EFFECTS OF ELF ELECTRIC FIELD EXPOSURE ON PHYSIOLOGICAL FUNCTION = POSSIBILITY OF BLOOD FLOW CHANGE IN HUMAN BODY SURFACE =

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1. Introduction

There has been much study conducted on the biological effects of electromagnetic fields [1]-[3]. However, the mechanism of the biological effect of ELF (Extremely Low Frequency) electric field remains unknown. As a clear effect, the stimulating sensation at the human body surface has been well known. The safety standard in Japan has been based on the perception threshold of this sensation.

We have found that the human perception threshold varied with seasons. The measure cause of the variability was found to be the change of the cutaneous sensation due to the change of the relative humidity. The variability of the perception threshold has been studied in detail [4]. These studies have posed the important question, i.e. whether this sensation induces any important physiological change in a human body. This paper reports the technique developed to detect this change and some preliminary results of the experiment.

2. Measurement system

As the first candidate of the physiological function, we have chosen a cutaneous blood flow. It is relatively easy to measure and is expected to reflect the physiological changes induced in a human body.

Fig. 1 illustrates the measurement system schematically. An electric field is exposed locally on the forearm of a human subject. The blood flow was measured in the vicinity of the expose area. The subject was told to report it orally, if he felt any sensation. An electric field was generated by applying a constant voltage (0-9 kV) between a pair of plane parallel electrodes (110×110 mm, 20 mm spacing). A circular hole (30 mm diameter) was open in the center of the lower electrode, and an electric field was applied to the outer surface of the human forearm. The blood flow was measured by a laser Doppler flowmeter. The measurement probe of the flowmeter was fixed on the heart side of the exposure area.

The arm of the subject was placed in a thermo-hygrostat for a certain period, and the measurement was conducted in the two relative humidities (R.H.), or 50% and 90%. In previous study [5]-[6], we have observed the distinct difference in the perception threshold at these relative humidities. The subject wore an eyemask and earphones with BGM to suppress the audio-visual disturbances.

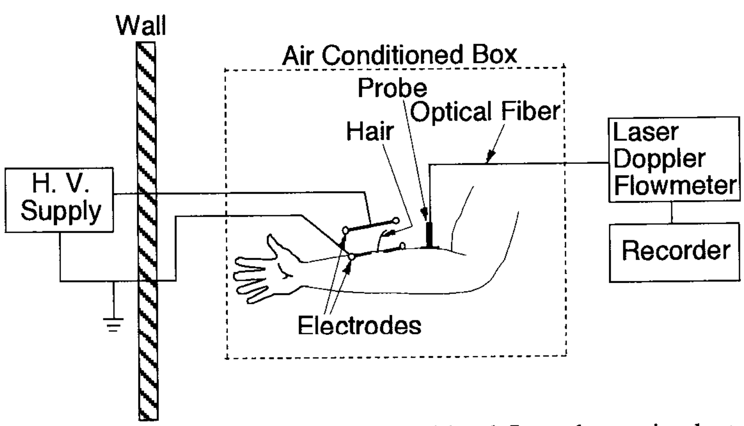

Fig. 1 Outline of experimental system to measure human blood flow change in electric field exposure.

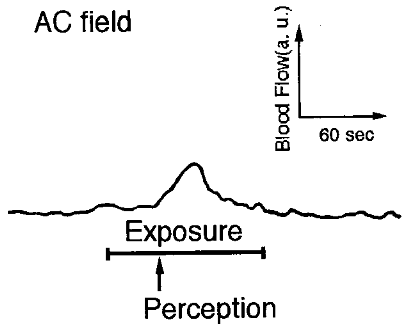

Fig. 2 Temporal change of blood flow in AC field exposure.

3. Blood flow change in field exposure

An example of the results is shown in Fig. 2. This is the temporal change of blood flow, when an AC electric field is exposed on the forearm of a healthy male subject (22 year-old). The magnitude of the electric field was gradually increased from 0 kV/m. After the perception, it was decreased to 0 kV/m gradually. The arrow ↑ in the figure indicates the instance of the field perception.

In this case, the subject perceived the filed at 250 kV/m, and a distinct increase in the blood flow was observed. As the field strength decreased, the flow level returned to the original level.

To examine the reproducibility, the same measurement was repeated with different subjects. The relation between the field perception and the blood flow change was investigated in the two relative humidities. The results were summarized in Table 1. This shows the occurrences of the perception and the flow change among 10 healthy male subjects (21-24 year-old).

As can be seen, the occurrence of these two coincided in many cases. For example, in the subject G, the coincidence was apparent. This result suggested the strong association between the field perception and the blood flow change.

4. Dependence on exposure conditions

In the previous study, we have investigated the mechanisms of the field perception [4]-[6]. It was made clear that the movement of the body hair was one of the major mechanisms of the field perception. Therefore, the perception becomes difficult if the body hair was removed. The perception threshold becomes low in a high humidity environment, because the electric force on the hair becomes large. The perception threshold is low in an AC field than a DC field, because the AC field vibrates the hair while the DC field moves it temporarily at the voltage onset.

Table 1 Incidence of field perception and blood flow change.

	Subject									
	A		B		C		D		E	
RH (%)	50	90	50	90	50	90	50	90	50	90
P	O	O	X	X	O	O	O	O	O	O
BF	O	O	X	X	O	O	O	O	O	O

	Subject									
	F		G		H		I		J	
RH (%)	50	90	50	90	50	90	50	90	50	90
P	X	X	X	O	O	O	O	O	O	O
BF	O	O	X	O	X	X	X	X	O	O

RH:Relative Humidity, P:Perception, BF:Blood Flow Change
O and X respectively indicate the incidence and the absence of perception and flow change.

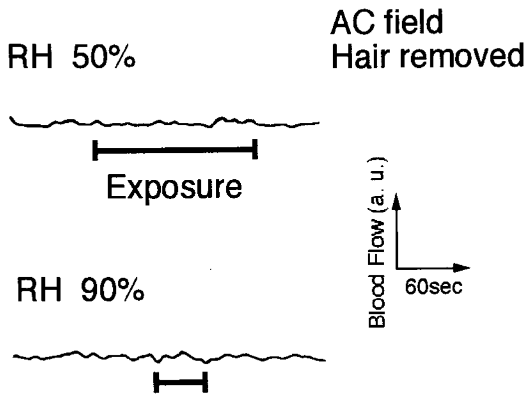

Fig. 3 Temporal change of blood flow with body hair removed.

If the blood flow change was caused by the sensation mediated by the hair movement, the similar tendency as the field perception is expected. Thus, the dependence of the blood flow change on these conditions was investigated.

An example of the result was shown in Fig. 3. This is the temporal change of the blood flow in the forearm of a healthy male subject with his body hair shaved off. The magnitude of the exposed field was increased to the maximum value (450 kV/m) applicable with our equipment. However, there was no change observed in either humidity.

Fig. 4 shows the dependence of the blood flow change on the relative humidity in the same subject. In this case, the field was exposed to the body surface with normal body hair. This subject perceived the field of 250 kV/m and 200 kV/m in the relative humidity of 50% and 90%, respectively. The increase in the blood flow is more distinct in the higher humidity. Similar dependence on the relative humidity has been observed often in the subjects who showed the flow change in both humidities.

Fig. 5 shows the comparison between the DC and AC field exposures. This subject perceived the field of DC 300 kV/m and AC 200 kV/m, respectively. Generally in an AC field exposure, the perception threshold is lower and blood change tended to be more distinct than a DC field exposure.

In these experiments, it was verified that the blood flow change was dependent on some exposure conditions and that the dependence agreed well with that of the field perception.

5. Discussion

Through these experimental studies, the possibility of blood flow change due to the filed exposure was almost confirmed. It is not easy to clarify the mechanism of the blood flow change, since it is controlled by complicated systems. As the first speculation, we consider the following mechanism is the base of the blood flow change measured by laser Doppler flowmeter.

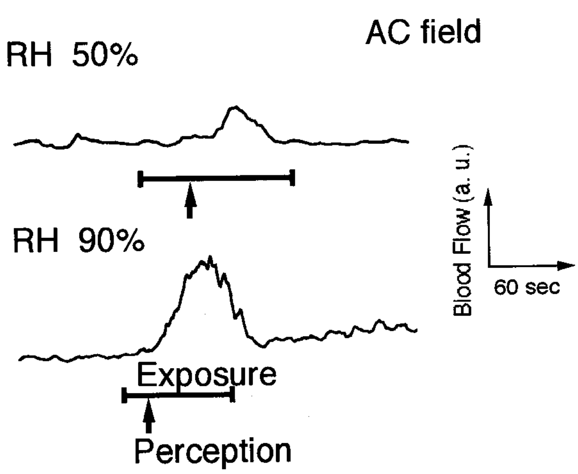

Fig. 4 Temporal change of blood flow in AC field exposure.

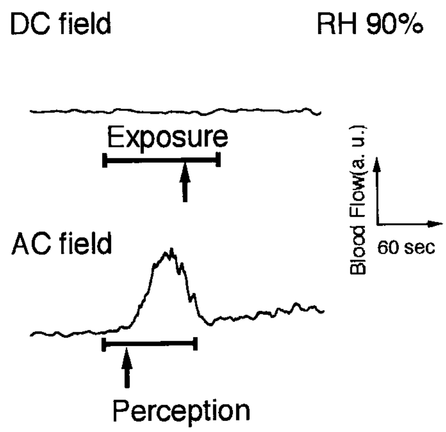

Fig. 5 Temporal change of blood flow in DC & AC field exposure.

When a human body is exposed to an electric field, an electric force is applied on the body hair. In the previous study, we showed that the force is proportional to the dielectric constant of the hair, and that the dielectric constant increases with the relative humidity. In a DC electric field, the body hair moves temporarily to stand up at the voltage onset. In an AC field, it vibrates continuously. This mechanical movement of the hair induces the sensation in the body surface. This sensation causes some effects on human nervous system. As a result, the blood vessel diameter innervated by the autonomic nervous system changes, and the peripheral blood flow changes.

In high humidity, the dielectric constant of the hair increases and the hair moves more than in low humidity. In the AC field, the perception threshold becomes low due to the continuous vibration of the body hair. Therefore, the blood flow change seems to occurr more distinctively in the high humidity and in the AC field exposure.

However, there were some cases which were contradictory to the above hypothesis. Although their number is relatively small, we need more study to examine the reasonability of the hypothesis.

6. Conclusions

To investigate the biological effect of an ELF electric field, a fundamental study was conducted on the human physiological change associated with electric field exposure. The change in the surface blood flow was detected, when a strong electric field was exposed on the forearm. In experiments, the dependence of the blood flow change on various physical factors was examined. The results suggested the close connection between the blood flow change and the field perception.

In order to confirm the reasonability of this preliminary result and to clarify the mechanism of this effect, further study is required.

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