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Tracking Warm Bathing Effects on Human Health with IoT: A Preliminary Quasi-Experimental Study

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Abstract: This study is proposed to integrate the latest wearable and portable devices into a system as the first try to collect people's vital signs: electrocardiogram (ECG), blood pressure (BP), and body temperature (BT) before and after each bath. Meanwhile, the variation in heart rate (HR) and core motion data is recorded during the whole bathing hour. As a pioneer study of the IoT system applied to the bathing environment for health tracking, two participants were asked to take a 3-week experiment with a one-group pretest-posttest design for evaluation. The results reveal that taking a full body warm bath regularly is beneficial to human health. Further research on the correlation between bathing ways and health perceptions is required to investigate the salutary effects of warm bathing.

Keywords: Internet of Things (IoT), full body warm bath, health informatics

1. Introduction

1.1 Background

Warm bathing is popular and widespread over the world. Based on the present study findings, it is determined that water immersion applied to healthy adults can cause physiological and cognitive-behavioral changes according to the thermal effect of water. [1]

One of the noteworthy points regarding the physiological effects is that warm water immersion is efficacious for cardiovascular function improvement. It can cause flow-mediated dilation of the artery to prevent ischemia-induced vascular dysfunction, or exhibit an occlusive reactive hyperemia effect, whereby it elicits the same effect as doing exercise to improve cardiopulmonary function. [3] The improvements in arterial stiffness due to an elevated core body temperature could also improve cardiovascular function by decreasing vascular resistance and increasing blood flow. Thus, the warm water immersion has clinical significance as an alternative therapy to exercise training.

1.2 Motivation

According to the Ministry of the Environment research conducted in 2016, Japan boasts over three thousand hot spring resorts, one of the world's biggest concentrations, let alone the conventional communal bathing places in the neighborhoods. Blessed with so many volcanic hot springs and rich groundwater from the rainy climate, it is no surprise that Japan is an onsen paradise, which cultivates Japanese people's traditional fondness for full body warm bathing. However, it is the Japanese-style bathing that hampers the update of supporting facilities, keeping the original function and state over time.

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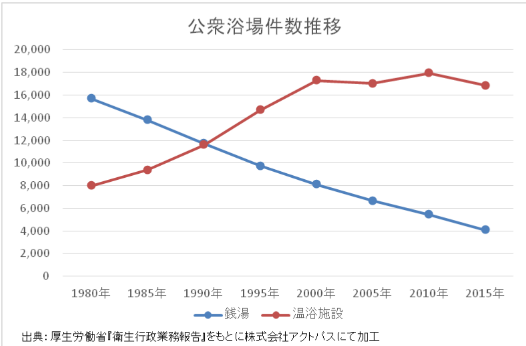


Fig. 1 Transition in the Number of Public Baths

In general, the role of public baths, Figure 1 [2], has been supplanted by private bathtubs due to availability, convenience, and the desire for privacy. However, it is notable that the spa facilities still act as a magnet for both overseas tourists and locals. Thus, it is important to figure out the potential factors related to the customer experience of warm bathing, and how can this information be used to support the operation management, becoming an impulse towards public baths recovery and development.

1.3 Research Goal

This paper presents an IoT scheme "SenTan", applied to the bathing environment for health tracking. In the initial system, the basic interconnecting network requires one IoT gateway and one server, whose storage has the capacity for organizing the data from each wearable and portable sensing device. With the data collection system, several sensors related to the heart rate (HR), electrocardiogram (ECG), blood pressure (BP), body temperature (BT), and accelerated velocity of the users are implemented in the experimental evaluation.

As a pioneer study of the IoT system for health tracking in the bathing environment, two participants are asked to take a 3-week experiment with a one-group pretest-posttest design for evaluation. Their vital signs: ECG, BP, and BT are collected before and after each bath, while the variation in HR and core motion data is recorded during the whole bathing hour. The visualized results of how whole-body immersion bathing and showering affect human health lead to some discussion about the main factors, which may give some inspiration to improve people's experience with bathing and support the health management of public baths.

The prototype SenTan system is supposed to evaluate and extrapolate users' health and activity metrics in the future. With this preliminary study of the acquired data from variable mobile sensors, the well-performed sensors will be embedded in one wearable device for further hardware development and research, ending up meeting the needs of health, safety, and effective operation management in the public baths industry.

2. Related Works and Technology

2.1 The Importance of Vital Signs Monitoring

Vital signs include temperature, respiratory rate, pulse, blood pressure and, where appropriate, blood oxygen saturation. As a means of rapidly quantifying the magnitude of an illness and how well the body is coping with the resultant physiologic stress, these numbers provide critical information about a person's state of health. In particular, they can identify the existence of an acute medical problem.

A study by Hashiguchi et al. [4] evaluated the difference of rectal temperature (Tre), mean skin temperature (Tsk), blood pressure (BP), heart rate (HR) and body weight loss before, during, and after each bathing ways in order to identify the bathroom thermal conditions effects on physiological and subjective responses. Though there is no significant difference in Tre after bathing among the room temperatures, it is surprising that whole-body bathing showed a larger increase in Tre and Tsk than showering. BP decreased rapidly during whole-body bathing compared to showering. HR during whole-body bathing was significantly higher than showering. Significant differences in body weight loss were observed among the bathing methods: whole-body bath > half-body bath > shower, which supports the general idea that water immersion has the same effect as exercise training.

For all that the thermal effects of water immersion are generally beneficial to health, bathing in Japanese style may carry negative effects as water pressure on the chest and thermal stimulus on hemodynamics. [6] The safety considerations in some studies were assessed to analyze the health effects while minimizing the adverse effects of water immersion.

According to research on accidents during bathing, sudden death during bathing accounts for 10 to 15% of all out-of-hospital cardiac arrests in Japan. Among the victims of accidents during bathing, 53% of them were cardiac arrest, and 25% were those who needed rescue from bathtub because of consciousness disturbance. Clinical observation of the rescued people indicated that they suffered from transient loss of consciousness, probably because of elevated body temperature (BT). [5] Water immersion is also associated with the risk of changes in BT according to the water temperature. The geriatric population is vulnerable to the bathing induced heat illness. Therefore, it is necessary to monitor

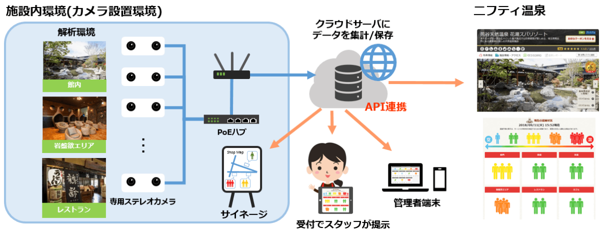


Fig. 2 System Architecture of Nifty Onsen Congestion Information Service

the bathing person for signs of hyperthermia and hypothermia by measuring the vital signs before, during, and after each full body warm bathing.

2.2 IoT Applications in Bathing Environment

The era of the super-smart city is here to stay. Most of us already have smartphones and other smart devices like watches or fitness monitors. As an emerging technology, the IoT is pushing the boundaries of next-generation technology more than ever. Numerous smart appliances and innovations in new and existing structures entitle the bathing environment possibilities.

Rodrigues, R. R. et al. [8] presented an IoT-based automated shower system for smart homes. The smart electric shower worked as a regular shower can be configured to maintain a comfortable temperature and collect several parameters related to power consumption, water flux, and bath temperature. It allows the user to analyze the utilization; however, the physiological factor should also be considered to control the resources.

Nifty Onsen, Figure 2 [7], is a representative of IoT applied to the public baths environment. The system offers a congestion information service that allows the operator to check the real-time congestion status of the central locations in the bathing area. Its primary function is to measure the number of people by detecting and counting the customer's shape with a stereo camera set at fixed places. It is a good try for easier operation management but neglects the customer satisfaction.

To sum up, these smart applications help optimizing resources and facility maintenance, such as electricity, water, and labor, reducing consumption and costs. However, there is no available system yet could readily apply to the bathing environment to improve the user experience of bathing. Physiological and cognitive-behavioral changes should be included to call up a blueprint for IoT applied to the bathing environment.

3. SenTan: an IoT System to Improve User Experience of Bathing

The proposed IoT system, SenTan, is constituent of three modules: data acquisition, data collection, and data accumulation. As Figure 3 shows, by leveraging the information gained from sensors, wearable objects will no longer be used to manage lockers but will become an integral part of user health and behavior through monitored and predictive data. The data will be continuously fed to the cloud, where further analysis takes place before being shared with the operator for contingency measures. This method not only improves user experience but also reduces overall costs.

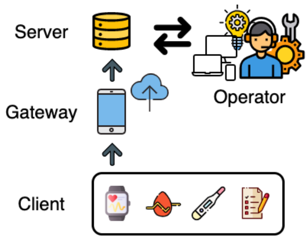
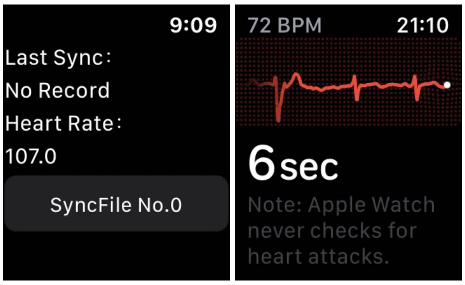


Fig. 3 Scenario of the SenTan



(a) SenTan (b) ECG

Fig. 4 Sensing with Apple Watch

3.1 Data Acquisition Module

The edge, illustrated as the Bluetooth Transmitter Module in Figure 5, comprises three smart devices: Apple Watch, Omron HeartGuide, and Omron Basal Thermometer. The embedded sensors and actuators, such as PPG, electrodes, accelerometer, gyroscope, BP, and BT, acquire the target health and core motion data before, during, and after each bath. They will first save the acquired data locally, then transmit it to the gateway by Bluetooth.

- SenTan Watchkit Extension App
  An iOS paired watchOS application, SenTan Watchkit Extension, is developed to gather the HR and core motion data from the embedded sensors in Apple Watch, Figure 4(a). During the bathing hour, once the SenTan Watchkit Extension app retrieves the HR, the variation will be displayed at the interface for prompt confirmation.
- ECG App
  With the default ECG app, Apple Watch is capable of generating an ECG similar to a single-lead electrocardiogram, Figure 4(b). The electrical impulses data is directly saved into the Health app.
- OMRON HeartAdvisor App
  OMRON HeartAdvisor is the official app paired to the Omron HeartGuide watch for BP synchronization. Once the BP data transmitted to the OMRON app, it will also sync with the Health app.
- OMRON Connect App
  OMRON Connect is the official app paired to the Omron Basal Thermometer for BT synchronization. Once the BT data transmitted to the OMRON app, it will also sync with the Health app.

3.2 Data Collection Module

In the implementation, iPhone as the gateway once collects the data from the edge, saves the corresponding data into the designated iOS app, and finally sends the data as files to the cloud.

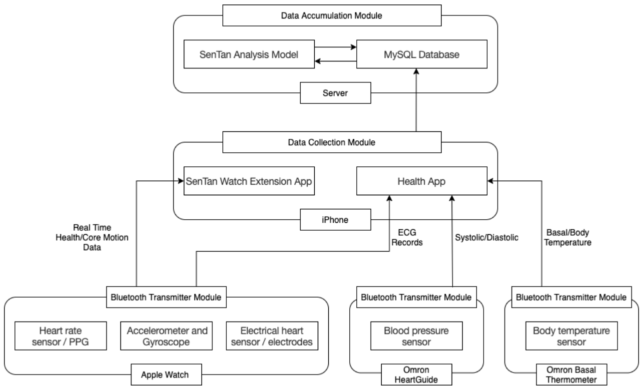


Fig. 5 System Architecture of the SenTan

- SenTan Watch Extension App
  As long as the iOS SenTan app receives the data from the watchOS one, it will upload the data to the server. To prevent data loss in the transmission among the edge, gateway, and the cloud, the SenTan app will archive the real-time data locally, both watch and mobile side.
- Health App
  The data from the ECG app and OMRON apps is converged at the default Health app. Entitled with the edit function, the user can check the data correctness before uploading it. All the health-related data can be exported as a ZIP file sending to the server.

3.3 Data Accumulation Module

The files sent from the gateway are accumulated at the server side. A Python module is written for data parse and file format conversion to CSV files. The categorized data will be merged into the database for later analysis.

4. Evaluation Plan: Whole-Body Immersion Bath and Shower

4.1 Evaluation Criteria

In light of the related works in Section 2, here raises the hypothesis and experimental methodology as the criteria for evaluation.

4.1.1 Hypothesis

1. Taking a warm bath or shower regularly is beneficial to human health.
2. The effect of whole-body immersion bathing is more salutary than showering.

4.1.2 Objective-Subjective Methodology

An experiment with a pretest-posttest design is adopted to determine the warm bathing effect on human health towards the intervention of whole-body immersion bathing or showering. The evaluations are carried out according to results before and after the experiment. As mental health is an indefinite part of being evaluated by auto-collected data, the initial and subsequent survey of health perceptions will support interpreting it. After the intervention, longitudinal and horizontal comparisons are made, combined with data-analysis and self-assessment.

- Health and Behavior Data Collected with the SenTan System
  With the Equation 1, the difference of each vital sign, ECG,

	Worse				Better
Skin Condition	1	2	3	4	5
Pain	1	2	3	4	5
Fatigue	1	2	3	4	5
Stress	1	2	3	4	5
Vigor	1	2	3	4	5

Table 1 5-Item Health Status Survey

	Not Very				Very Much
Overall Satisfaction	1	2	3	4	5
	Worse				**Better**
Heartbeat-Frequency	1	2	3	4	5
Breath-Comfort	1	2	3	4	5

Table 2 Bathing Feedback

BP, and BT, will be compared during the statistical analysis. The variation in HR and core motion data will assist in confirming the result.

$$Difference_{Vital\ Signs} = Value_{Posttest} - Value_{Pretest} \quad (1)$$

- An Initial and Subsequent Survey of Health Perceptions
  Before and after each bath, the participant is asked to fill in the survey in stages. There is a 5-item health status survey, Table 1, to be answered twice a bath, followed by the bathing feedback, Table 2.
  The survey is designed in an ordinal scale for later quantitative analysis with the Equation 2. From 1 to 5, the degree indicates respectively, as worse, bad, normal, good, and better.

$$Difference_{Health\ Status} = Value_{Subsequent} - Value_{Initial} (2)$$

4.2 Experiment

4.2.1 One-Group Pretest-Posttest Design

This study is conducted by using pre-experimental designs in which there is a one-group of people with wearable and portable devices where the pretest-posttest is performed. The one-group pretest-posttest study design is chosen as the same participants and devices for collecting health-related data and surveys, which is needed to be observed in the set time and environment every day.

As a preliminary study, two adult participants as a group will take a 3-week domestic bathing experiment in June. The participants in this study are picked from college students with regular work and rest schedules in one's 20s. The devices and sensors to detect are selected by the portability and data availability within the SenTan system, preparing for further research, development, and promotion.

This one-group trial will assess the effects of a total 3-week intervention consisting of a 1-week shower bathing without immersion intervention after a 2-week whole-body immersion bathing (40° C for 10 min) intervention, so as to compare the overall warm bathing effects between the two interventions.

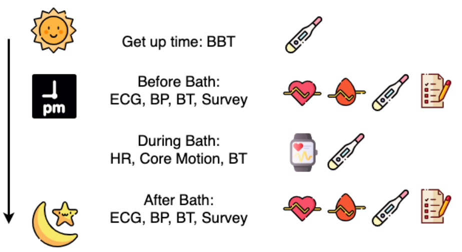


Fig. 6 Experimental Procedure

4.2.2 Experimental Procedure

Shown in the Figure 6, the daily experiment consists of four phases. The first phase is in the morning when the participant gets up, which is the best moment to get one's basal body temperature (BBT). The second phase is before taking a bath as the pretest around 9 PM. ECG, BP, BT will be detected as the baseline with an initial health status survey. During the bathing hour, the participant is asked to activate the SenTan Watch Extension app, wearing the Apple Watch to retrieve the HR and motion-related data all the time. In the middle of the bathing, BT will be sensed once more. The last phase is after bathing, with the same variables to be detected for the posttest. Bathing feedback is attached to the subsequent health status survey.

5. Implementation and Results

5.1 System Implementation

This intervention study was conducted from June 8 to June 28, 2020, to investigate the two bathing methods of whole-body immersion bath (Ofuro) in 40° C warm water for 10 min and showering without immersion. Participants were two healthy adults (2 women; mean age, 22 years), recruited from students at Keio University. They were considered one group who took the intervention of bathing for two weeks, followed by showering for one week. None of the participants consumed any medication or reported illness during the experiment period.

The Ethics Committee of Keio University had approved the experimental study to be carried out in the Lifelog Protocol of Nakazawa Laboratory. All work was conducted according to the principle of data anonymization.

5.2 Dataset Overview

The two participants remained in good health during the 3-week intervention study and completed all measurement items. For each participant, there were 21 pairs of vital sign records (ECG, BP, BT) and survey answers without missing data. The statistical tool MS Excel and R were used for data analysis.

- ECG
  With the 42 pairs of ECG records, no abnormal heart rhythm is discovered, Figure 7 is a one-day sample. As the cardiac rhythm is regular, HR can be determined by the interval between two successive QRS complexes, which is in accordance with the variation in HR detected during the bathing hour.
- BP
  The mean value of three BP measurements in each experiment phase is used to calculate the daily BP change. The

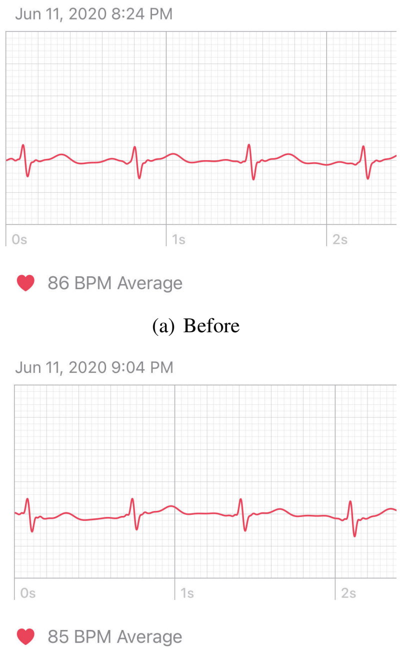


Fig. 7 ECG Sample

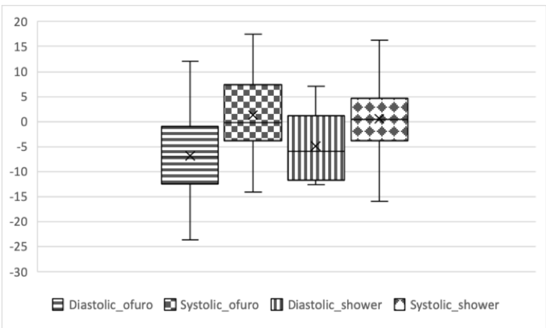


Fig. 8 Difference of BP

difference is then divided by two bathing ways and shown in the box and whisker chart.

Looking at the difference of BP in Figure 8, it is apparent that the diastolic is alleviated around 5mmHg in both bathing ways, while the effect on systolic is slight. The BP analysis will mainly focus on the difference in diastolic change between the two interventions.

- BT

  Figure 9 shows an overview of the BT trend in the 3-week experiment period, 2-week ofuro followed by a 1-week shower. BBT line is as the reference to calculate the absolute value of BT change in the bathing intervention. It can be discerned evidently from the width among the other three lines that both bathing ways have a thermal effect on the body. Furthermore, the first 14-day ofuro presents a more considerable BT raise than the next 7-day shower, either within a half bathing hour or the overall intervention.

- Health Status

  Figure 10 displays the median and range of scores for each health dimension. From each chart, it can be seen that the health perception has been improved to a certain degree after taking a bath. What stands out in the figure is that no matter what kind of bad condition in pain and fatigue, after having the ofuro, the degree will recover to the normal level. The whole-body immersion effect on pain and fatigue recovery should raise attention.

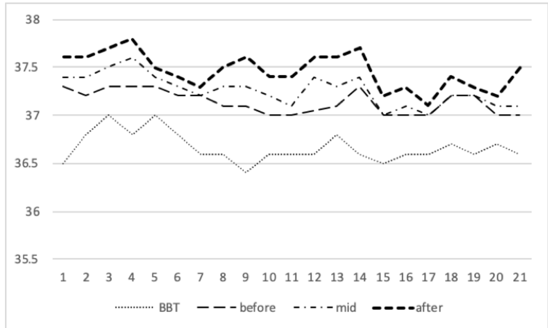
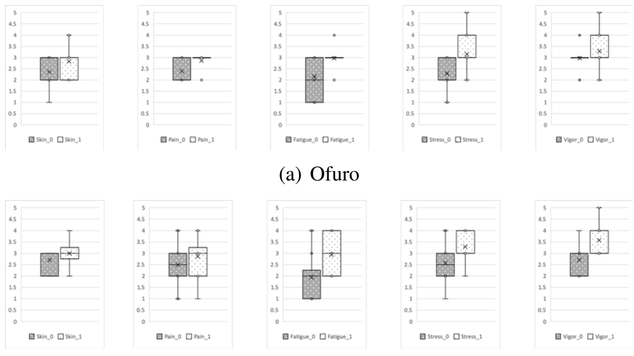


Fig. 9 BT Trend in 3-Week



(a) Ofuro

(b) Shower

Fig. 10 Health Status Overview

5.3 Results

5.3.1 ECG

Though the ECG can reflect the variation in HR to some extent, there is no notable discovery or result of ECG that can be concluded in this preliminary study with the limited sample. Further studies with the background information about the electrical impulse in medicine are required for heart problem investigation.

In any case, it is undeniable that ECG detection is a suitable means of precaution for acute cardiac diseases.

5.3.2 BP

By deriving the mean values before and after each intervention, the diastolic are pointed in Figure 11. The connected trendline reveals that there has been a steeper downtrend slope of BP diastolic after an ofuro intervention.

This result provides support for the hypothesis that taking a bath is beneficial to BP alleviation. Besides, whole-body immersion bathing has a better thermal effect on adjusting BP diastolic than showering.

5.3.3 BT

To better understand the BT variation in the bathing hour, the mean value of BT in each experiment phase is plotted in Figure 12, the trendline is delineated to connect the points. By excluding the BT measurement bias, the differential BT lines are derived from the polynomial trendlines, sharing the same original point in one simulation diagram.

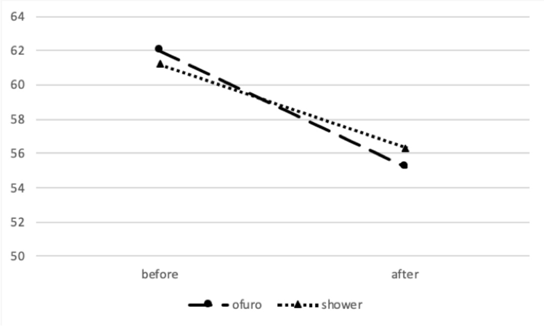


Fig. 11 Downtrend of BP Diastolic

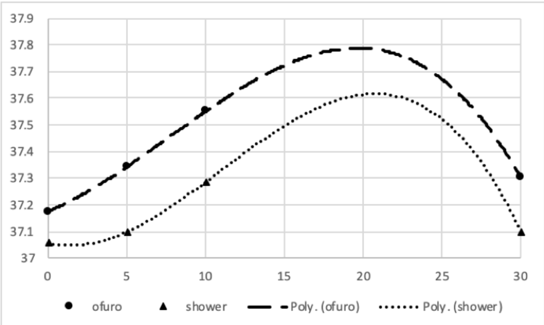


Fig. 12 BT Plot in 30 mins

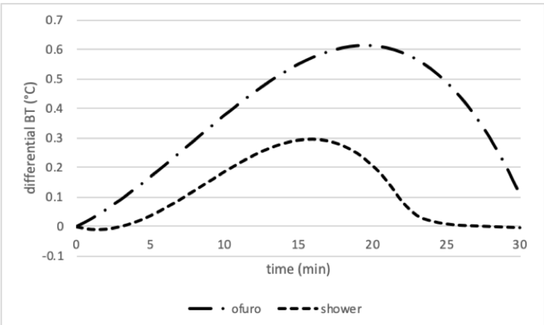


Fig. 13 Differential BT in 30 mins

As shown in Figure 13, there is a clear trend of the BT variation as a hump in each bathing intervention. BT will first increase along with the bathing time, and then gradually reach the cap under the lasting thermal effect, finally return to the average level alike to the condition before taking a bath.

What is striking about the curves is that the ofuro one covers a broader range of the chart. It stands out that the whole-body immersion bathing has a far influence on the period of thermal effect, let alone the BT variation range.

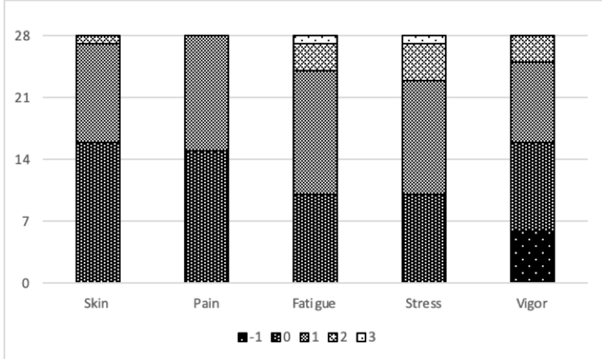
These findings have important implications for discussing the correlation between thermal effect and bathing ways.

5.3.4 Health Status

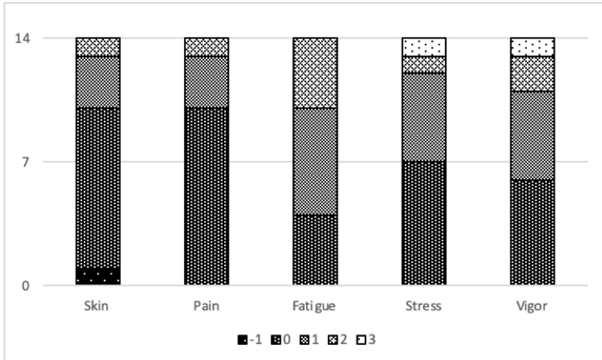
Closer inspection of the proportion of the difference in health perception, Figure 14, shows that the vast majority of the health status has been improved in varying degrees after a bath.

What is interesting in the ofuro chart, Figure 14(a), is that over one-fifth health perceptions reported that the vigor status is worse after ofuro. The finding indicates that the whole-body immersion bathing is not invariably conducive to the overall health status. In some cases, showering has better performance, Figure 14(b).

To figure out the causality of such perception and whether these attributes of health status are correlated with each other need more incisive analysis and discussion in the next chapter.



(a) Ofuro



(b) Shower

Fig. 14 Proportion of Difference in Health Perception

6. Discussion

6.1 Correlation and Causality

6.1.1 Attributes of Health Status

Health status is an individual's comparable level of wellness and illness, taking into account the signs of physiological dysfunction, symptoms, and functional impairment. Alterations of attributes of an individual's health status may lead to distress, interference with daily activities, or contact with health services.

Within the bathing environment, it may be a presence of acute disease, heart arrest, disorder, consciousness disturbance, injury, or trauma, reflecting other health-related states such as emergency, aging, stress, congenital anomaly, or genetic predisposition. Have a panoramic command of the individual health status and health-related states in advance may help check the safety risk during the bathing hour.

After interpreting the answers of the health perception survey into the numerical one, the correlation of the initial and subsequent health status of each bathing way is calculated in Table 3 and Table 4. Areas where significant differences have been found, include fatigue and vigor. Given the imperfection of limited survey answers, the results shown in the tables are further reviewed with an interview in the following sections.

6.1.2 Health Condition and Perception

The perceived health status is subjective ratings by the affected individual of his or her health status. Some people perceive themselves as general healthy levels despite suffering from chronic diseases or ailment, while others perceive themselves in adverse

	Skin	Pain	Fatigue	Stress	Vigor
Skin	1	0.812	0.648	0.733	0.056
Pain	0.812	1	0.751	0.799	−0.245
Fatigue	0.648	0.751	1	0.666	−0.375
Stress	0.733	0.799	0.666	1	0.112
Vigor	0.056	−0.245	−0.375	0.112	1

Table 3 Correlation of Health Status in Ofuro

	Skin	Pain	Fatigue	Stress	Vigor
Skin	1	0.096	−0.405	0.248	0.622
Pain	0.096	1	−0.155	0.057	0.219
Fatigue	−0.405	−0.155	1	0	0
Stress	0.248	0.057	0	1	0.393
Vigor	0.622	0.219	0	0.393	1

Table 4 Correlation of Health Status in Shower

conditions as ill when no objective evidence of disease can be found. That is why this study adopts the objective-subjective methodology and discusses the correlation and causality of experiment results.

In terms of the distinction revealed in the correlation tables, the participants accepted an additional interview and shared their exact experience of the 3-week experiment. There is a consistent sense of the participants that receiving a regular full body warm bathing before sleep helps them recover from the hectic daily life. However, according to the feedback survey, neither of them could point out which bathing way has an impressive advantage over the other.

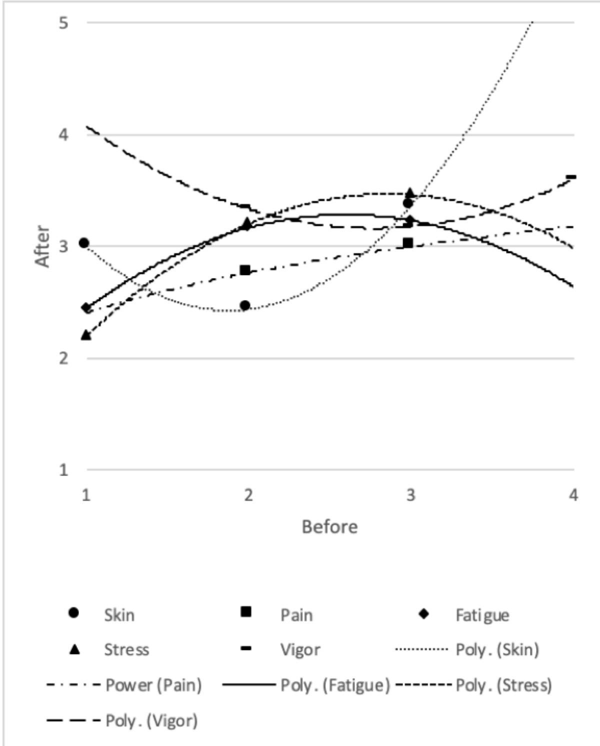
They have found that keeping a relative-rest sitting position in the who-body immersion bathing could relieve their feeling of fatigue but lead a lethargic effect on the health perception reflected in vigor. At the same time, though, showering has a weaker affection on the amelioration of health status other than vigor, they are satisfied with the quick refreshment in routine life. In general, they have acknowledged that taking a warm bath regularly is beneficial to health, while there is no preference for any bathing way.

A trendline attached health perception plot, Figure 15, provides more information about the bathing experience and the transition in each perceived health status. The most striking observation to emerge from the data comparison is that intuitive feelings of bathing experience are more substantial at worse initial health status. When the participant has a 1-worse or 2-bad initial health perception below the average level, taking a bath may have a conspicuous positive effect on mitigating the sick feeling to the regular pattern. In contrast, when the participant already stays in good health before taking a bath, the influence brought by bathing is slightly reflected in the perception. This is a surprising finding not only about the bathing effect but also gives a new perspective to offer customized service to improve user experience in public baths.

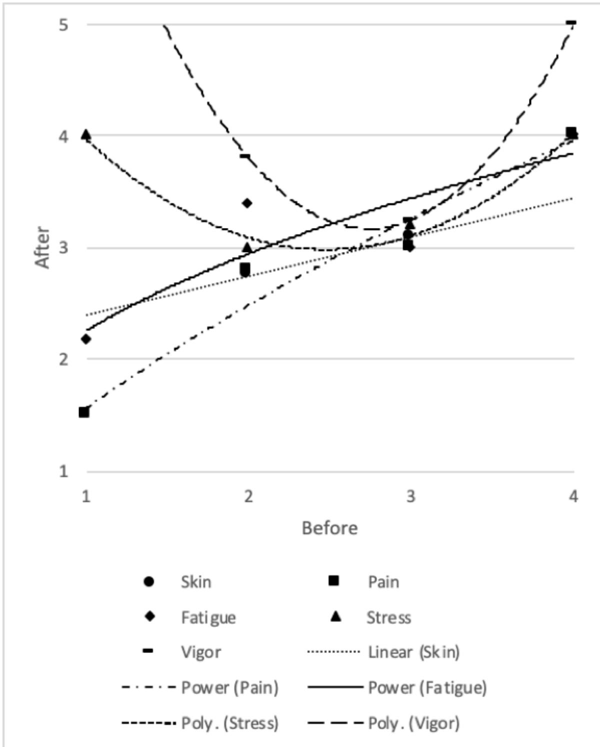
6.1.3 Bathing Experience and Ways

Having an insight into the two charts in Figure 15 with the findings of the health status correlation and interview mentioned before, there are more estimable phenomenons of bathing experience distinguished by bathing ways worth discussing.

Considering Figure 15(a) with the significant correlation in Table 3 together, the positively associated health status of skin, pain, fatigue, and stress can prominently have an integrated recovery from an initial worse health perception to an average level with a whole-body immersion bathing, which performs better than showering. However, in most of the cases, when the participant initially stays active or regular status, the bathing experience effected by immersion bathing is poorer than showering.



(a) Ofuro



(b) Shower

Fig. 15 Health Perception Plot

In summary, the whole-body immersion bath is an effective way to affect people getting complete recovery from a lousy health perception in a short time or as a relish to routine life; the shower is efficient and economical to meet everyday refreshment needs.

6.2 Limitation

This preliminary study aimed to determine the warm bathing effect by tracking human health with a proposed IoT system. For all the collected data offered plenty of estimable information, there are concerns that the study was limited in various aspects, such as the necessity of implemented sensors, control of the bathing environment, sample size, and individual difference in the bathing habit. In order to manage further research on health monitoring with IoT in the real public baths environment, these limitations will be taken into account to develop an improvement scheme in future work.

7. Conclusion

7.1 Summary of the SenTan

An IoT system, SenTan, is proposed to collect user's vital signs and core motion data for improving user experience of bathing in this study. Within a 3-week experimental evaluation, the participants' health-related data has been tracked by the SenTan with surveys. The difference and variation in vital signs and health status are distinguished by bathing ways to portray the full body warm bathing effect on human health.

7.2 Contribution

As a pioneer study of the IoT system applied to the bathing environment for improving user experience, a health-tracking system, SenTan, is proposed and implemented in a 3-week quasi-experimental evaluation to figure out the warm bathing effect on human health. By evaluating the objective health-related data collected by the SenTan and the health perceptions from surveys, a conclusion can be drawn that taking a full body warm bath regularly is beneficial to human health. The findings in the discussion may serve as a stimulus for further investigation of the correlation between bathing ways and health perceptions, to clarify the salutary effects of warm bathing, facilitating the public baths industry.

7.3 Future work

As a starting point, this research is conceived to inspire a series of novel research to be conducted in future graduate studies. Depending on the practical progress of system engineering, larger-scale implementation and experiment will be carried forward progressively. To have a randomized controlled trial within the public baths environment could be an ideal way to impartially detect and control the potential environmental factors (such as room/water temperature, ambient humidity, water quality/pressure) on bathing experience. Furthermore, discovering and identifying high-correlated data from the vast health and activity metrics might be the question remaining unsolved. A background of medicine in the cardiovascular system is crucial to having an insight into further research and exploring the causality. Something new might be probed in data science to raise public attention far more than health and safety.

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References

[1] J. An, I. Lee, and Y. Yi. The thermal effects of water immersion on health outcomes: an integrative review. *International journal of environmental research and public health*, 16(7):1280, 2019.

[2] AQUTPAS Inc. History and current state of the public baths industry, 2017.

[3] V. E. Brunt, A. T. Jeckell, B. R. Ely, M. J. Howard, D. H. Thijssen, and C. T. Minson. Acute hot water immersion is protective against impaired vascular function following forearm ischemia-reperfusion in young healthy humans. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 311(6):R1060–R1067, 2016.

[4] N. Hashiguchi, F. Ni, and Y. Tochihara. Effects of room temperature on physiological and subjective responses during whole-body bathing, half-body bathing and showering. *Journal of physiological anthropology and applied human science*, 21(6):277–283, 2002.

[5] S. Hori, M. Suzuki, K. Ueno, Y. Sato, and T. Kurihara. Accidents during bathing. *Nihon rinsho. Japanese journal of clinical medicine*, 71(6):1047–1052, 2013.

[6] Y. Kataoka and F. Yoshida. The change of hemodynamics and heart rate variability on bathing by the gap of water temperature. *Biomedicine & pharmacotherapy*, 59:S92–S99, 2005.

[7] NIFTY Lifestyle Co., Ltd. Nifty Onsen IoT Service. https://onsen.nifty.com/ip-onsenIoT/, 2018.

[8] R. R. Rodrigues, J. J. P. C. Rodrigues, M. A. A. da Cruz, A. Khanna, and D. Gupta. An iot-based automated shower system for smart homes. In *2018 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, pages 254–258, 2018.