European Journal of Molecular & Clinical Medicine, 7(1): 21–26

Research Article

Influence of Ambient Temperature on Recording of Skin and Deep Tissue Temperature in Region of Lumbar Spine

A.V. Tarakanov[1], A.A. Tarakanov[1], S Vesnin[2], V.V. Efremov[1], N Roberts and I Goryanin[3]*

A.V. Tarakanov[1], A.A. Tarakanov[1], S Vesnin[2], V.V. Efremov[1], N Roberts and I Goryanin[3]*

[1]Rostov State Medical University, Rostov-on-Don, Russian Federation
[2]MMWR LTD, UK
[3]School of Clinical Sciences, University of Edinburgh, Edinburgh, UK

Correspondence

I Goryanin

School of Clinical Sciences, University of Edinburgh, Edinburgh, UK

E-mail: goryanin@gmail.com

History

- Received: May 05, 2020
- Accepted: June 04, 2020
- Published: June 10, 2020

DOI : http://doi.org/10.5334/ejmcm.274

ABSTRACT

Medical Microwave Radiometry (MWR) allows non-invasive measurement of human internal body temperature which is potentially useful for diagnosing a range of pathologies. The technique is used to to meaure so-called brightness temperature and it is recommended that investigations are performed in a room with temperature controlled in the range 20 to 24°C. This is not always possible in impromptu investigations or if studies are to be conducted in certain remote facilities or outdoors. We have therefore investigated the influnce of room temperature on brightness temperature (BT) and skin temperature (ST) measurements were obtained using the respective microwave and infra red sensors of the MMWR2020 (former RTM-01-RES) system (www.mmwr.co.uk).

MWR measurements of BT and ST were obtained for 93 healthy subjects in the sitting position. Recordings were taken above each of the L1 to L5 vertebral bodies and along corresponding left and right paravertebral lines. The data were subdivided according to whether room temperature was recorded as being from 17.1 to 21.9°C (n=24) (i.e. low temperature), 22.0 to 26.9°C (n =56) (i.e. moderate temperature) or 27.0 to 29.5°C (n=13) (i.e. high temperature). The average value of BT was identical at low and moderate temperatures. No correlation is observed between BT and room temerature. On the other hand average value of ST is linearly proportional to rise in room temperature (R2 = 0.36).

In conclusion, the present study has shown that reliable values of BT, but not ST, can be obtained even when room temperature can vary between 17 and 30°C. However, to ensure patient comfort and to support simultaneous measurement of ST, MWR study of the lumbar region should be conducted with room temperature controlled to lie between 22 and 26°C.

Keywords: Medical Microwave Radiometry (MWR), lumbar region, brightness temperature (BT), skin temperature (ST)

INTRODUCTION

The core temperature of the human body although physiologically controlled to be on average 37°C in all humans shows local variation depending upon various factors such as Body Mass Index (BMI), regulation of regional vascularization, heat conduction of subcutaneous tissue and level of metabolic processes. There are two principal methods are used for thermal imaging. The first is thermal infrared imaging (IR) for which Lawson (1956, 1957) coined the terms "thermography". The temperature that is recorded corresponds to a depth of 0.5 to 1.5 mm and is referred to as skin temperature (ST). The second technique is known as Microwave Radiometry (MWR) which measures so-called brightness temperature (BT) and refers to a depth of between 5 and 7 centimetres. Variation in the muscular, ligamentous and fatty tissue, bone and deep layers of the skin and presence of pathology may all influence measurements of ST and BT.

The microwave radiation recorded in MWR is the intrinsic electromagnetic radiation that is passively emitted from the internal tissues of the body in the 1 to 10 GHz range. MWR was first used by Barrett in 1975 to diagnose breast cancer (Barrett et al., 1975). The intensity of this radiation is directly proportional to the brightness temperature of the tissue (Barrett et al., 1975). The radiation emitted from a cylindrical volume (Figure 1) lying directly below the antenna is directly proportional to the BT of the tissues and is referred to as internal temperature by medical professionals. BT is typically higher that ST and will be lower the greater the thickness of subcutaneous fat.

Because it simply involves a passive measurement of the intensity of intrinsic electromagnetic radiation emitted from human tissues the MWR technique is safe and harmless. Clinically, MWR has primarily been used for the early diagnosis and monitoring treatment of breast cancer (Vesnin et al., 2017, Vidyukov et al., 2016). However, in recent years other applications are being developed including monitoring treatment of stroke by hyperthermia (Stauffer et al., 2014, Butrov et al., 2012), invasive detection of vesicoureteral reflux (Snow et al., 2011), detection of subclinical synovial inflammation (Zampeli et al., 2013), detection of vulnerable atherosclerotic plaques (Toutouzas et al., 2017) and for monitoring behaviour of protein solutions and enzymes (Ivanovm et al., 2016, Ivanov et al., 2018). Back pain has high prevalence, causes long periods of disability and only a small number of diagnostic and treatment methods have a sound evidence base (Costa et al., 2009, Vos et al., 2012, Bichbinder et al., 2013) and thus is an important potential area of application (Mikhailov et al., 2009, Tarakanov et al.,

EJMCM

Cite this article: Tarakanov AA. 2020. Influence of Ambient Temperature on Recording of Skin and Deep Tissue Temperature in Region of Lumbar Spine. European Journal of Molecular & Clinical Medicine, 7(1), pp. 21–26, DOI: https://doi.org/10.5334/ejmcm.274

2015). Standard Operating Procedures (SOPs) have been developed for clinical application of MWR for studies of the breast but still need to be developed for studies of the lower back. Because a large undraped region of the body is exposed when studies are performed for the lower back it is important to determine the potential influence of room (i.e. ambient) temperature on MWR measurements. Thus, the objective of the present study is to determine in a group of healthy subjects the optimum room temperature range for obtaining reliable measurements of BT and ST.

MATERIAL AND METHODS

Approval for this study was obtained from the local Research Ethics Committee (REC) and the study which was carried out in the Laboratory of Physical Diagnostic and Treatment Methods at Rostov State Medical University, Russian Federation. A total of 93 healthy control subjects aged between 18 and 69 years were recruited (43 women and 50 men). Subjects with somatic and infectious diseases in acute or subacute stages were excluded and none had experienced LBP for one year prior to the study.

Measurements of BT and ST were obtained using a MWR2020 (former RTM-01-RES) system (MMWR Ltd, Edinburgh, UK) which is approved for clinical use in Russia and has a class I CE mark. The system operates in the frequency range 1 to 4 GHz, has an antenna applicator with diameter of 39 mm and reported accuracy of ± 0.2°C for both BT and ST measurements (Radiometer diagnostic computerized integral depth temperature of soft and bone tissue RTM -01-RES. Method of verification. Moscow. 14 p. 2007) and is sensitive for detecting temperature abnormalities at depths of between 3 and 7 cm.

Subjects disrobed to expose their lower back and recording began after 10 minutes to allow thermal equilibrium to be established between skin and room temperature. Recordings were taken at points at the skin surface immediately above the L1 to L5 vertebral bodies and along corresponding left and right paravertebral lines 3 to 5 cm lateral of the central vertebral line (Figure 1). Each recording took 8 seconds to obtain. Recordings were obtained between 9 am and 11 and room temperature and humidity in the room were recorded.

After the recording were taken subjects were divided into three groups according to whether room temperature was in the range 17.1 to 21.9°C (n=24, mean age 37.9 ± 3.8 years) (i.e. low temperature), 22.0 to 26.9°C (n = 56, mean age 46.2 ± 2.4 years) (i.e. moderate temperature) or 27.0 to 29.5°C (n = 13, mean age 38.7 ± 4.6 years) (i.e. high temperature). Humidity was in the range of 50 to 60% for all recordings, consistent with hygienic standards and microclimatic conditions in medical rooms with fixed air.

Statistical analysis was performed using Statistica software (Version 6.0, Dell, California, USA) The parametric Student t-test and non-parametric $\chi 2$ Pearson criterion were applied to test for group differences and confidence intervals were obtained using the Fisher Z-transformation. Differences were considered significant at $p < 0.05$ (Glass et al., 1970). Regression analysis was performed using Excel (Microsoft, Washington, USA).

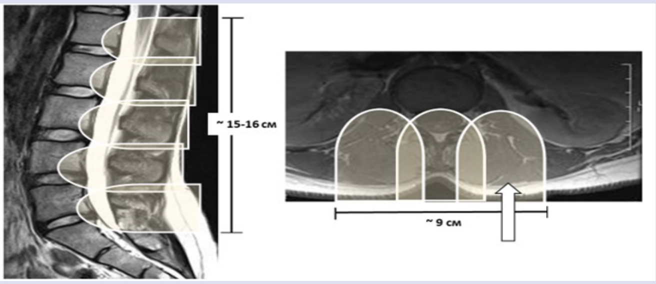

Figure 1. A scheme of setting the microwave radio antenna and the zones for brightness temperature measurements.

RESULTS

As expected, when studying healthy volunteer subjects without back pain have no obvious and pronounced temperature anomalies and thermal asymmetries are observed. The most symmetric patterns are obtained for BT at high room temperature and for ST at moderate room temperature. The maximum value of BT was recordered in the paravertebral lines at the levels L1 and L2 being 0.5 to 1.1°C higher than at level L5 (Figure 2), and with no variation of ST between levels L1 and L5 (Figure 3).

Temperature variation among the 15 recording points is in the range of 0.5 to 0.9°C, is higher in the central vertebral than the left and right paravertebral lines by 0.2 to 0.5°C ($p < 0.05$) and tends to be lower at levels L4 and L5. The influence of room temperature on the recordings of obtained for all 15 points in all 93 subjects is presented for BT in Figure 4 and for ST in Figure 5. Analysis of the data showed that the average value of BT is the same at low and moderate ambient temperatures and is significantly higher by 1°C at high ambient temperature in both the central vertebral and left and right paravertebral lines. As with BT, ST is higher in the central vertebral than in the left and right paravertebral lines. However, in contrast to BT, for ST there is a clear temperature response of the skin related to changes in ambient temperature, increasing from 30.9 to 31.9°C at low ambient temperature to 31.8 to 32.7°C at moderate ambient temperature to 33.2 to 33.9°C at high ambient temperature which is an overall increase of 2 to 3°C.

In a healthy body, there is homeostasis between the temperature of the internal organs (i.e. BT) and ST with a steady heat transfer from the core to the exterior. The correlation coefficients between BT and ST at all the vertebral and paravertebral recording points are presented in Table 1. There is a high and significant correlation for almost all the recording points. The smallest variation in the correlation coefficients is observed at moderate ambient temperature and the greatest variation is at a high ambient temperature.

DISCUSSION

The human body is an open thermodynamic system receiving energy during the oxidation of food products and thus tending to resist developing a thermodynamic equilibrium with the environment and thus BT remains higher than ST. This is because energy production from physiological processes like blood flow, brain and muscle metabolism and digestive processes serve to maintain a higher core temperature. During an MWR examination this system is perturbed by exposure of a certain part of the body to the ambient temperature of the external environment. Compared to the breast, a large part of the body is exposed to the air in studying the lumbar region. Since the thermal capacity of tissues in the lumbar region (i.e. skin, subcutaneous fat, fascia, muscle and bone) is different and has different tissue thickness compared to breast different heat transfer from the internal tissues to the skin is expected. The skin and subcutaneous fat are insulating layers whereas muscle tissue and blood vessels exhibit pronounced thermal conductivity. Taken together these effects produce a stable BT for the low, moderate and high ambient temperature groups (Figure 6) whereas there is a linear dependence of ST on ambient temperature (Figure 7).

The value of ST in the lumbar region at hot ambient temperature is greater than at low ambient temperature by almost 1.5°C. The corresponding values of BT may be estimated by adding the contribution of the skin layers as proposed in 2008 by Vesnin. In particular,

$$BT = k * ST * (k-1) * IT \quad (1)$$

Table 1. The correlation coefficients between BT and ST in the central vertebral lone L1 to L5 and corresponding left and right paravertebral lines at different ambient room temperatures.

Temperature in the room, °C	n	Location	Lumbar vertebrae				
			L1	L2	L3	L4	L5
17,1-21,9 (20,56 ± 0,24)	24	Left	0,638	0,621	0,598	0,783	0,720
		Centre	0,730	0,550	0,655	0,709	0,818
		Right	0,448	0,635	0,771	0,808	0,728
22,0-26,9 (24,55 ± 0,21)	56	Left	0,762	0,742	0,716	0,776	0,793
		Centre	0,623	0,612	0,675	0,775	0,803
		Right	0,691	0,678	0,729	0,738	0,731
27,0-29,5 (27,58 ± 0,18)	13	Left	0,528	0,819	0,713	0,692	0,724
		Centre	0,347	0,489	0,507	0,699	0,654
		Right	0,389	0,403	0,590	0,693	0,555

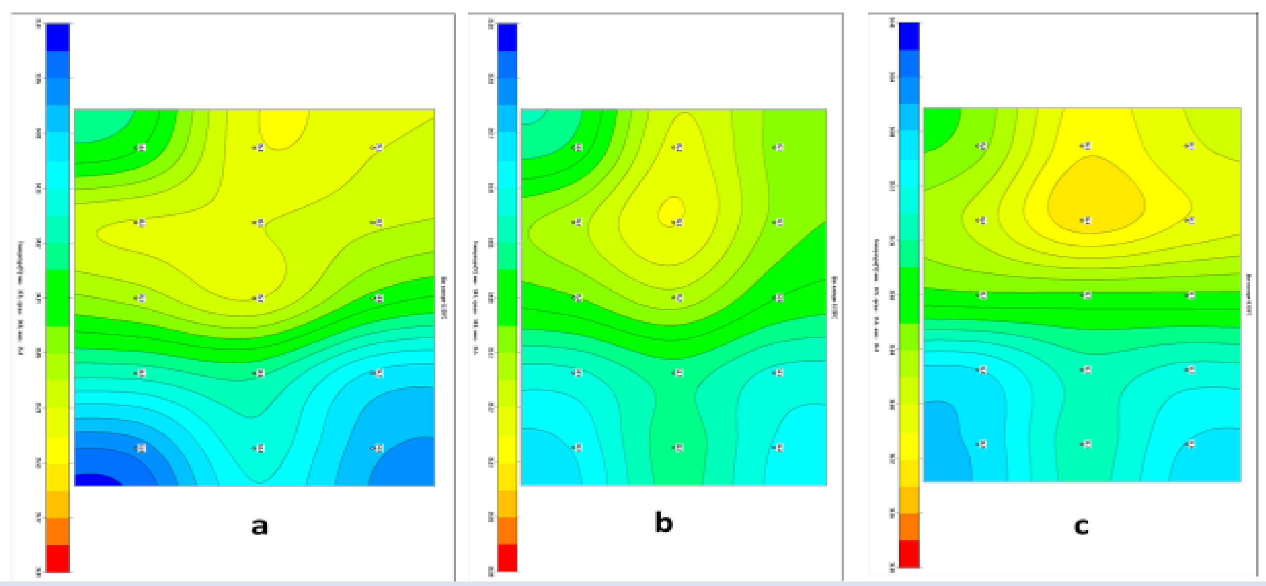

Figure 2. Maps of BT for central and left and right paravertebral lines for a) Group 1 - 17.1 to 21.9°C, b) Group 2 - 22.0 to 26.9°C and c) Group 3 - 27.0 to 29.5°C. Blue to green to red represent increasing temperature.

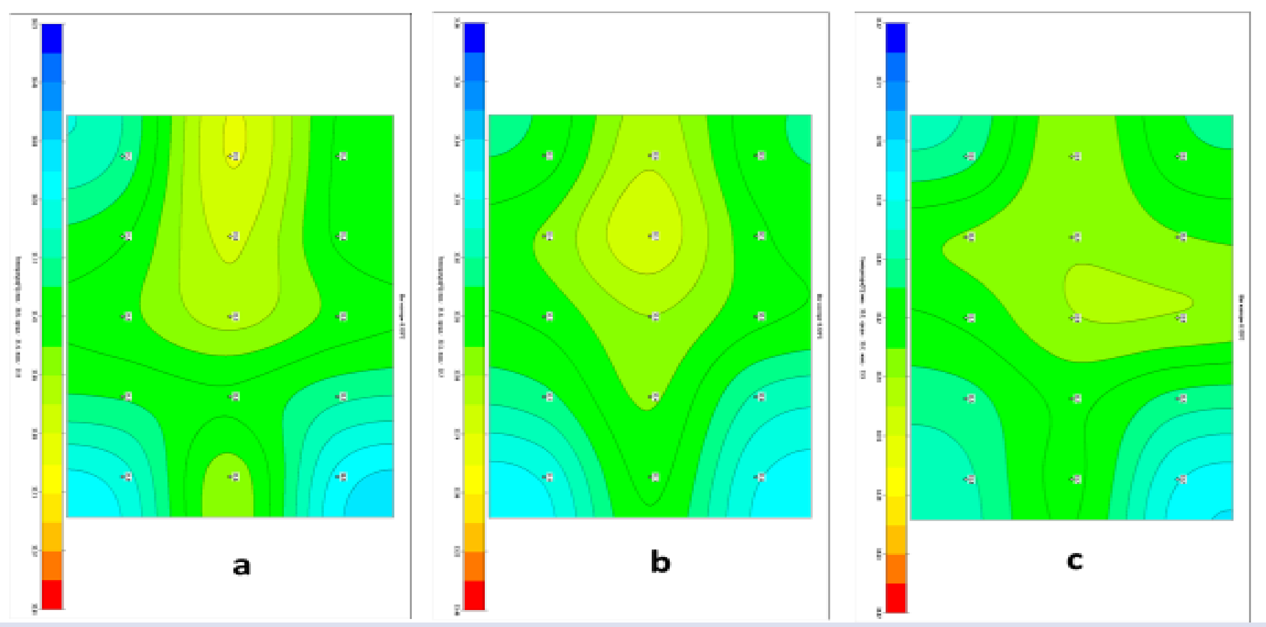

Figure 3. F Maps of ST for central and left and right paravertebral lines for a) Group 1 - 17.1 to 21.9°C, b) Group 2 - 22.0 to 26.9°C and c) Group 3 - 27.0 to 29.5°C. Blue to green to red represent increasing temperature.

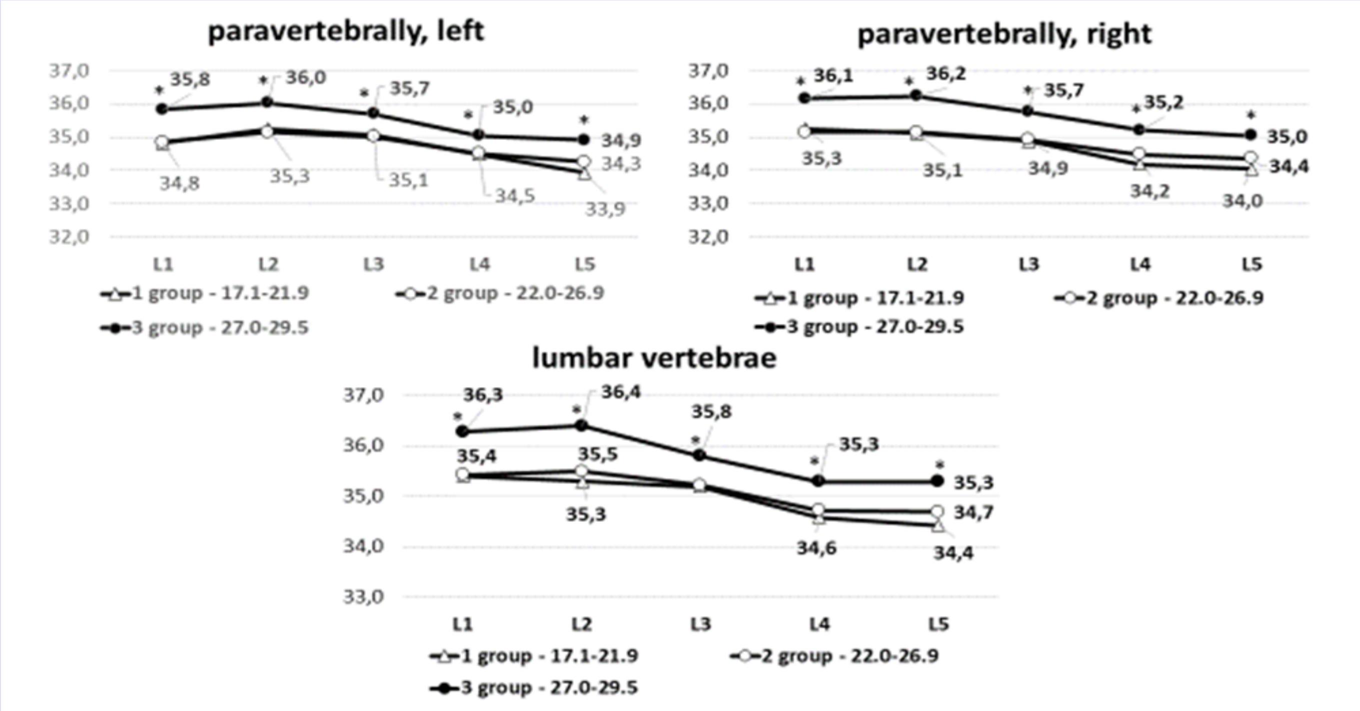

Figure 4. Dependence of BT on room temperature for central and left and right paravertebral lines for a) Group 1 - 17.1 to 21.9°C, b) Group 2 - 22.0 to 26.9°C and c) Group 3 - 27.0 to 29.5°C.

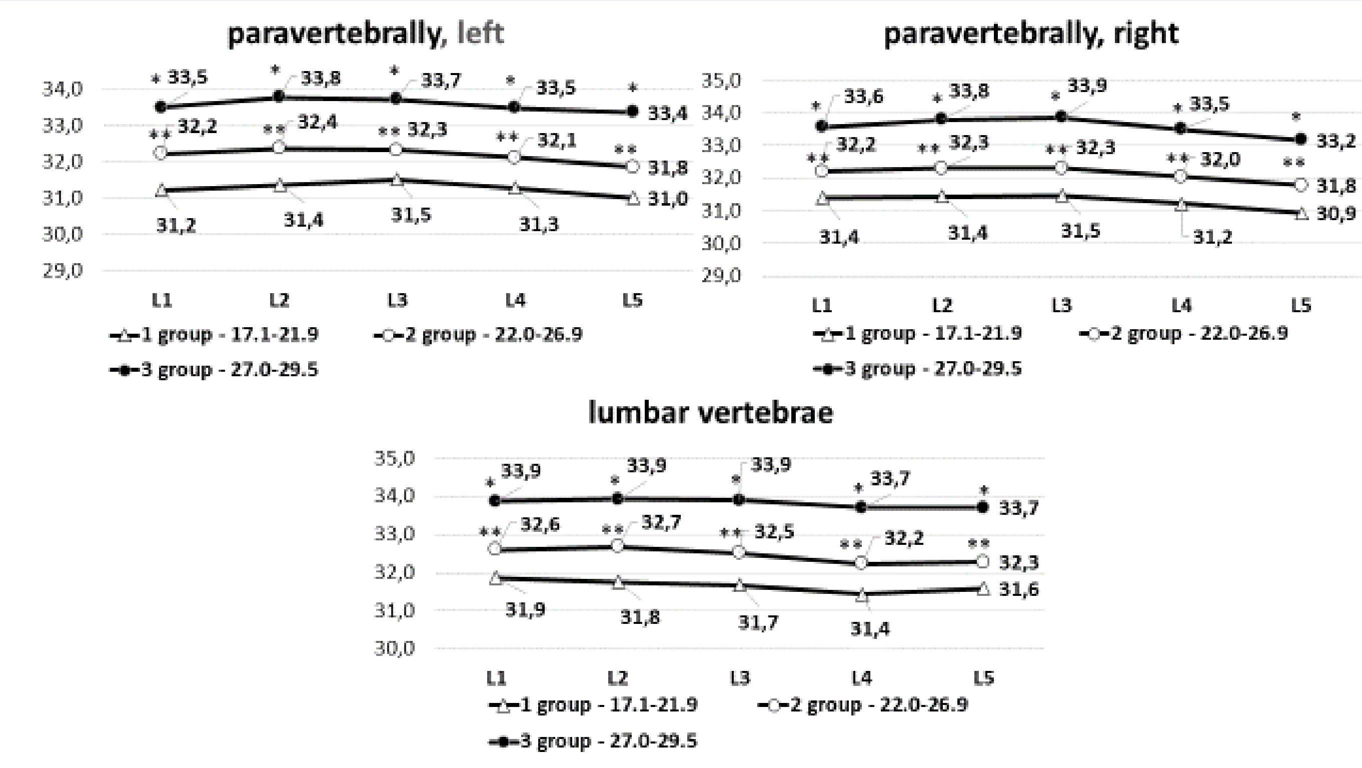

Figure 5. Dependence of ST on room temperature for central and left and right paravertebral lines for a) Group 1 - 17.1 to 21.9°C, b) Group 2 - 22.0 to 26.9°C and c) Group 3 - 27.0 to 29.5°C.
*** - the difference is significant at p <0.05 for Groups 1 and 2.**
**** - the difference is significant at p <0.05 for Group 1.**

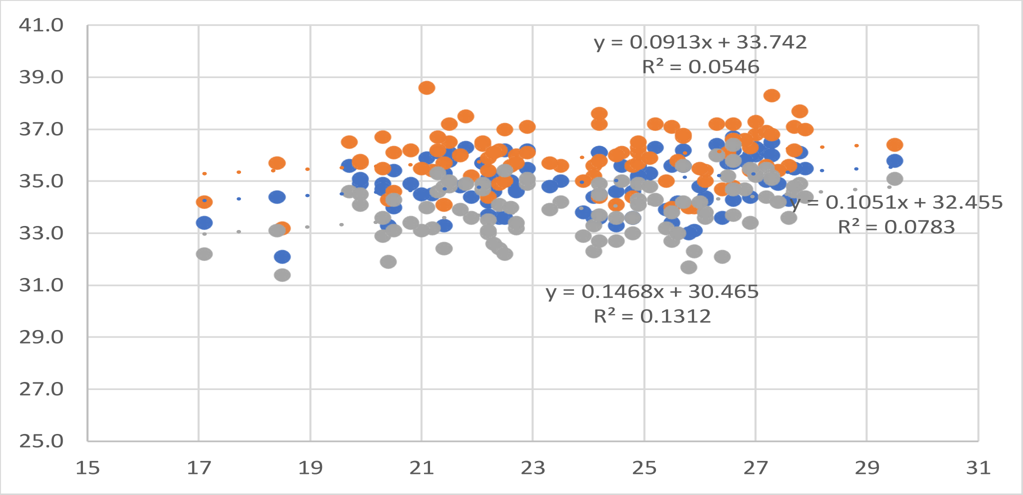

Figure 6. Linear regression of BT. Grey – min, Blue -average, Orange -max.

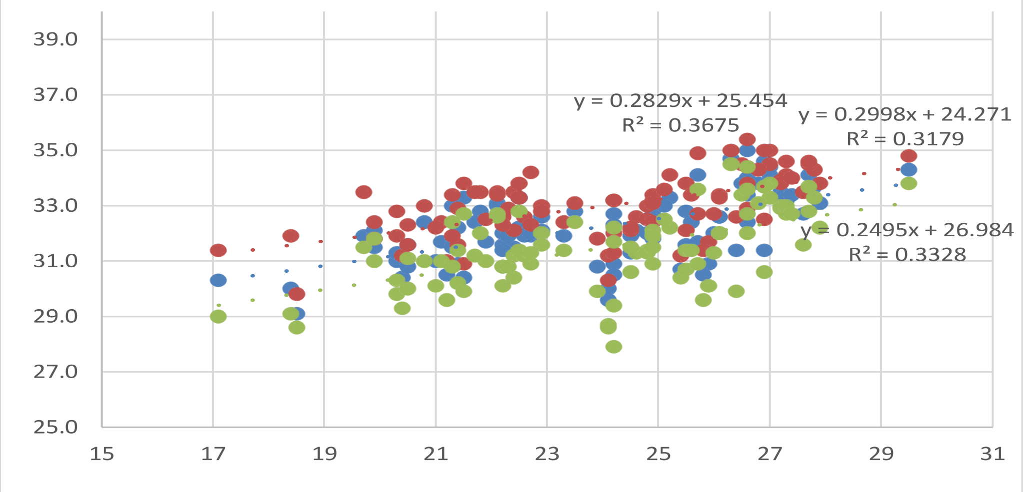

Figure 7. Linear regression of ST. Green -min, Blue -average, Red -max.

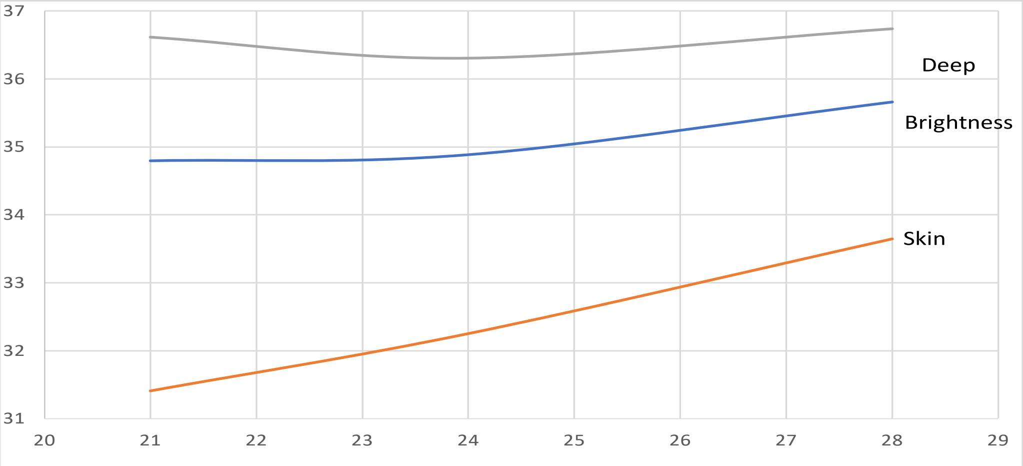

Figure 8. The dependence of BT, IT and ST on ambient room temperature.

Where IT is internal temperature of the inner layers, BT is brightness temperature, ST is skin temperature and K is a dimensionless coefficient characterizing the contribution of skin temperature to the brightness temperature. From (1) it follows that IT can be calculated by the following formula:

$$IT = \frac{BT - kST}{1 - k} \quad (1a)$$

and contribution of ST to BT can be estimated using a numerical solution of a mathematical model for a multilayer lossy environment (Vesnin et al., 2008). For muscle studied using MMR in the frequency range 1.2 to 1.3 GHz the coefficient k is about 0.35 (Figure 8).

When ST rises above 25°C this will affect BT and this must be taken into account in planning clinical studies. Furthermore, if studies of skin temperature are planned it is desirable to conduct them at moderate ambient temperature controlled within +/-0.2°C.

CONCLUSION

When MWR measurements are obtained at low, moderate and high ambient room temperature the value of BT is almost the same at all temperatures. However, ST rises as ambient room temperature rises and this must be taken into account in planning clinical studies. Under normal conditions the balance of heat production and heat transfer in a healthy body (absence of pain and discomfort in the lumbar region) is optimal in the range from 17.1 to 29.5°C and with high correlation between BT, IT and ST at all recording sites. We further recommend to begin recordings after 10 and after 15 min of subject exposure to ambient conditions and for a trained observer to repeat obtaining measurements at least twice and reviewed by a medical doctor.

REFERENCES

1. Lawson, RN. 1956. Breast cancer. Canad Med Assoc J, 75, 309-310.
2. Lawson, RN. 1957. Thermography - a new tool in the investigation of breast lesions. Canad Serv Med J, 13, 517-524.
3. Barrett, AH, Myers, Ph. C. 1975. Subcutaneous temperature: A method of noninvasive sensing", Science, 190, 669-671. doi: 10.1126/science.1188361.
4. Vesnin, SG, Turnbull, AK, Dixon, M, Goryanin, I. 2017. Modern microwave thermometry for breast cancer. J Mol Imag Dynamic 7, 136. doi: 10.1109 / ICIIBMS.2017.8279720.
5. Vidyukov, VI, Mustafin, Ch K, Kerimov, RA, Fisher, LN. 2016. Tumors of the female reproductive system. - 2016 - T. 12. - number 1. - C. 26-31. (In Russian)
6. Stauffer, PR, Snow, BW, Rodrigues, DB, Salahi, S, Oliveira, TR, Reudink, D, Maccarini, PF. 2014. Non-invasive measurement of brain temperature with microwave radiometry: demonstration in a head phantom and clinical case. The Neuroradiology Journal, 27, 51-60. doi: 10.15274/NRJ-2014-10001.
7. Butrov, AV, Shevelev, OA, Cheboksarov, DV, Khodorovich, NA. 2012. Non-invasive thermocartication of the brain ischemic stroke with craniocerebral hypothermia. Bull Pfur Ser Med 7, 62–64. doi: 10.3389/ fneur.2011.00080.
8. Snow, BW, Arunachalam, K, De Luca, V. 2011. Non-invasive vesicoureteral reflux detection: Heating. Journal of Pediatric Urology, 7, 624-630. doi: 10.1016/j.jpurol.2011.05.005.
9. Zampeli, E, Raftakis, I, Michelongona, A, Nikolaou, C, Elezoglou, A. 2013. Detection of Subclinical Synovial Inflammation by Microwave Radiometry. PLoS ONE, 8, e64606. doi: 10.1371/journal.pone.0064606.
10. Toutouzas, K, Benetos, G, Koutagiar, I, Barampoutis, N, Mitropoulou, F, Davlouros, F, Sfikakis, PP, Alexopoulos, D, Stefanadis, C, Siores, E, Tousoulis, D. 2017. Carotid artery temperature in patients with coronary artery disease. Atherosclerosis, 262, 25e30. doi: https://doi.org/10.1016/j.atherosclerosis.2017.04.019.
11. Ivanovm, YaD, Malgagova, KA, Izotov, AA, Pleshakova, TO, Tatur, VYu, Vesnin, SG, Ivanova, ND, Usanov, SA, Archakov, AI. 2016. CYP102 A1 detection during cytochrome reaction during the enzyme reaction. Biochemistry and Biophysics Reports, 5, 285-289.
12. Ivanov, Y, Kozlov, AF, Galiullin, RA, Tatur, VY, Ziborov, VS, Ivanova, ND, Pleshakova, TO, Vesnin, SG, Goryanin I. 2018. Use of Microwave Radiometry to Monitor Thermal Denaturation of Albumin Front Physiol, 9, 956. doi: 10.3389/fphys.2018.00956.
13. Mikhailov, VP, Stebnitskaya, SA, Polosukhin, AD, Kuzmichev, AA. 2009. Back pain and attempts to objectify it. Spinal Surgery, 3, 64-70. doi: 10.3390/brainsci5040521.
14. Tarakanov, AV, Efremov, VV, Tarakanov, AA. 2015. Microwave radiometry for pain in the lumbar spine. Perspectives of application. Russian Journal of Pain, 1, 127-128. doi: https://doi.org/10.1016/j.drudis.2020.01.016.
15. Costa, L, Maher, C, McAuley, J. 2009. Prognosis for patients with chronic low back pain: inception cohort study. BMJ, 339, 3829. doi: https://doi.org/10.1136/bmj.b3829.
16. Vos, T, Flaxman, A, Naghavi, M. 2012. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet, 380, 2163-2196. doi: https://doi.org/10.1016/S0140-6736(12)61729-2.
17. Bichbinder, R, Blyth, F, March, L, Brooks, P, Woolf, AD, Hoy, DG. 2013. Placing the back pain in context. Best Pract Res Clin Rheumatol 5, 575-589, doi: 10.1016/j.berh.2013.10.007.
18. Radiometer diagnostic computerized integral depth temperature of soft and bone tissue RTM -01-RES. Method of verification. Moscow. 14 p. (2007).
19. Glass, J, Stanley, J. 1970. Statistical methods in Education and Psychology, New Jersey, Prentice-Hall.
20. Vesnin, SG. 2008. Patent of the Russian Federation № 2407429 from 26.12. 2008.
21. Vesnin, SG, Sedankin, MK. 2010. Mathematical modelling of the radiation of human tissues in the microwave range. Biomeditsinskaya Radio Electronics, 9, 33-43.

Cite this article: Tarakanov AA. 2020. Influence of Ambient Temperature on Recording of Skin and Deep Tissue Temperature in Region of Lumbar Spine. European Journal of Molecular & Clinical Medicine, 7(1), pp. 21–26, DOI: https://doi.org/10.5334/ejmcm.274