Physiology and pharmacology of Temperature Regulation

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NON-INVASIVE MONITORING OF BODY INTERNAL TEMPERATURE USING A PASSIVE MICROWAVE RADIOMETER

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The rationale is the sensitivity of passive microwave radiometry to the natural electromagnetic radiation of living tissue. The intensity of radiation received is proportional to the radiometric temperature (T_{rad}), defined as a weighted mean of tissue volume temperature. A 1.15GHz antenna and an 8-12μ infrared (IR) detector (RESLtd, Russia) were placed in contact with areas of the right arm. Using a 4 s acquisition time, the estimated accuracy for internal T_{rad} in 25cm^3 of tissue was 0.15°C. In 10 experiments with hands (30-34 mm thick), infrared and radiometric temperatures of the palm were monitored for 6 min at room temperature. The measurements were repeated for 5 min, while a 17°C cold patch (ThermoTek, USA) was applied to the dorsum of the hand. The measurements were repeated again with the patch at 40°C, and one final time with a 17°C cold patch. Only the microwave sensor placed at the palm followed the same curve as the temperature of the dorsally-placed temperature patch.

In five experiments with the upper arm (95-120 mm thick), both IR and T_{rad} were monitored for 3 min to establish a baseline, and then during recovery following 2 min of moderate exercise (pushups). After an hour break, the exercises were repeated, followed immediately by 15min of cooling of the ipsilateral palm in the presence of a mild vacuum at 17°C (AVAcore Technologies, USA) and temperature measurements, as before. After the completion of exercise-evoked heating, the rate of T_{rad} decrease at the triceps was 0.012°C/min. With the addition of palm cooling, the rate of temperature decrease during recovery was 0.06°C/min.

GOAL: to evaluate the specificity of microwave radiometry to deep temperature changes in assessment of human body temperature heterogeneity.

THEORY

I. PASSIVE MICROWAVE RADIOMETRY

$$P_{\mathrm{microwave}} = kT_{rad}\Delta f$$

where: $k = 1.38 * 10^{-23} \frac{J}{K}$ Δf – –frequencyrange

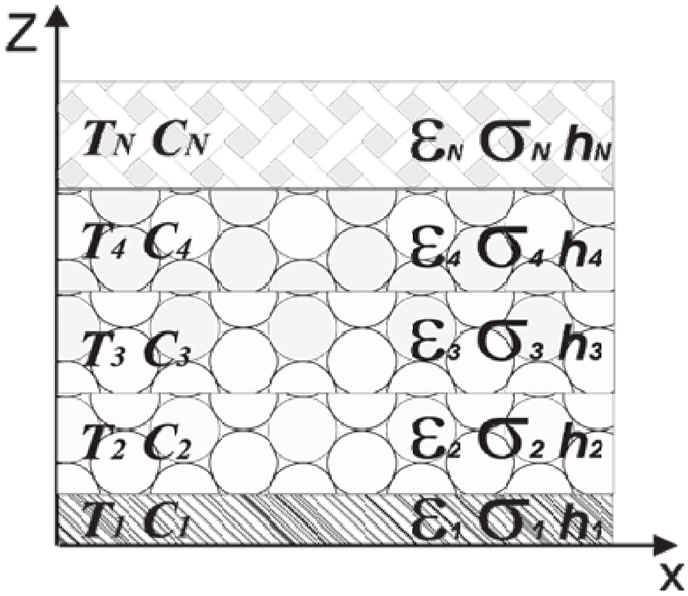
$$T_{rad} = \iiint T(x,y,z) * W(x,y,z)\,dV$$

where: *T(x,y,z)* - - thermodynamic (real) temperature
x, y, z - - current coordinates
W(x,y,z) - - antenna receiving pattern

$$W(x,y,z) = \frac{\sigma\left|\overline{E}(x,y,z)\right|^2}{\iiint \sigma \left|\overline{E}(x,y,z)\right|^2 dV}$$

where: σ -- tissue conductivity
$\overline{E}(x,y,z)$--vector of the electric field in tissue
(according to antenna reciprocity theorem)

II. RADIOMETRIC TEMPERATURE FOR LAYER STRUCTURE



$$T_{rad} = \sum_{i=1}^{N} T_i * C_i$$

$$C_i = \frac{\sigma_i \iiint\limits_{V_i} \left|\overline{E}(x,y,z)\right|^2 dV}{U}$$

$$U = \sum_{i=1}^{N} \sigma_i \iiint\limits_{V_i} \left|\overline{E}(x,y,z)\right|^2 dV$$

$$D(z) = \sum_{i=1}^{N_z} C_i$$

$$z = \sum_{i=1}^{N_z} h_i$$

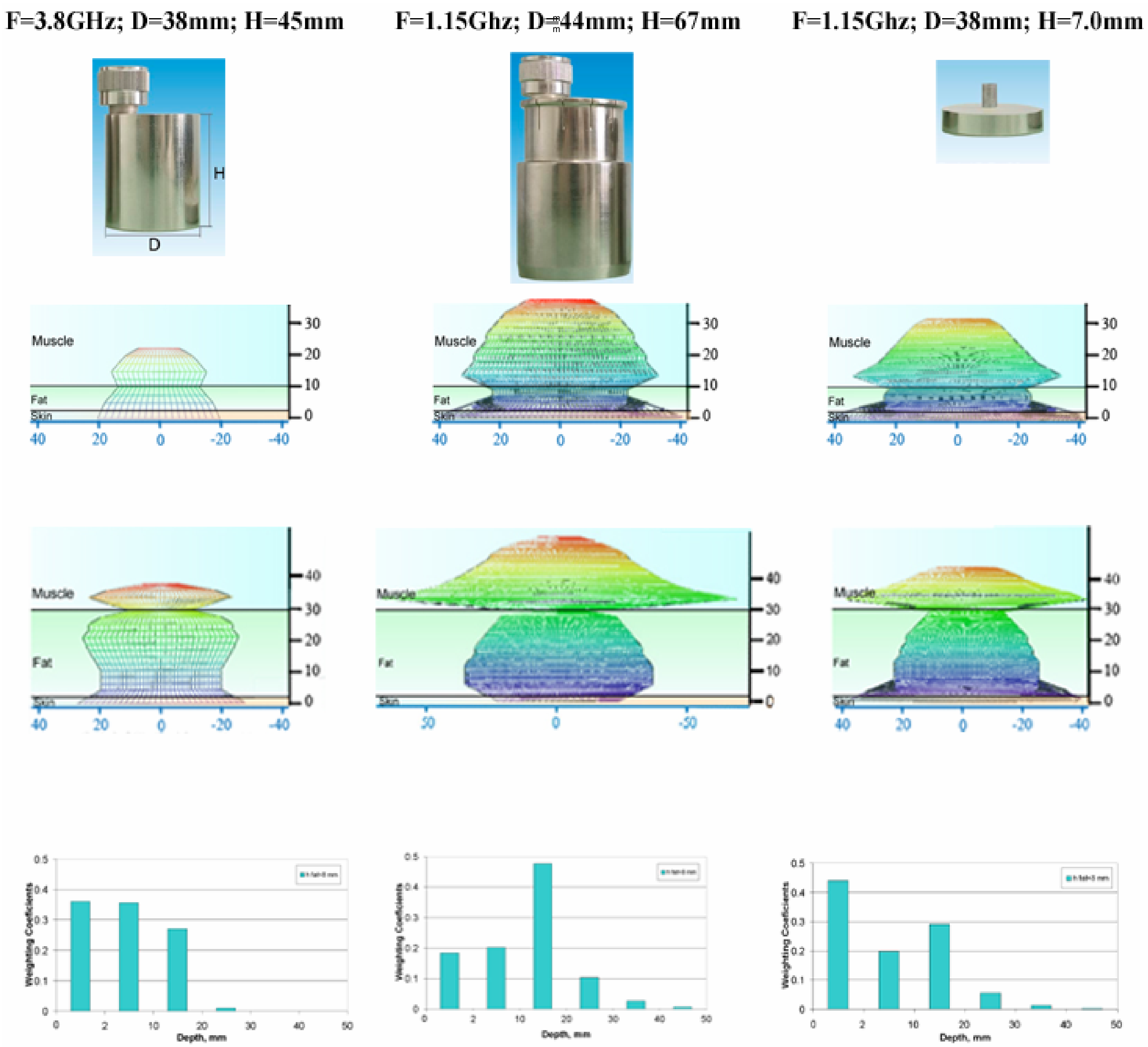
where: *Ci* -- weighting coefficients for layer structure

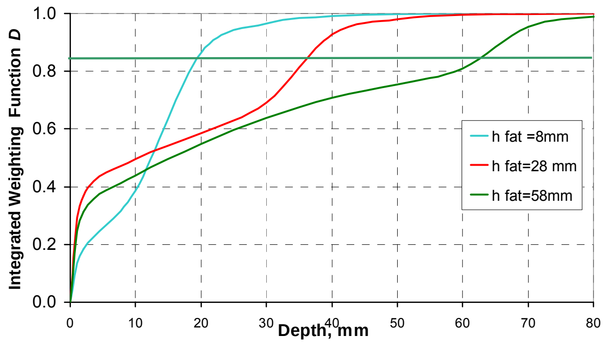
D(z) -- integration weighting function for layer structure

METHOD

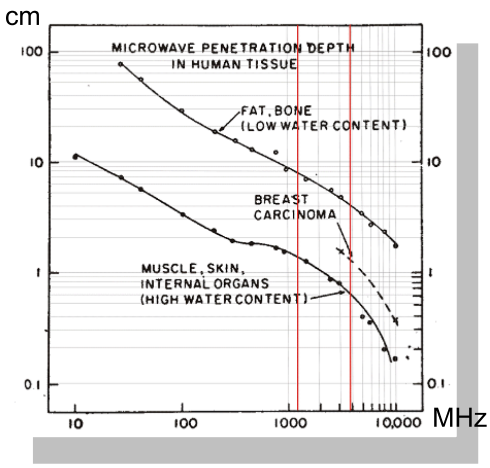
Microwave detector

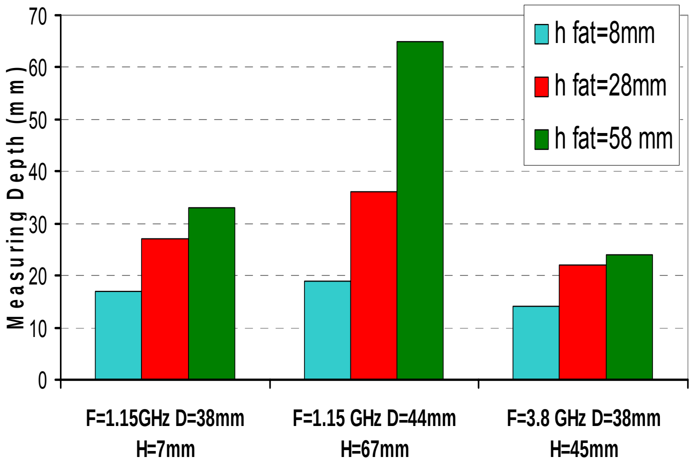
IR detector





	F=1.15 GHz			F=3.8 GHz		
	Skin	Fat	Muscle	Skin	Fat	Muscle
Dielectric constant ε	55.4	5.5	46	55.4	5.16	46
Conductivity σ (s/m)	1.08	0.055	2.55	2.76	0.31	5.48



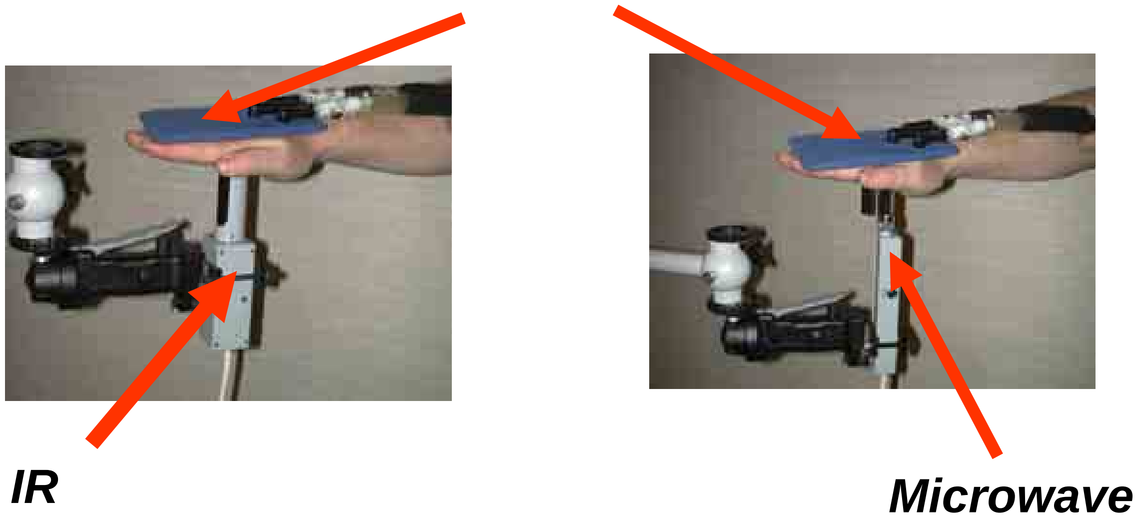


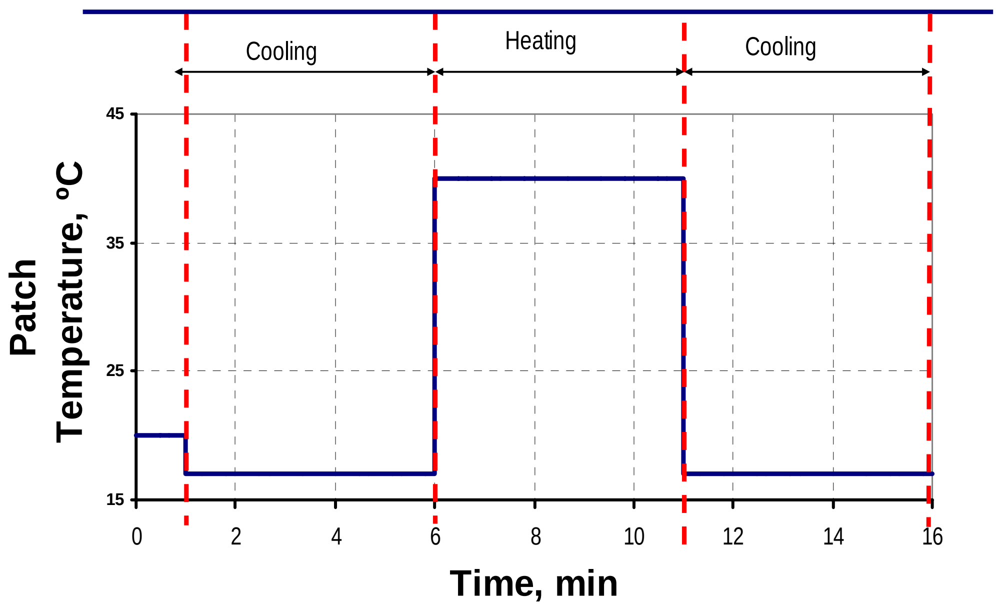
A. Barrett & P. Myers, Science, 1975

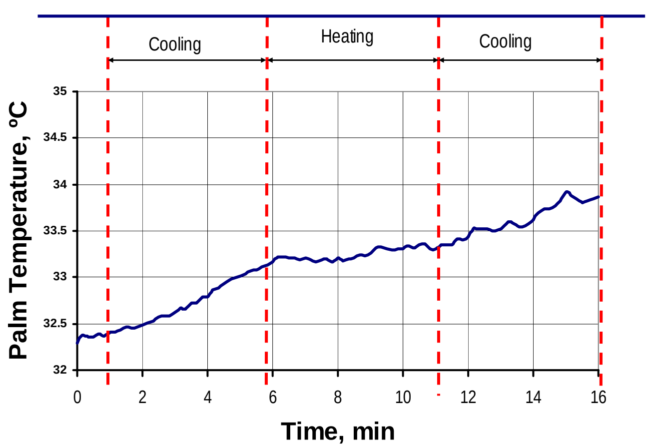
Cold/heat thermo patch (*ThermoTek, Inc.*) 7 x 4 in.

Palm cooler is designed (*AVAcore Technologies Inc.)* to enhance heat extraction through the palms by amplifying local blood flow using slight vacuum under controlled temperature settings

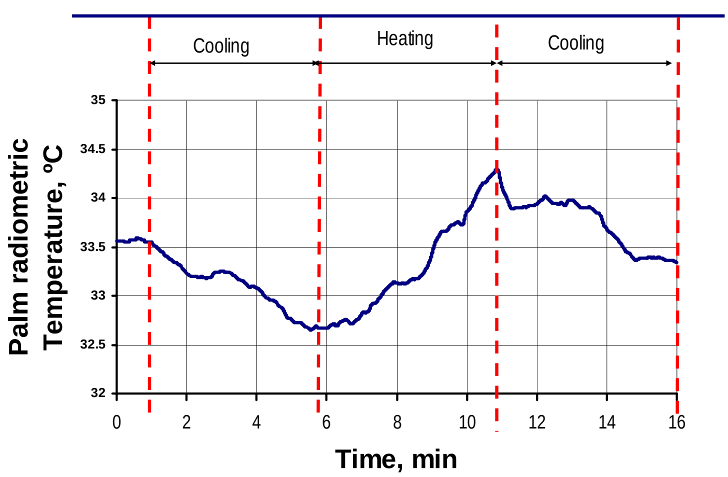
STUDY DESIGN I



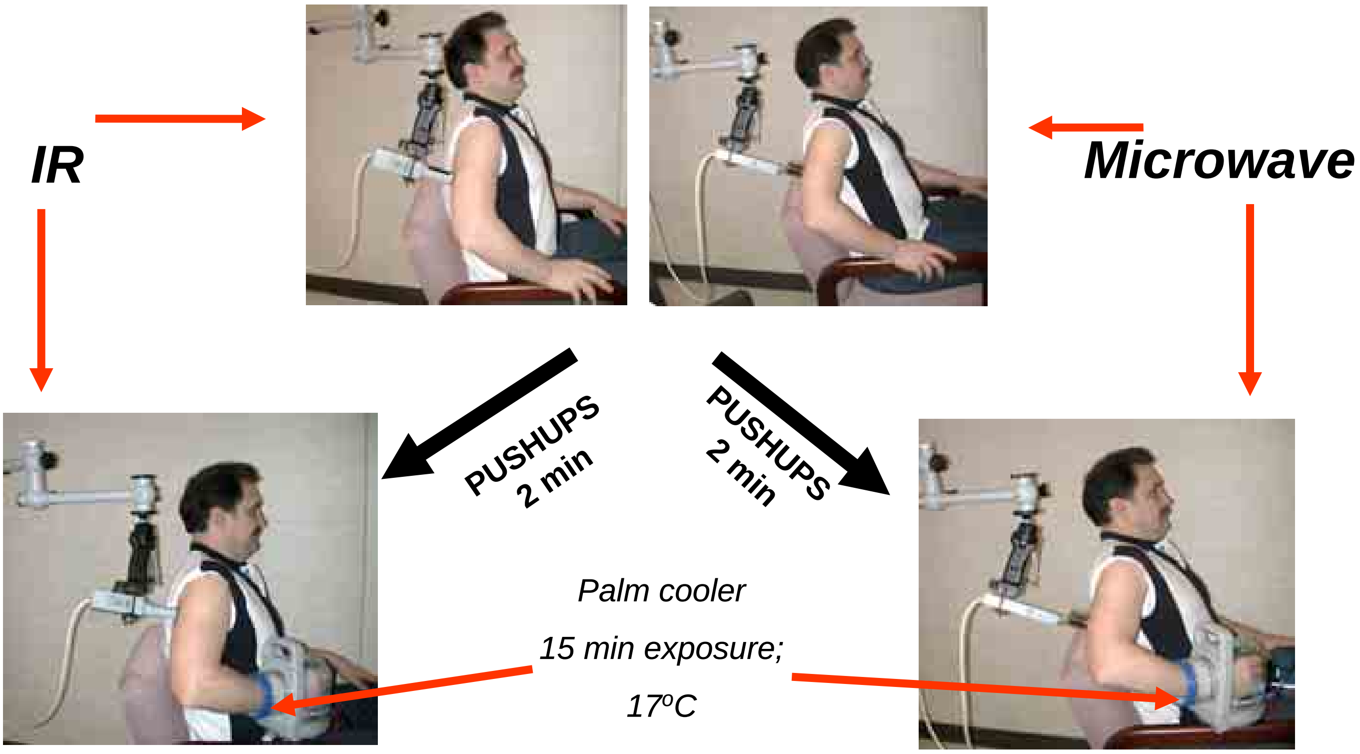


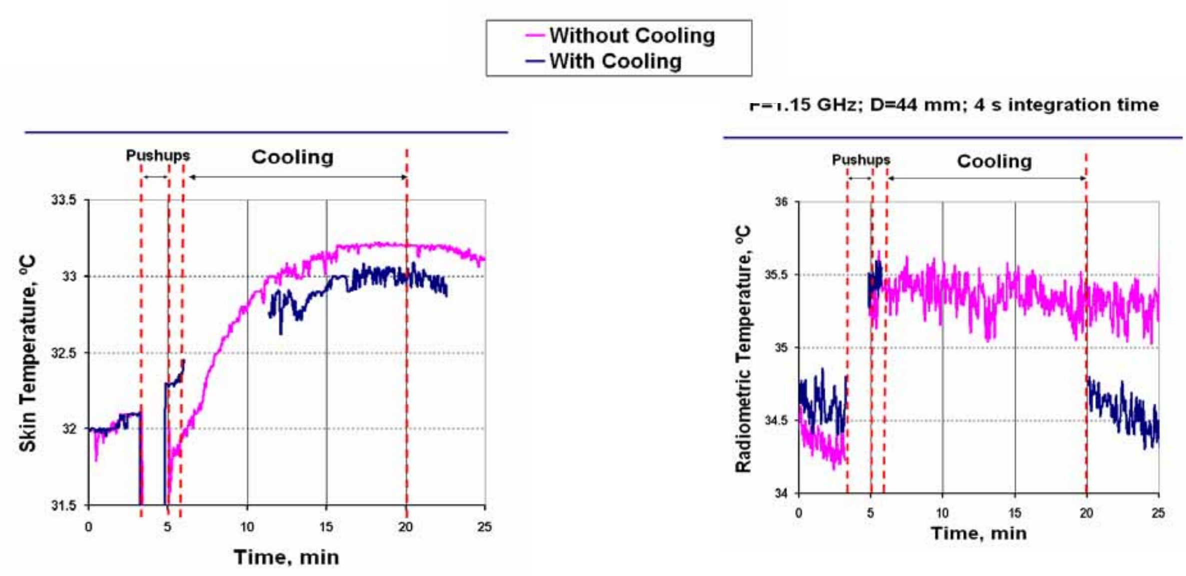


F=1.15 GHz; D=44 mm; 1.0 min integration time



STUDY DESIGN II





CONCLUSION

Only the microwave antenna was sensitive to body temperature changes due to application of a distant heating/cooling patch or exercise.