

Healthy bathroom—bathrooms of the future

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ABSTRACT

The paper describes the development of a daily health monitoring system for a bathroom. The system will detect the bather's electrocardiogram (ECG) signal through the bathtub water, the bathers do not have to attach any sensors to their body and they can use it for daily health care at their home on a regular basis and without mental stress.

Bathers' heart rate in different hot water temperatures and for different health conditions are shown. Results showed that the system can be used for daily health care and for real-time health monitoring as a security system. It can also be used for remote-diagnostic service. Doctors can diagnose bathers by receiving their bathtub ECG data automatically through the Internet.

The experiment of estimating the bather's mental stress condition from the heart rate is also shown. The method analyses the heart rate variability caused by respiration, which is often used for estimating mental stress. The result indicates that there is a significant difference between a relaxed condition and a stressed condition while bathing.

INDEX TERMS

Health monitoring; Heart rate; Bathroom; Mental stress

INTRODUCTION

The Japanese take baths every day at a regular time and prefer staying in hot water for a long time. Therefore, the bathroom can have various functions. It is one of the best places to record bio-signals for monitoring the daily health condition. It is also one of the highest risk environments within the home because the temperature of the bath is relatively high. Each year, in Japan, about 14 000 people died in their bathroom, most of them drown in the bathtub with heart disease or by losing consciousness (Takahashi, 2003).

Considering these situations, several research and development projects about healthcare and security in the bathroom have been carried out in Japan. Most of the healthcare systems in the bathroom were designed for a medical treatment which requires expert knowledge or a medical doctor's help when people use them at home (Kawarada *et al.*, 1998). On the other hand, several security products which detect accidents in the bathroom have been developed and some of them have come into the market recently (Ando Y *et al.*, 2001).

In this paper, a health monitoring system in the bathroom, which can be easily used at home without expert knowledge or doctor's help, is discussed.

MEASUREMENT

For daily health monitoring, heart rate is generally considered as an indicator of health condition that is relatively easy to obtain. There are two methods for the heart rate measurement. One method is an indirect method, which uses infrared or sound sensors attached to a finger, an arm or an ear. This method is widely used for training at gyms, or for a simple sphygmomanometer. Another method is a direct method, which requires the attachment of electrodes to the human body and measures the electrocardiogram. This method is generally used in hospitals and medical facilities. Both methods require the attachment of sensors to the human body; therefore, it does not seem to be appropriate for daily use.

The bathtub ECG method which can measure the bather's ECG by attaching electrodes to the inside of the bathtub had been developed from the late 1980s to the early 1990s (Ishijima and Togawa, 1989). Electrodes, which are located at both sides of the bather, obtain the bather's ECG as voltage signals through the bathtub water (Figure 1).

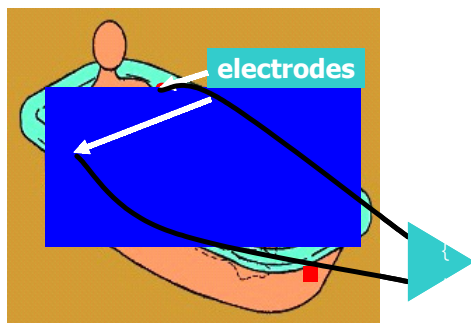


Figure 1 The bathtub ECG method.

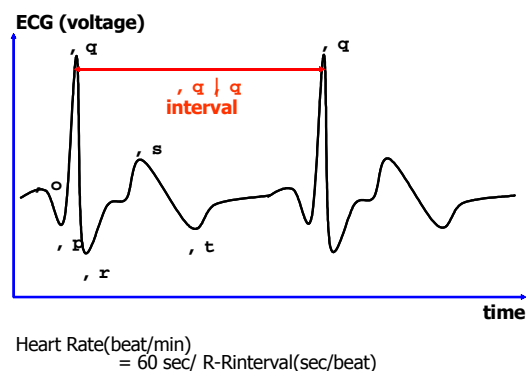


Figure 2 A general ECG wave form.

Figure 2 shows a general ECG wave form. The signals contain high frequency wave forms called 'R waves'. The peak voltage of an R-wave is generally 100–500 μV and they are amplified to 300 mV–1.5 V. Heart rates (beats/min) are calculated by measuring the interval time between two continuous peaks or R-waves, called the 'R–R wave interval', or counting the number of peaks in 1 min. Using this method, several experiments had been carried out in the project for showing the possibility of daily health monitoring as described below.

HEART RATE AND HOT WATER TEMPERATURE

The Japanese prefer to stay in the bath for a relatively long time with high water temperatures, around 40°C or higher. This habit is considered as one of the reasons for the number of accidents that happen in the bathroom and the recent recommendation for bathtub water temperature is between 38 and 40°C. But many people still prefer higher temperatures.

Therefore, it is important to show people how high bathtub water temperature affects their body. An example of the relationship between bather's heart rate and the bathtub water temperature is shown in Figure 3.

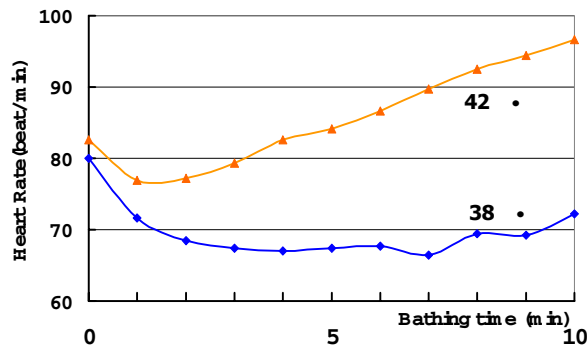


Figure 3 The relationship between bather's heart rate and the bathtub water temperature.

Figure 3 shows a bather's heart rate profiles while bathing in different temperatures. If the temperature is 42°C, the heart rate starts increasing in 1 min, while if the temperature is 38°C, the heart rate is stable while bathing. The increase of heart rate is considered as increase in stress to the bather's body. Therefore, if bathers know their heart rate while bathing, they can be aware of the risk themselves and find the appropriate bathing time.

HEART RATE AND HEALTH CONDITION

To examine the relationship between the bather's health condition and heart rate, heart rate measurements in the bathtub were carried out for 2 months at 10 single family houses. During these experiments, one subject got sick and recovered. Figure 4 shows the subject's heart rate profiles in 3 days with three different health conditions: good condition, a touch of cold and chills.

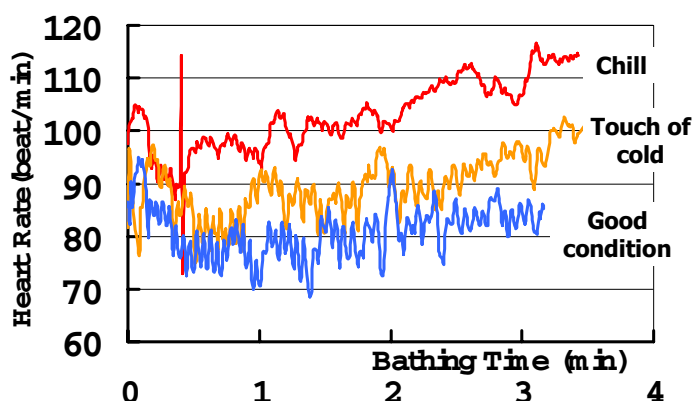


Figure 4 Heart rate profile with different health conditions.

Bathtub water temperatures were kept around 42°C during the measurements. An irregular heartbeat was also observed on the day when the bather was in the worst condition. This result implies that bathers can be aware of their health condition by measuring the heart rates in the bathroom every day and comparing them with their average heart rates.

HEART RATE AND MENTAL STRESS

The heart rate provides physical health information. In addition it can be used for mental stress information. Experiments were carried out with two subjects to examine the possibility of using heart rate as a relaxation estimation method, which is often used for estimating mental stress while working. The method analyses the heart rate variability caused by respiration. For example, if one feels stress, the heart rate variability will be small, whereas if one feels relaxed, it will be large. The typical data are shown in Figure 5(a)–(c). Results indicate that there is a significant difference between a relaxed condition and a stressed condition while bathing. Further experimentation will be needed before this mental health estimation system can be put to practical use, but these results show that this relaxation estimation method is possible.

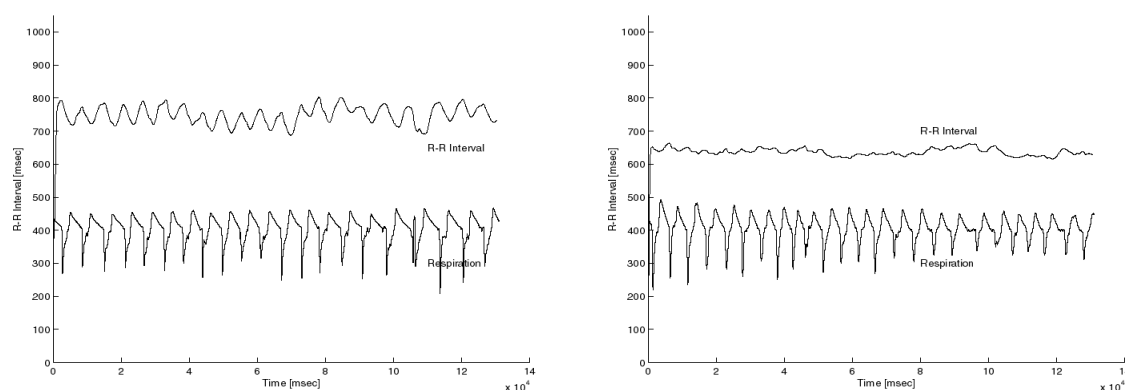


Figure 5 (a) Heart rate and respiration-curve (left: relaxed condition, right: stressed condition).

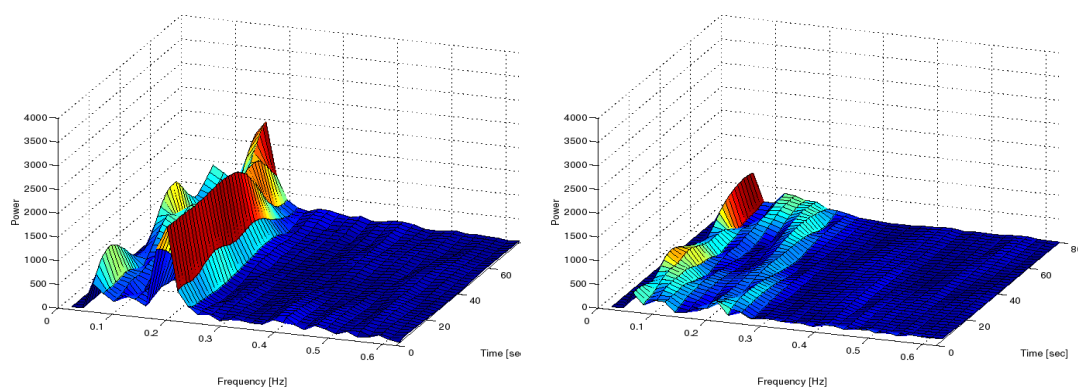


Figure 5 (b) Spectral analysis of the series of heart rate (left: relaxed condition, right: stressed condition).

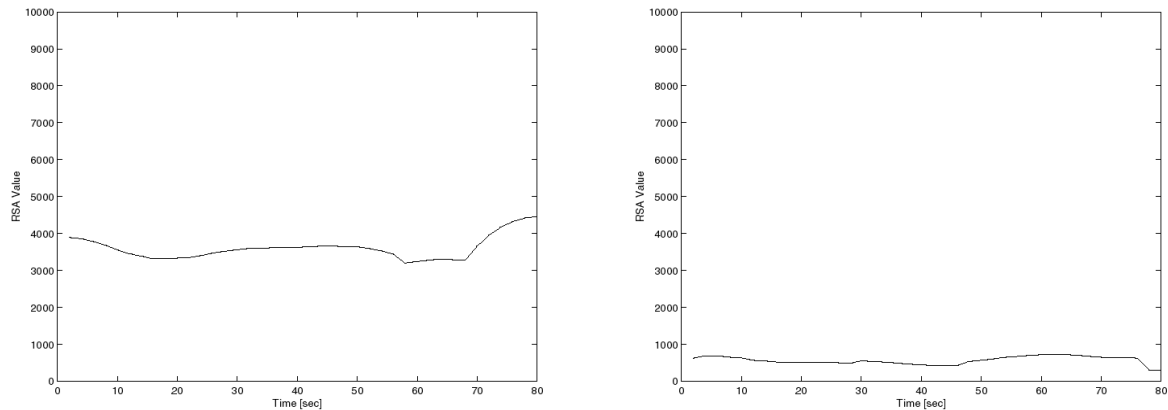


Figure 5 (c) Estimated relaxation level (left: relaxed condition, right: stressed condition).

BATHTUB HEART RATE MONITORING SYSTEM

Figure 6 shows the bathtub heart rate monitoring system.

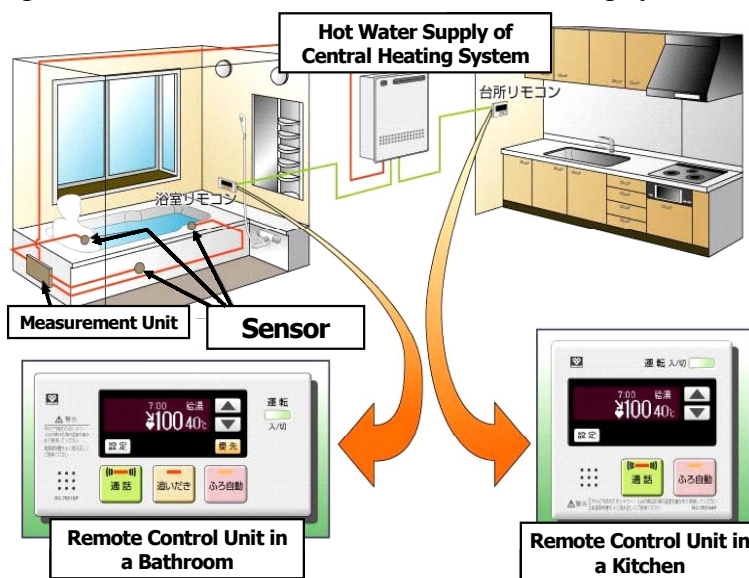


Figure 6 The bathtub heart rate monitoring system.

Bather's heart rate is shown in the remote control unit in the bathroom. Using a communication line of the hot water supply system, the bather's heart rate can be seen by his or her family in the kitchen. This function was mainly designed for the elderly whose families are anxious about their health condition during bathing. The system was brought to the Japanese market in April 2002.

CONCLUSION

The system is appropriate especially for those who take a bath everyday at a regular time. The experimental results show that bathers can be aware of their health condition without feeling

the stress related to applying measurement equipment. The results also show that the system can be used for checking if the bathtub water temperature is appropriate for the bathers or not. The possibility of estimating bather's mental stress condition was also shown in the preliminary results.

There are many different bathing styles in each country. For applying the system in other countries, further investigations are required. But as long as bathing is the habit of human beings, the system or measurement can be adapted to other bathing styles.

ACKNOWLEDGEMENT

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