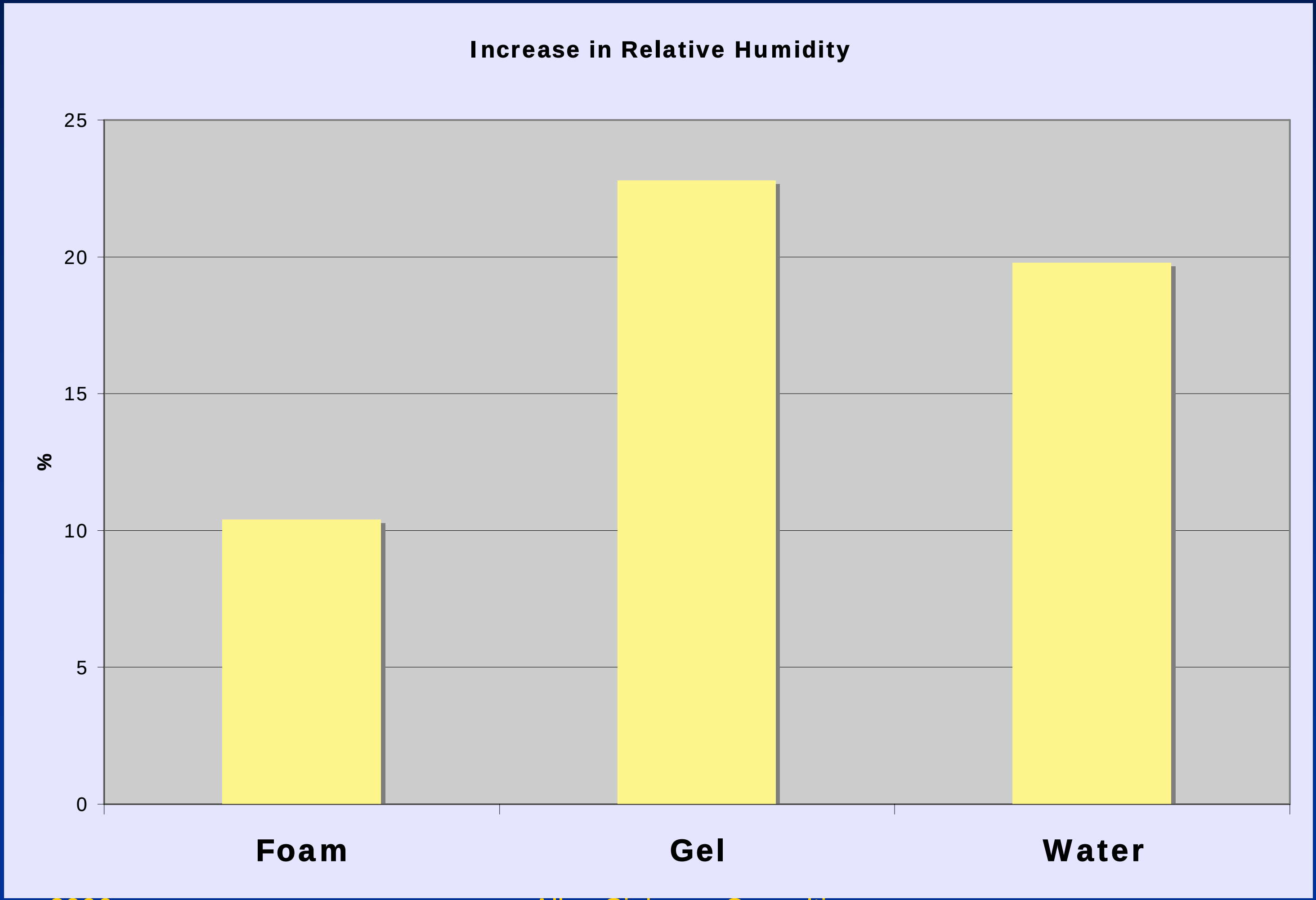


Change in Heat Flux

(Stewart, Palmieri & Cochran, 1980)

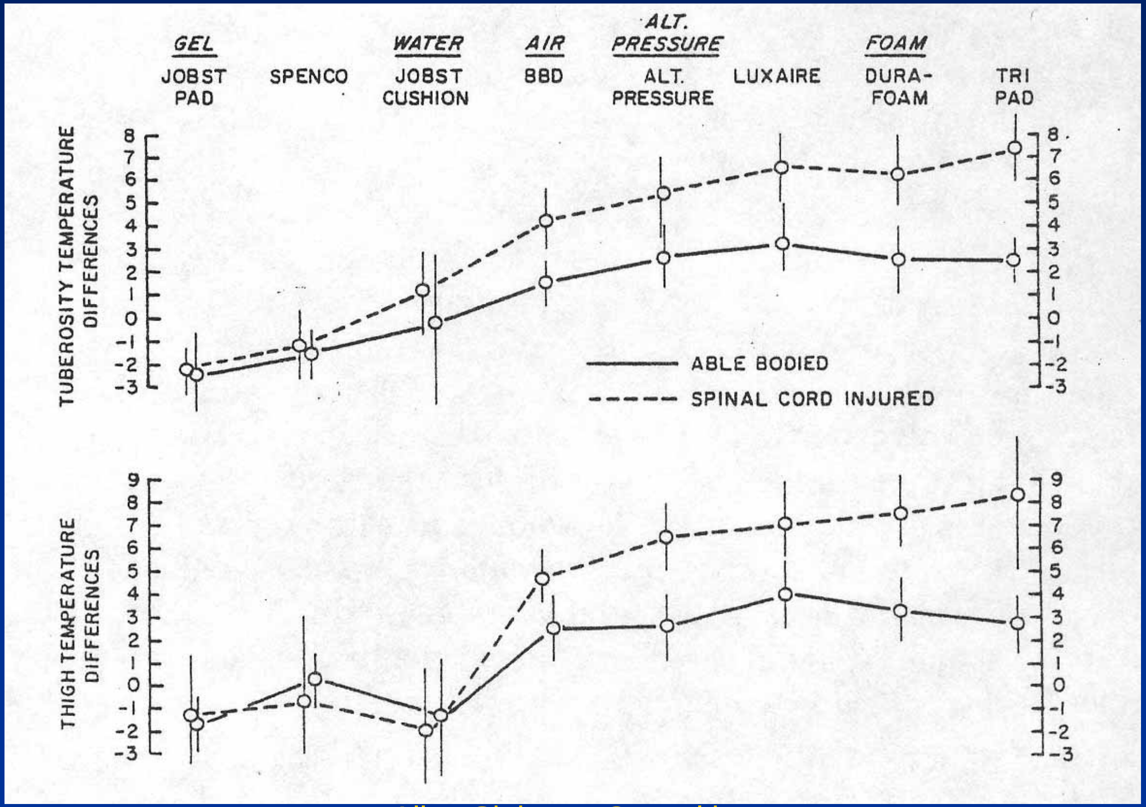


Change in Relative Humidity
(Stewart, Palmieri & Cochran, 1980)



Foam, Gel, Water, Alt-Pressure & Air Cushions - Comparing temperature changes SCI to non SCI subjects

(Seymour & Lacefield, 1985)

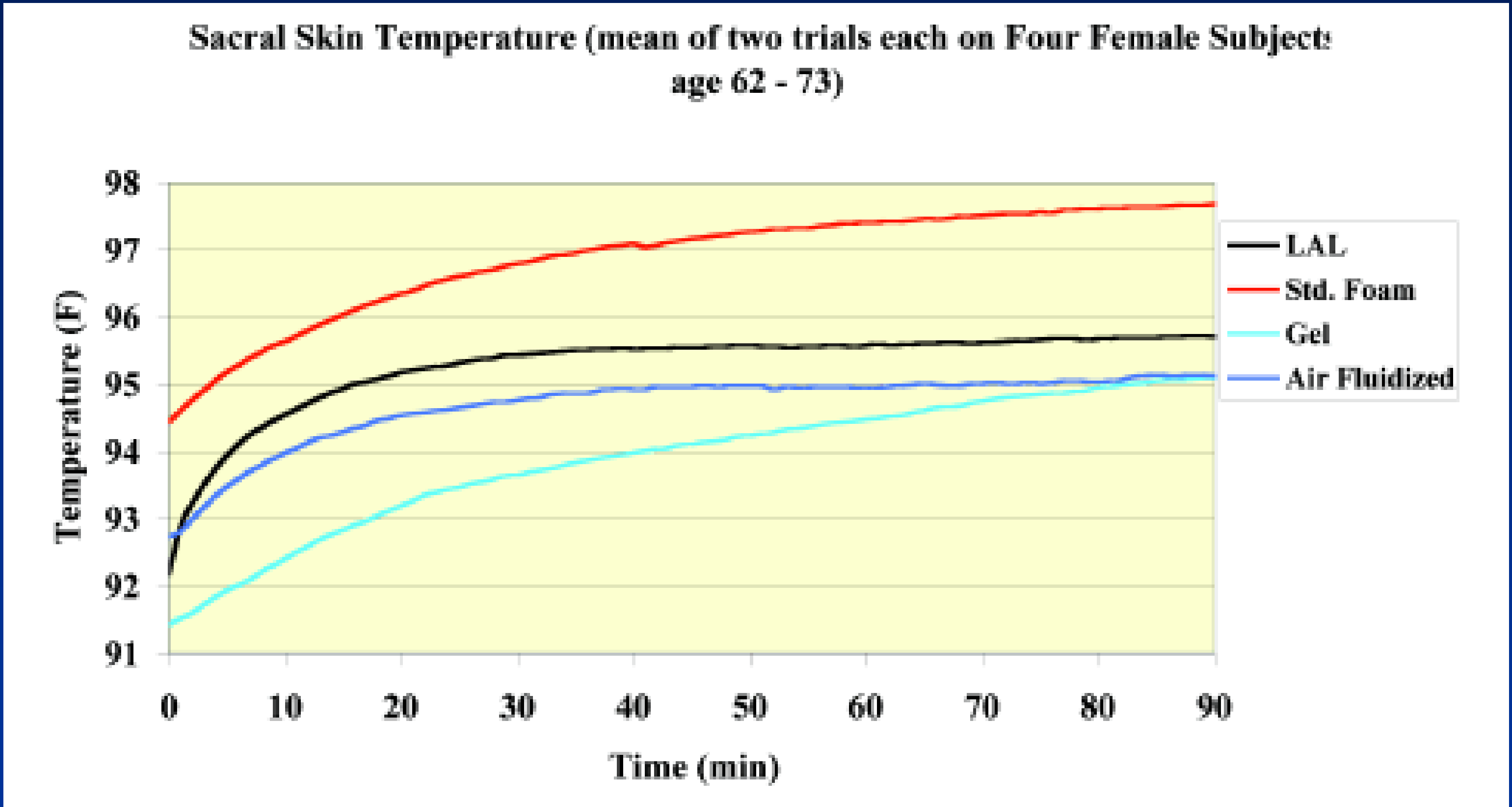


Thermal Properties Measured Different Cushions

(Ferrarin & Ludwig, 2000)

- Air-filled cushion warm up faster than Gel cushion
- Peak temperature: flat surface foam > air-filled > bubble-shaped surface

Sacral Skin Temperature on Four Mattress Types



(Barnett et al., 1999; Lanchenbruch, 2005)

A system for measuring the thermodynamic behaviour of wheelchair cushions is under development

Graham Nicholson[1], Martin Ferguson-Pell[1] Evan Call[2] and Hirose Hideyuki[3]

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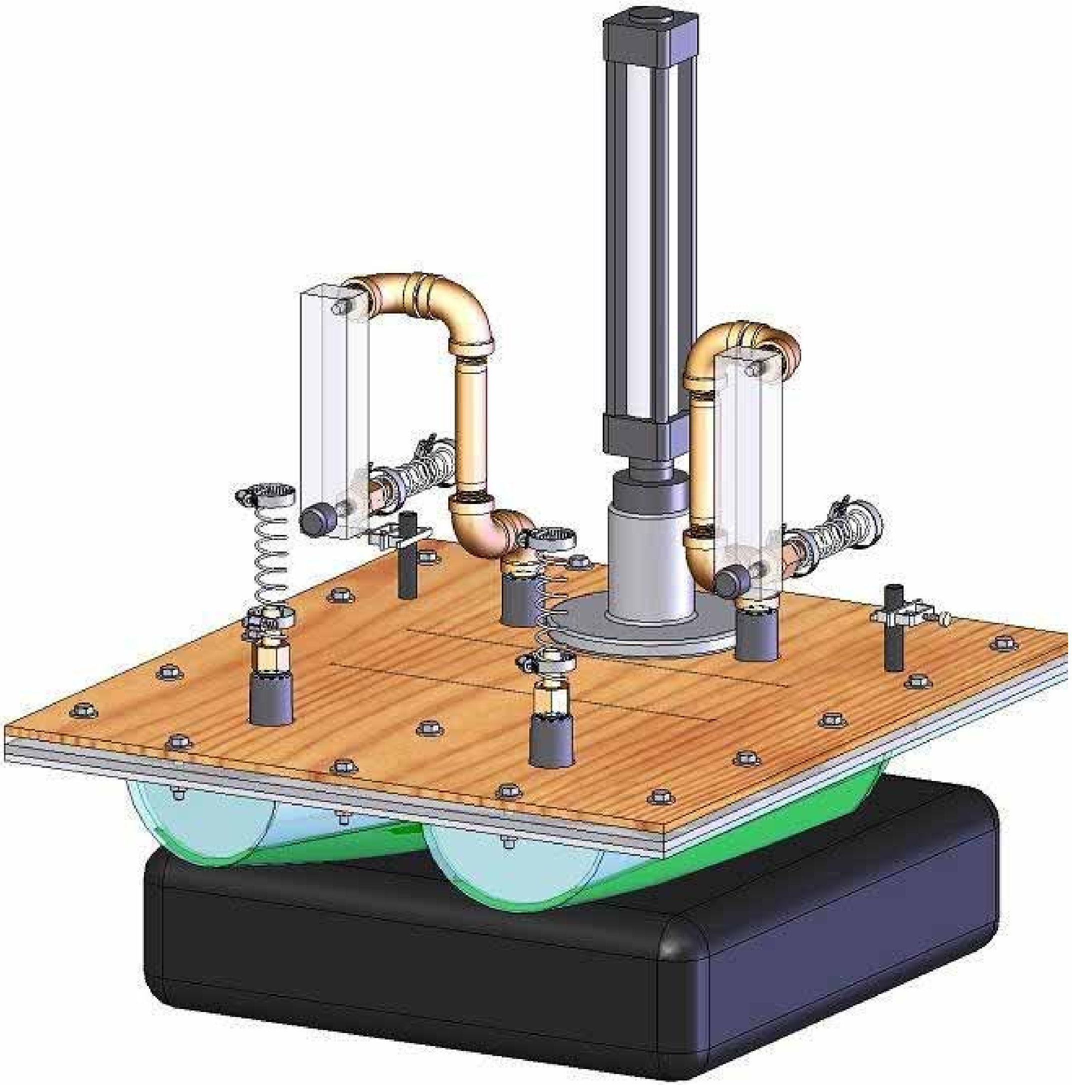
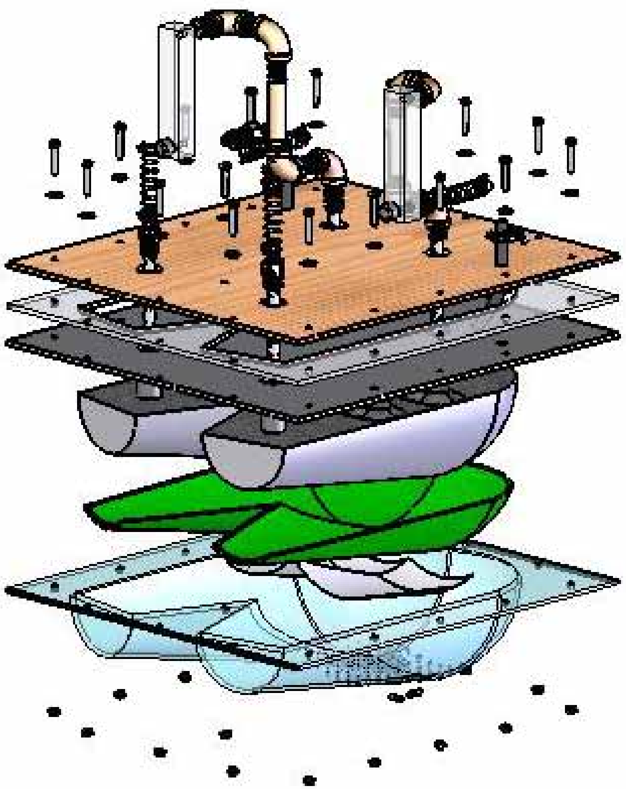
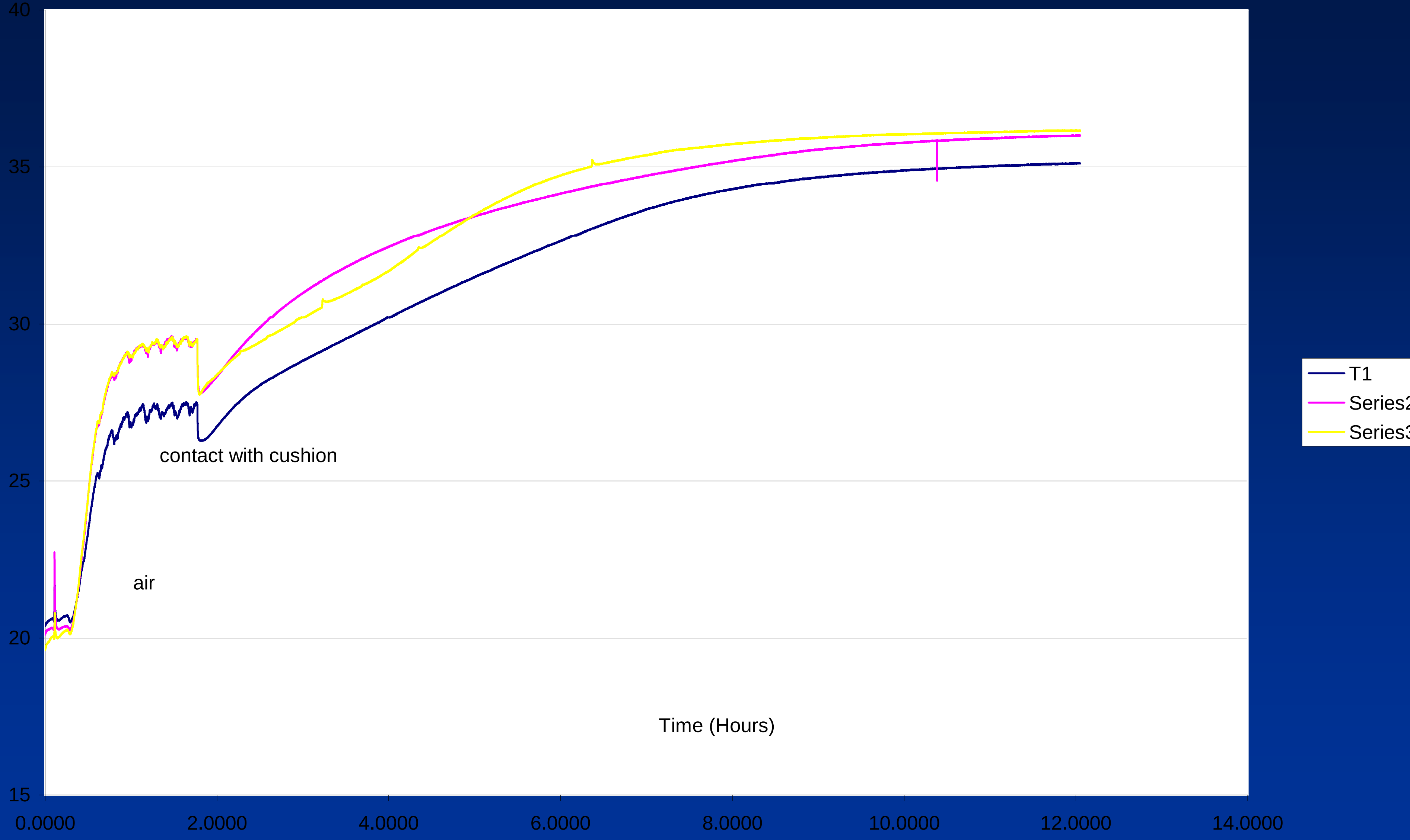
Design of Thermodynamic Cushion Loading Indenter

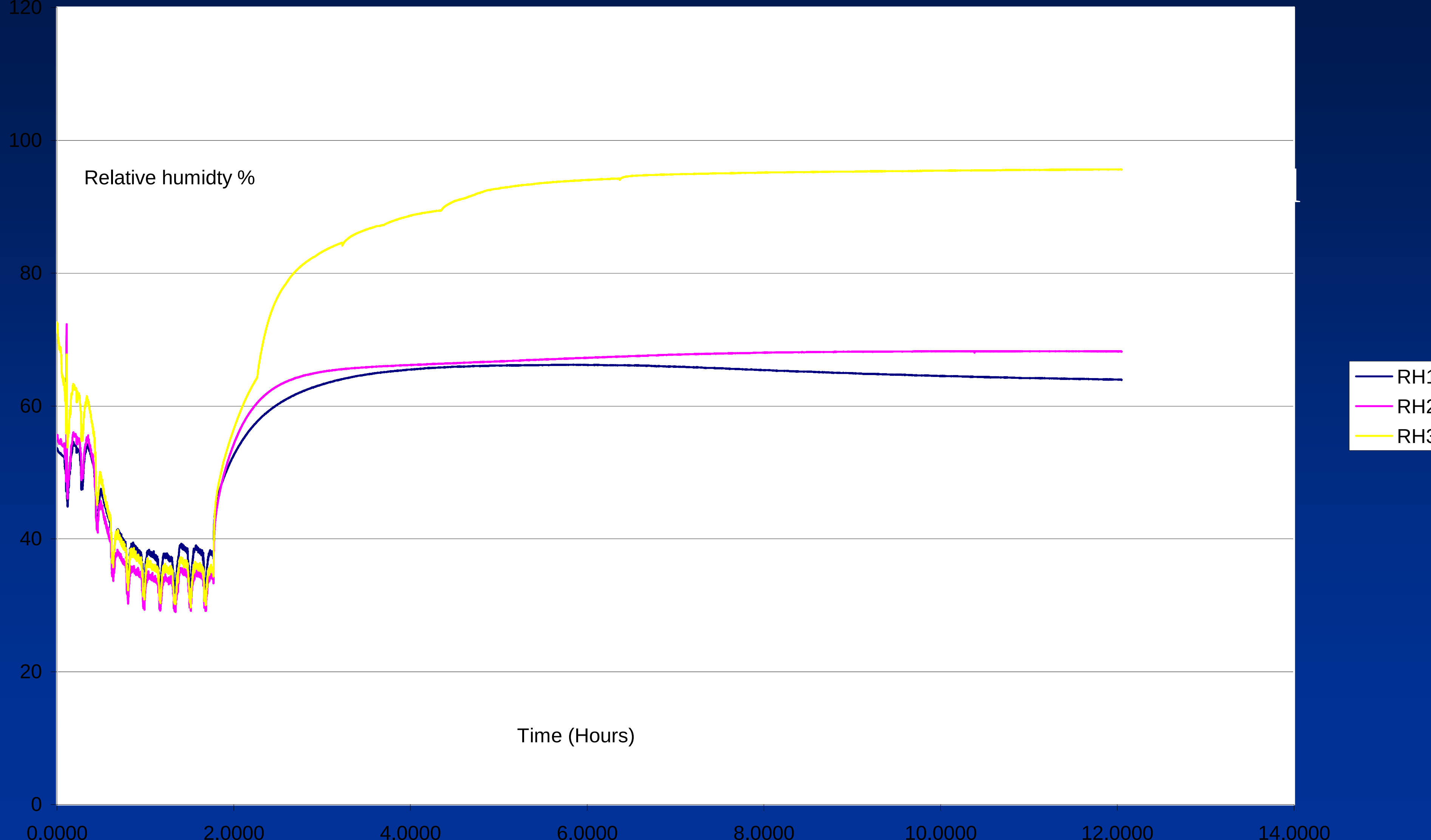




Sample Data (from 3 temperature sensors)



Sample Data (from 3 humidity sensors)

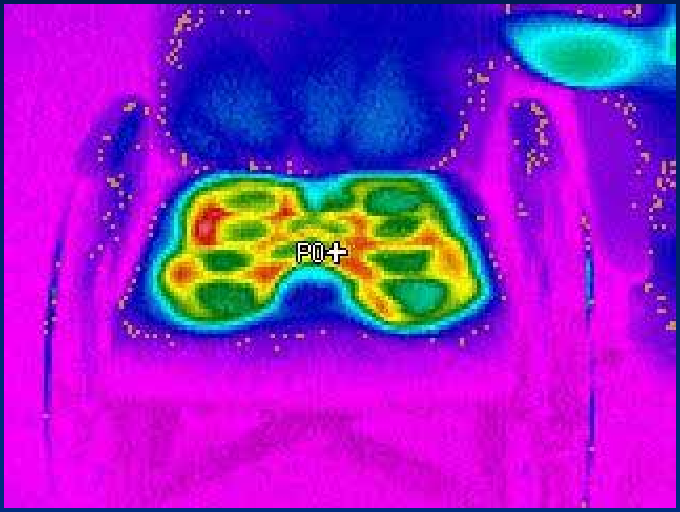


Heated Buttock

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

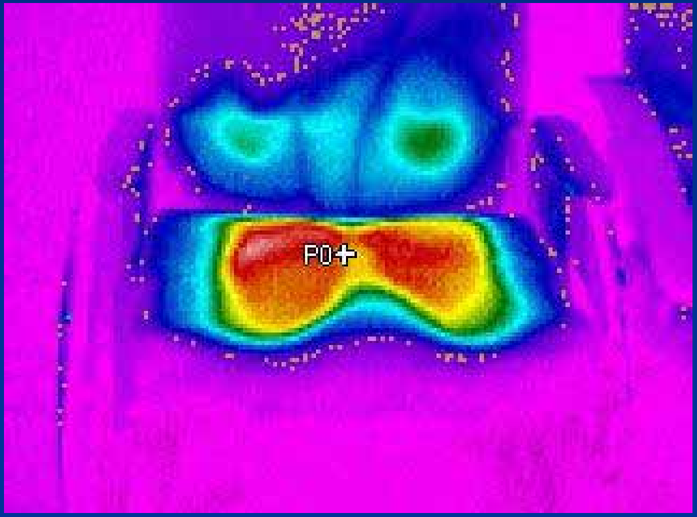
Results of Heated Indenter Tests

Cushion 1



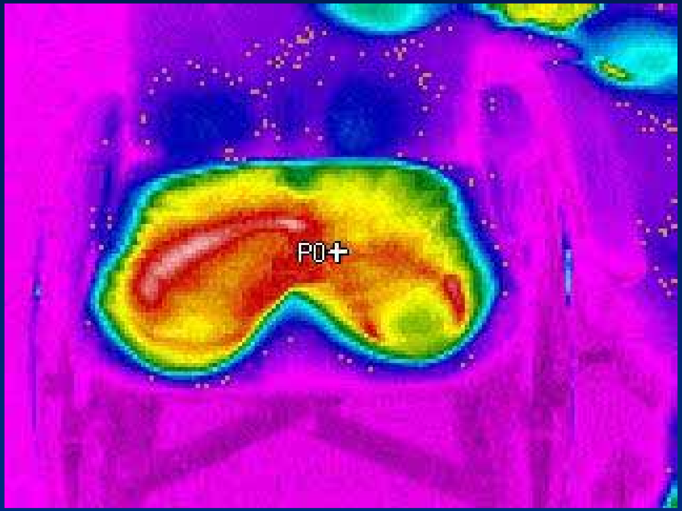
IR photos after 1 hour simulated use

Cushion 2



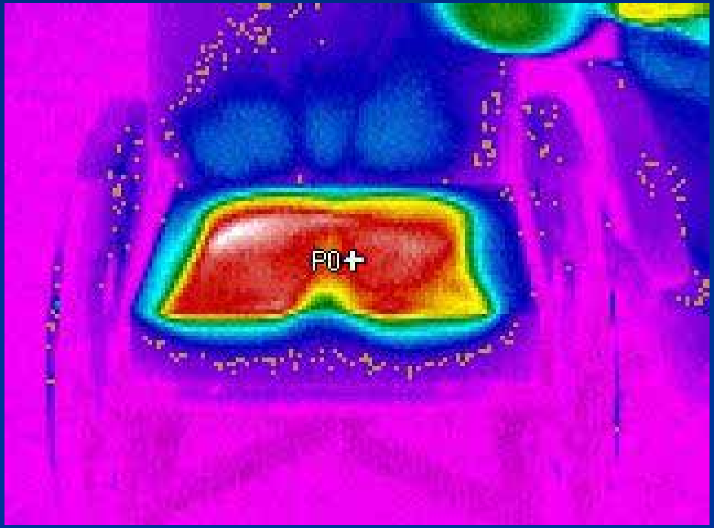
Results of Heated Indenter Tests

Cushion 3



IR photos after 1 hour simulated use

Cushion 4



Current Status

- We now have data for 40 different cushions
- We are determining the best method to disclose data that is repeatable and sensitive to differences between cushions
- We are completing inter-lab validation of current TCLI design – there are 5 TCLIs in use at present
- A proposed New Work Item to develop an ISO standard based for wheelchair cushions, based on this approach, has been submitted to ISO.

Testing Temperature and Humidity at the Cushion Interface (Human Subjects)

Central Coast Testing

Ben Lomond, California USA

Pilot Study

- This study explored test methods for measuring the wheelchair seat cushion’s effect on skin temperature and relative humidity over a period of 1 to 2 hours of sitting in a wheelchair.

Study Outline

- 6 Subjects
- Controlled temperature and humidity environment

  (Room at 22C +/- 2C Humidity 50% +/- 5%)

- 4 Cushion Environments
  - 3 Cushions
    - 3 Commercial Cushions
      - Viscous Fluid
      - Honeycomb Composite
      - Molded foam with 2 operating modes
        - » Fan OFF
        - » Fan ON

Study Objectives

The objectives for this study include:

– Determine the sitting time required for skin temperature and humidity readings to plateau.

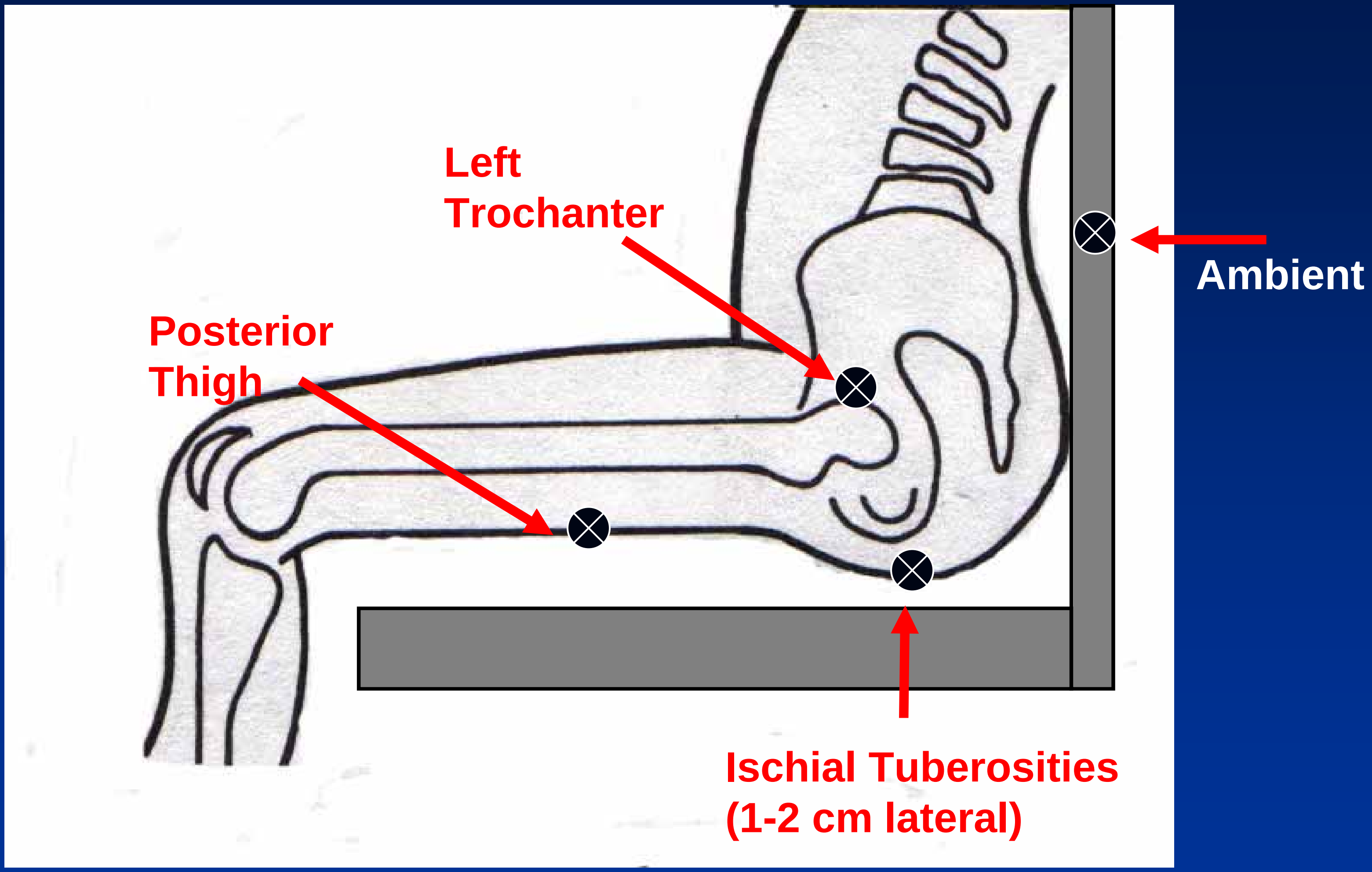
– Determine if there is a measurable difference in skin temperature and humidity readings between different cushions.

Sensor Locations

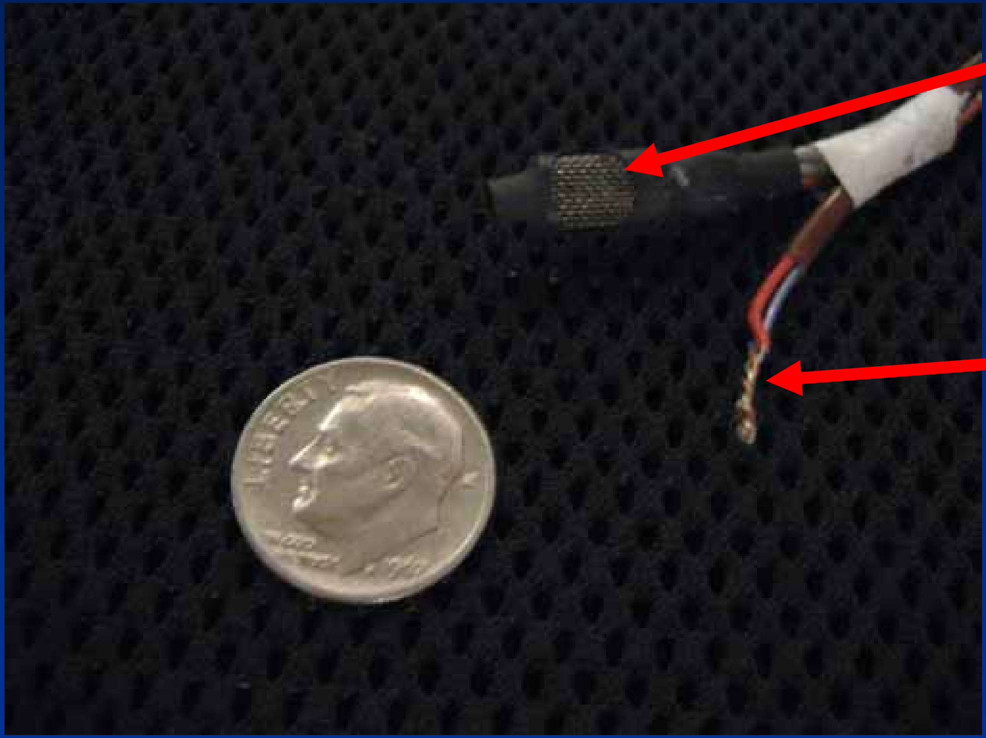
Sensor locations

- At areas of known high risk for ulcer development or in areas identified as having high skin temperatures
  - Medial to the Ischial Tuberosities
  - Posterior thigh
  - Left trochanter
  - Ambient room measurements

Sensor Placement



Sensors



Humidity Sensor

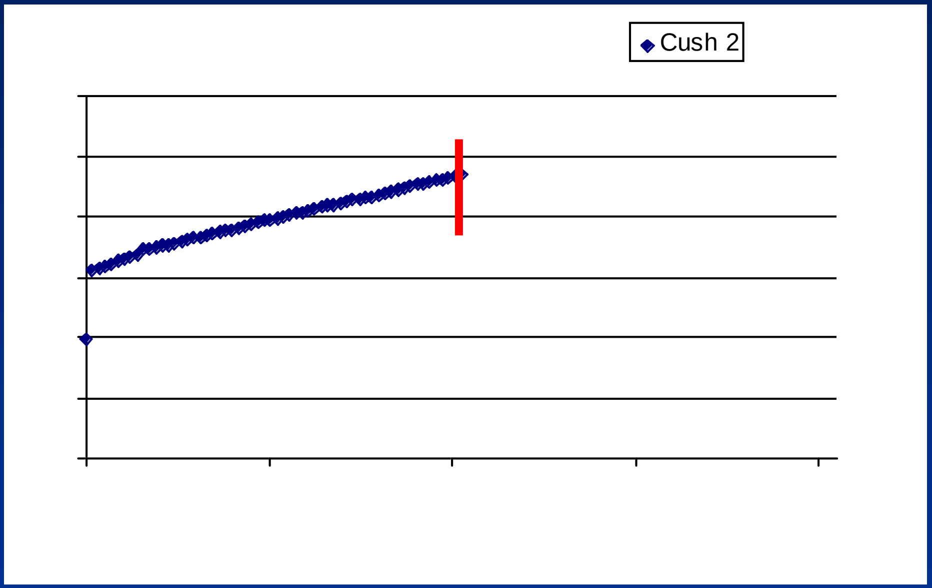
Temperature Sensor

Results 1-Hour

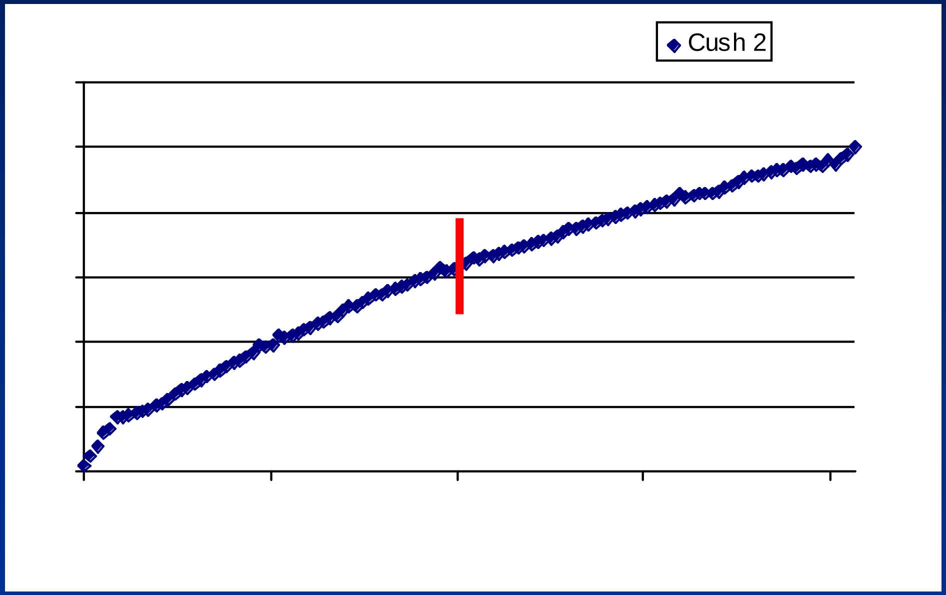
- The first two subjects were tested for 1 hour on each cushion variation

- Humidity and Temperature did not plateau at 60 minutes

Comparison 1-2 hours



One Hour, Cushion 2



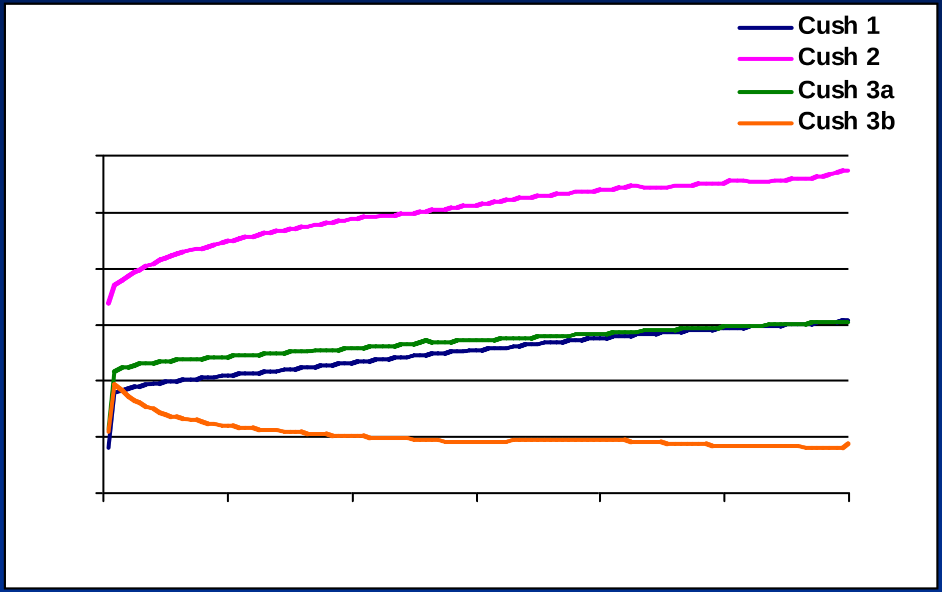
Two Hours, Cushion 2

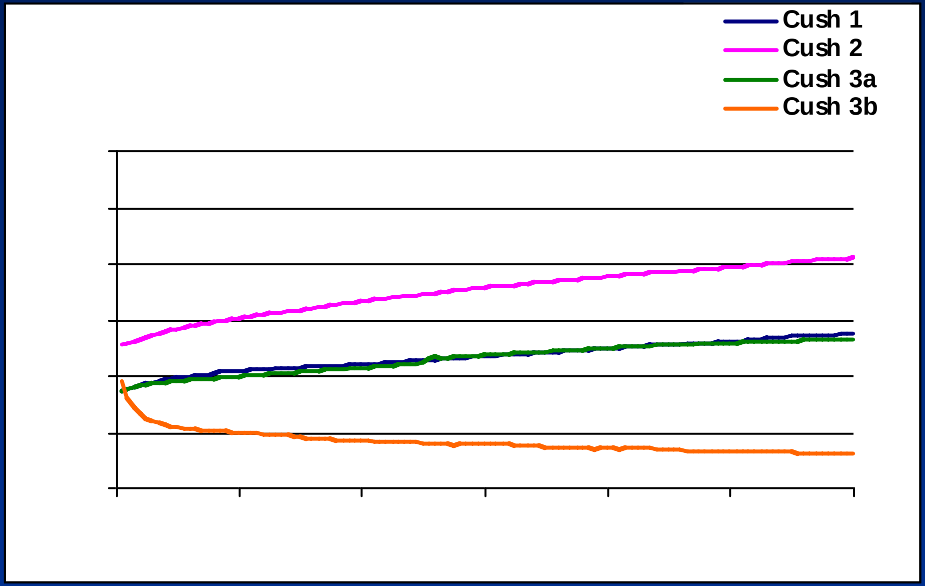
Results 2-Hours
(Humidity)

- Humidity levels continued to rise on most cushions during the 2-hour testing
- Humidity levels reached a plateau and/or decreased on one cushion (3b)
- Ambient and trochanter humidity levels remained stable over the four cushion trials

Results 2-Hours

(Humidity)





Results 2-Hours

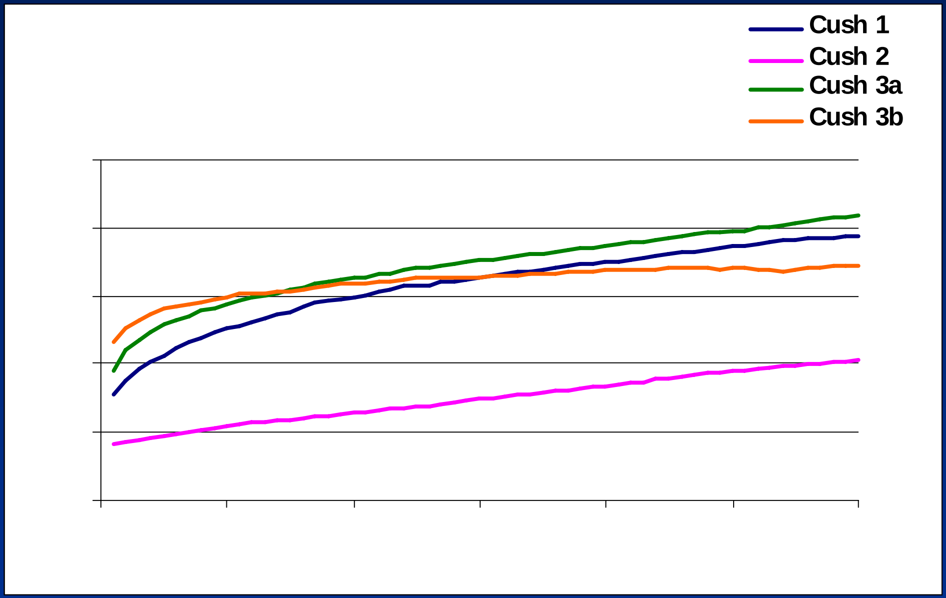
(Temperature)

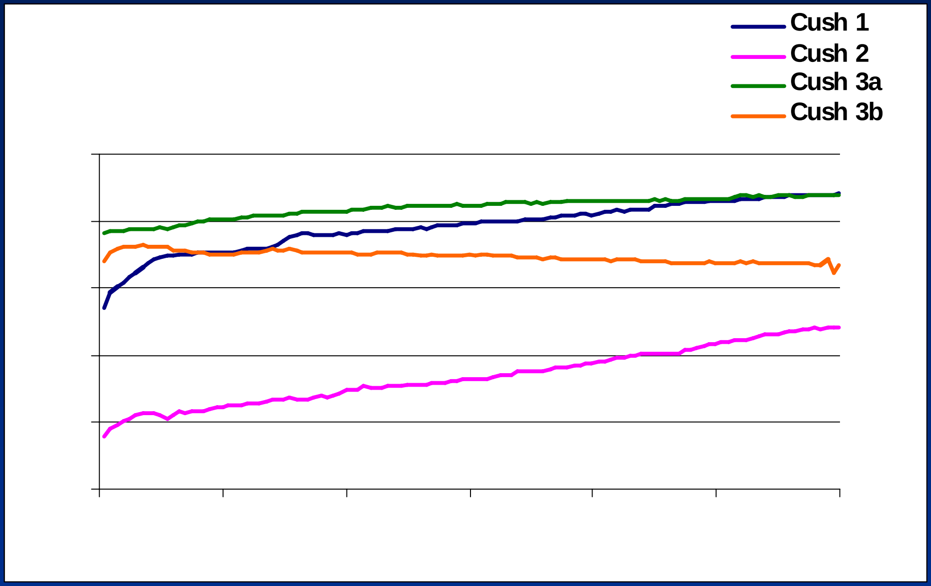
- Results did not show a consistent trend over all subjects and all sites.

- Although there was no consistent trend, temperature data for two participants indicated lower temperatures that parallel the lower humidity readings on cushion 3b.

Results 2-Hours

(Temperature)





Temperature reached plateau or decreased on cushion 3b on subjects 124-01 and 124-06

Discussion

- One-hour testing was not sufficient to allow temperature and humidity to stabilize.
- Two-hour testing did result in reaching plateau for some cushions at some sites

Discussion
(Humidity)

- It is possible to detect the influence that cushion design and materials may have on humidity

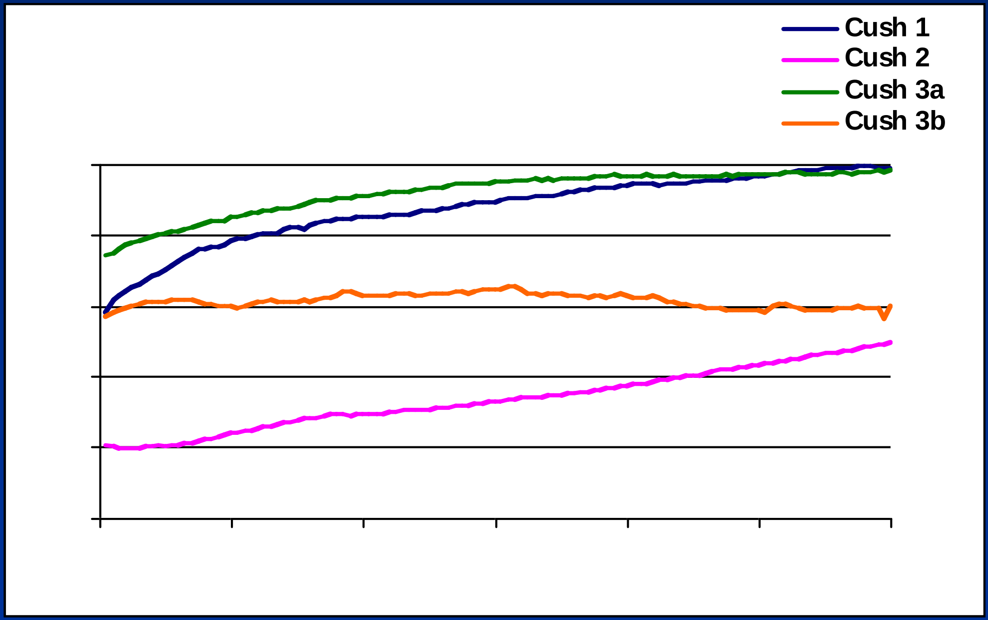
- Ambient and Base-line skin temperature remain stable with marked changes in skin RH at ischials and trochanters

Discussion
(Temperature)

- Temperature data was inconsistent across all subjects and sensor sites
- Longer trial times (2.5 hours) may be adequate for temperature testing.
- Trials at higher ambient temperatures combined with user activity may yield significant differences.

Discussion
(Temperature)

Data from individual subjects indicated that temperatures were stable or had significant separation on some cushions



Conclusions

- Testing for One-hour is not sufficient but Testing for two hours is adequate to bring some cushion to plateau temperatures.
- It is possible to detect humidity differences between cushions
- Preliminary data suggests that cushion types have an effect on humidity at the buttocks to cushion interface.

Conclusions

- More research is needed
  - Larger study population
  - Higher ambient temperatures and humidity
  - Longer duration tests including full-day testing
    (using portable data logging devices)
  - Test with active users

Acknowledgements

- Thanks to my colleagues who continue to share their knowledge, experience and skills.
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- Funding for the Human Subject Pilot Study was provide by AireRx Healthcare, www.airerx.com

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