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Letter to Editor

Effects of microwave hyperthermia at two different frequencies (434 and 2450 MHz) on human muscle temperature

Dear Editor-in-chief,

Heat therapy is commonly used to treat injured muscles, and recently, hyperthermia which has been used in oncology was introduced as a modality for use in sports medicine. The important physiological response which produces most of the beneficial effects of hyperthermia is increased blood flow (Sekins et al., 1984). Effective clinical response occurs when the temperature reaches 41 to 45 °C (Lehmann and de Lateur, 1982), increasing blood flow up to 15 times (Song, 1984). Sekins et al. (1984) reported that to produce observable variations in blood perfusion, temperature must rise above 41.5 °C as fast as possible. While there are several heating modalities, studies have shown that electromagnetic waves are more effective than other thermal modalities for treating injured muscles at depth of 1-4cm (Giombini et al., 2007). However, because of lack of research-based evidence of the microwave hyperthermia treatment, clinical and research studies need to be completed to confirm the therapeutic effectiveness of hyperthermia. We recently reported that hyperthermia treatment with a 434-MHz microwave and direct-contact applicator increased and maintained the muscle temperature locally by 6.3–11.4°C without causing muscle damage (Ichinoseki-Sekine et al., 2007). This system has also been found to be a highly innovative and reliable modality for treating acute muscle injuries (Giombini et al., 2001). However, most of the hyperthermia systems commonly used in clinical situations is equipped with a 2450-MHz microwave generator and a non-contact applicator. The possibility exists that the muscle temperature is influenced by the frequency and applicator style. Thus, the aim of this study was to investigate the changes in human muscle temperature induced by two different types of microwave hyperthermia systems. Our results could assist to solve the lack of research-based evidence for the clinical effectiveness of hyperthermia treatment.

In this study two different microwave hyperthermia systems were used. One was a direct-contact microwave hyperthermia device (ALBA Hyperthermia System, Restek SRL, Rome, Italy) equipped with a 434-MHz microwave generator having a curve-shaped microstrip antenna applicator, and a silicon bolus filled with thermostatic water. The skin temperature was automatically controlled by a decrease/increase in the power output to maintain the skin pilot temperature. The microwave power source was set to turn on/off periodically as the default setting, and the temperature data were measured during the power-off phase. The other device was a non-contact microwave device (Microtizer, MT-SDi, Minato Medical Co. Ltd., Osaka, Japan) equipped with a 2450-MHz microwave applicator including a helical antenna. This system does not contain any temperature measurement system, and the skin temperature was maintained manually by reducing the power output or varying the distance between the applicator and skin surface. The settings of both hyperthermia systems were established in accordance with the manufacturers' instructions. The 434-MHz system was set with a power of 60 W, a skin baseline temperature of 40˚C, and a bolus water temperature of 38˚C. The applicator was placed on the lateral side of one thigh, and the center of the applicator position was adjusted to the position of the thermocouple. The 2450-MHz system was set with a power of 150 W, and the distance between the skin surface and applicator was approximately 15 cm. The skin and muscle temperatures were measured using a digital thermometer (PTW-301, Unique Medical, Tokyo, Japan) every 3 min for 10 s during the power-off phase, and the center of the applicator position was adjusted to the position of the thermocouple.

Eleven healthy adult males (24.3 ± 2.2 years, 1.74 ± 0.06 m, 70.0 ± 5.3 kg; mean ± SD) participated in this study. The subjects were placed in the supine position and underwent 30 min of hyperthermia treatment with either the 434 or 2450-MHz system on different days. At least 1 week elapsed between the two measurements. All procedures described in this study were performed with the approval of the Juntendo University Human Ethics Committee and complied with the Declaration of Helsinki. All subjects gave written informed consent. The thermocouple for determining the skin temperature was placed on the belly of the vastus lateralis muscle. After anesthesia with a 60% lidocaine tape (Penles, Wyeth K.K., Tokyo, Japan), a 23-G thermocouple (IT-23, Physitemp Instruments, Clifton, NJ) was inserted into the muscle, and its temperature at a depth of 2.0 ± 0.2 cm was measured. The room temperature and humidity were controlled at 24.5 ± 0.3˚C and 51.6 ± 8.9%, respectively. In addition, to determine the depth of the maximum heating point, we evaluated the vertical heating pattern using a muscle equivalent phantom (Okano, et al., 2000). After microwaves were applied, the temperature distribution on the vertical cutting surface of the phantom was recorded immediately using a thermal camera (Thermo Tracer TH71000, NEC San-ei Instruments, Tokyo, Japan).

As results, the muscle temperature with the 434-MHz system showed a single peak at approximately 10 min. Significant differences were detected between the systems in peak muscle temperature, temperature rise, and time to peak temperature ($p < 0.001$; Table 1). The maximum heating point using the 434-MHz system (approximately 2 cm) was deeper than that of the 2450-MHz system (approximately 1 cm). The peak skin temperatures were not significantly different between the two systems.

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Table 1. Peak temperatures in the skin surface and muscle induced by microwave hyperthermia at two radio frequencies. Because a warm water bolus was placed on the thigh before treatment, the baseline skin temperature increased in the 434-MHz system.

	Baseline T *ºC*	Peak T *ºC*	Temperature rise *ºC*	Time to peak T *min*
434-MHz system				
Skin surface				
Mean (SD)	34.2 (1.4) *	39.2 (.5)	5.0 (1.5) *	10.7 (1.6)
Range	31.6-35.9	38.2-39.8	3.1-8.2	8.4-13. 7
Muscle				
Mean (SD)	35.0 (1.3)	43.7 (.8) **	8.9 (1.4) **	9.9 (1.4) **
Range	33.2-37.9	42.8-45.4	6.3-11.4	8.4-12.5
2450-MHz system				
Skin surface				
Mean (SD)	32.3 (1.1)	39.2 (.8)	6.9 (1.5)	15.9 (7.3)
Range	30.8-33.9	38.0-40.6	4.1-8.3	4.8-30.2
Muscle				
Mean (SD)	35.0 (.8)	41.1 (1.3)	6.1 (1.4)	20.0 (7.5)
Range	33.6-36.0	39.6-43.2	3.9-8.5	9.5-30.3

* and ** denote $p < 0.05$ and 0.01, respectively compared with 2450-MHz system.

However, the changes in muscle temperature did show different patterns; a single peak at 10 min was seen with the 434-MHz system, whereas a slope was observed with the 2450-MHz system. This behaviour with the 2450-MHz system caused the substantial variation in the time to peak temperature.

In general, the therapeutic range for heat treatment in sports medicine is assumed to be from 41 to 45ºC (Lehmann and de Lateur, 1982). When the local muscle temperature first exceeds a threshold of 42 to 45ºC, a rapid perfusion of cooling blood flow is induced in the high-temperature region (Sekins et al., 1982). This thermal washout reduces the temperature to prevent the muscle from overheating. Our results suggest that the 434-MHz system increased the muscle temperature to this therapeutic range and caused thermal washout. However, some subjects could not reach the therapeutic range with the 2450-MHz system, and thermal washout might not have occurred because a large temperature reduction was not observed. We showed that the radiation frequency and applicator type of a microwave hyperthermia system influence the change in human muscle temperature, but not skin temperature. According to the phantom experiment results, the maximum heating point was shallow in the 2450-MHz system; thus, the actual maximum temperature induced by the 2450-MHz system might have been higher by 1ºC than our results. Even so, the muscle temperature in some subjects may not have reached the temperature necessary to cause thermal washout.

There are some studies that showed the benefits of hyperthermia at 434-MHz system. Hyperthermia has benefits in acute muscle injuries, chronic overuse tendinopathies and pain reduction (Giombini et al., 2002), with short-term clinical improvement, good safety and no side effects. The important physiological response which produces most of the beneficial effects of hyperthermia is increased blood flow, and the effective clinical response occurs when the temperature reaches 41 to 45ºC. Hyperthermia produces an increase in nutrients and oxygen in the heated region, and both two events are necessary to affect tissue repair. Our result showed that 434-MHz hyperthermia system rapidly increases muscle temperature to above 41ºC, and it support the previous reports.

To obtain the effect of hyperthermia treatment efficiently, both time and temperature of application must be controlled. However, to our knowledge, no study measured the changes in human muscle temperature induced by different types of microwave hyperthermia systems. We believe that our results provided research-based evidence for the clinical effectiveness of hyperthermia treatment.

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References

Giombini, A., Casciello, G., Di Cesare, M.C., Di Cesare, A., Dragoni, S. and Sorrenti D. (2001) A controlled study on the effects of hyperthermia at 434 MHz and conventional ultrasound upon muscle injuries in sport. *The Journal of Sports Medicine and Physical Fitness* **41,** 521-527.

Giombini, A., Di Cesare, A., Casciello, G., Sorrenti, D., Dragoni, S. and Gabriele, P. (2002) Hyperthermia at 434 MHz in the treatment of overuse sport tendinopathies: a randomised controlled clinical trial. *International Journal of Sports Medicine* **23,** 207-11.

Giombini, A., Giovannini, V., Di Cesare, A., Pacetti, P., Ichinoseki-Sekine, N., Shiraishi, M., Naito, H. and Maffulli, N. (2007) Hyperthermia induced by microwave diathermy in the management of muscle and tendon injuries. *British Medical Bulletin* **83,** 379-96.

Ichinoseki-Sekine, N., Naito, H., Saga, N., Ogura, Y., Shiraishi, M., Giombini, A., Giovannini, V. and Katamoto, S. (2007) Changes in muscle temperature induced by 434-MHz microwave hyperthermia. *British Journal of Sports Medicine* **41,** 425-429.

Lehmann, J.F. and de Lateur, B.J. (1982) Therapeutic heat. In: *Therapeutic heat and cold.* Ed: Lehmann, J.F. 3rd edition. Baltimore: Williams & Wilkins. 404-562.

Okano, Y., Ito, K., Ida, I. and Takahashi, M. (2000) The SAR evaluation method by a combination of thermographic experiments and biological tissue-equivalent phantoms. *IEEE Transactions on Microwave Theory and Techniques* **48,** 2094-103.

Sekins, K.M., Emery, A.F., Lehmann, J.F. and MacDougall, J.A. (1982) Determination of perfusion field during local hyperthermia with the aid of finite element thermal models. *Journal of Biomechanical Engineering* **104,** 272-9.

Sekins, K.M., Lehmann, J.F., Esselman, P., Dundore, D., Emery, A.F., deLateur, B.J. and Nelp, W.B. (1984) Local muscle blood flow and temperature responses to 915MHz diathermy as simultaneously measured and numerically predicted. *Archives of Physical Medicine and Rehabilitation* **65,** 1-7.

Song C.W. (1984) Effect of local hyperthermia on blood flow and microenvironment: a review. *Cancer Research* **44 (10 Suppl),** 4721s-30s.

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