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Article

Comparison of the Physical Properties of Showers that the Satisfaction of Shower Feeling among Users in Three Asian Countries

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Abstract: The purpose of this study was to construct a scheme that makes it possible to compare the relationship between water usage, satisfaction, and physical properties in three countries. The physical properties of the shower were measured using physical properties testing apparatus of water-saving standard or scheme for showerheads issued in several water-saving countries and data for users satisfaction evaluation was acquired through bathing experiments. In this paper, we analyzed the result from Taiwanese and Vietnamese individuals to compare them to of Japanese subjects analyzed in the previous study. We compared the physical properties of showers assessed low in satisfaction by Taiwanese, Vietnamese and Japanese subjects. It was assumed that spray pattern tends to decrease satisfaction when the water volume ratio within 100 mm and 150 mm of a measuring device is located a 450 mm distance from the showerhead is low, and that, because all three countries showed the same value, it was imagined that there were no differences in the water volume ratio of high-satisfaction showerheads among three countries. On the other hand, the values of Spray Force-per-Hole, Temperature Drop, and Spray Angle were different among three countries. We speculated that these differences are affected respectively by ethnic differences in pain tolerance, thermoregulatory response and bathing habit.

Keywords: shower; standard; physical property; Taiwan; Vietnam

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1. Introduction

In recent years, the shortage of water resources has become a serious global issue. The use of water-saving showers, which are expected to reduce the amount of water used daily, is thought to preserve water resources. In addition, using water, especially to heat it up, consumes energy for its transportation and purification, as well as for sewage treatment. It is pointed out that this consumption of energy also results in the emission of CO_2. Several studies have reported that there are large amounts of CO_2 emission from bathrooms, where a large amount of water is used [1,2]. As a result, the use of water-saving showers that can reduce the amount of daily water usage is also effective in reducing the volume of CO_2 emissions.

However, it is noted in previous reports [3] and in our own research [4] that the satisfaction feeling of shower is virtually dependent on flow rate. In other words, there is a trend where, as usage flow rate decreases, satisfaction also decreases, showering that there exists a trade-off between satisfaction and water-saving. Unless water-saving showers that can deliver a satisfying feeling to its users are developed, they will not be accepted by the market, thus not leading to a reduction in the amount of water usage. Water-saving showerheads that can deliver a satisfying shower experience are required in order to promote the efficient use of water through the popularization of water-saving showers.

In past studies regarding to satisfaction of high-efficiency showerheads, perceptions and satisfaction of shower were assessed by sensory evaluation [5,6]. These studies identify the perceptions (e.g., spray force) that affect the satisfaction of shower feelings. However, there is fear that assessment score can vary due to individual characteristics of subjects. There are also other studies that analyze the physical factors affecting satisfaction through the analysis of the relationship between satisfaction evaluations and the physical property values of the shower [6–14]. In these studies, the physical properties of showers that enhance the satisfaction feelings of showers are investigated. To promote reduction of water use through the popularization of high efficiency showerheads, it is essential to compare differences of the physical properties that affect satisfactions between several populations. However, comparison is difficult because methods for determining physical properties are different among respective researchers.

This study was made to propose a method that analyzes the relationship between satisfaction, water usage, and physical properties of shower that were determined using existing physical properties test apparatus for water-saving showerheads. The goal of this study was (1) to construct the method that makes it possible to compare the result between consumers in different countries; and (2) to clarify the design requirement of showerhead reducing water consumption and having high satisfaction feelings of shower. Recently, we reported the result of analysis of the relationship between water consumption, satisfaction feelings of shower and physics of shower spray in Japanese subjects [4]. This paper presents the result of analysis of Taiwanese and Vietnamese subjects and compares the results with that of Japanese subjects.

Following is the summary of the research procedure.

(1) Satisfaction feelings of nine showerheads are assessed by sensory scale.
(2) The physics of the showerheads spray are determined with existing physical properties test apparatus.
(3) The relationship between water consumptions, satisfaction feelings of shower and physics of shower spray in Taiwan and Vietnam are analyzed.

These results are compared with the result of Japan analyzed in previous study.

2. Methods

2.1. Determination of Physical Properties

Design parameter and flow rate of showerhead are shown in Table 1. Physical properties of the shower obtained from the previous study [4] are used for this analysis. The determinations were conducted in accordance with AS/NZS3662:2013 [15]. However, the values for the usage water flow conditions are those determined in Table 1.

Table 1. Design value of showerheads and usage flow rate.

Shower No.	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Flow Rate [L/min]	6.5	5.5	6.9	8	4.9	5.5	7.5	13	9.5
Hole diameter [mm] × Number of holes	φ 1.15 × 42	φ 0.5 × 33 φ 1.0 × 20	φ 0.3 × 236	φ 0.8 × 47	φ 0.6 × 36	φ 0.65 × 32	φ 1.3 × 90	φ 1.3 × 90	φ 0.7 × 86
Total area of spray holes [mm^2]	44	13	17	24	10	11	119	119	33
Spray velocity [m/s]	2.98	8.20	6.89	5.64	8.02	8.63	1.81	1.05	4.78
Face plate size [mm]	Lh: 34, 30 Lw: 42	36	50	26	48	32	120	120	120
Average of hole diameters [mm]	42	52	236	47	36	32	90	90	86

Summaries of the determination procedure [4] for each of the physical properties are as follows. Spray Force was determined using a water receiving plate with a digital force gauge attached. The measured value is the force value of the water sprayed on the water receiving plate vertically from above. Spray Pattern was measured using a water collection device positioned on concentric circles centered on 50 mm diameter circle, gradually enlarged in 50 mm diameter intervals. The water discharge distribution is measured when water is sprayed vertically from above the water collection apparatus. The measured value is the ratio of water volume collected in each concentric circle in relation to the total volume of water sprayed. The same determination apparatus used for measuring Spray Pattern is used to measure Spray Angle, and is calculated using the measured value and a formula defined in the standard. Temperature Drop is measured by measuring the difference between the spray temperatures adjacent to the showerhead and at a set distance from the showerhead. The measurement distance for the physical properties took into consideration the use of the shower when holding it by hand and by attaching it to the wall, just as for bathing experiment conditions, and the distance from the shower faceplate to the apparatus for Spray Force, Spray Pattern, and Spray Angle was set to 450 mm.

2.2. Evaluation of Satisfaction

2.2.1. Evaluation Method

Bathing experiments were conducted and sensory evaluations for satisfaction of shower feeling were performed for the showerheads indicated in Table 1. Although evaluations of satisfaction for showers may include exterior design, weight, and ease of handling, in this paper, evaluation was limited to the satisfaction of the sprayed water as the objective was to develop a shower spray that provides a high level of satisfaction.

Showerheads adjusted using valves to dispense the spray flow rate predetermined in Table 1 were set in advance in the bathrooms used for the experiment. Subjects held the showerheads in their hands in the bathroom, adjusted the spray so that the water hit their chests, and then performed evaluations. Evaluations of the satisfaction of the spray were based on seven levels: Very unsatisfied, unsatisfied, slightly unsatisfied, neutral, slightly satisfied, satisfied, very satisfied. The evaluations were assigned grades of 1 to 7 and the results tabulated. When evaluation of one showerhead was completed, it was replaced with another showerhead, and the evaluation was repeated using the same procedure.

2.2.2. Experiment Location, Experiment Period, Subjects

The experiments were conducted in Taipei and Taichung (TAIWAN) in October 2013, and in Hanoi (VIETNAM) in December 2013. There were 18 subjects (healthy Taiwanese individuals consisting of 9 males and 9 females) and 19 subjects (healthy Vietnamese individuals consisting of 8 males and 11 females).

2.2.3. Survey of Bathing Habit

The survey of bathing habit for subjects was conducted. The question item was the frequency bathing using bathtub.

2.3. Survey of Shower Water Temperature

A survey of shower water temperature was conducted in households of Japan and Taiwan. The participants of this survey were 30 people in Japan (Fukuoka, Japan), and 63 other people (from Taipei, Taichung, Taiwan). First, the participants adjusted shower water temperature as usual in each home. Next, they filled a bucket with water discharged from the shower. Finally, the participants measured the water temperature by a thermometer.

3. Results and Discussion

3.1. Analysis of Relationship between Physical Properties, Usage Water Flow and Satisfaction

The correlation coefficient between the usage water flow and satisfaction was 0.147 in Taiwan and 0.129 in Vietnam. There were no significant correlations through uncorrelated tests. It is believed that there were no relationship between satisfaction grades and usage water flow with these two countries, as opposed to Japan where, according to our previous research [4], satisfaction grade increased with the increase in usage water flow.

Next, in order to analyze factors other than the usage water flow that influence satisfaction, analyses were made to determine if there were differences in satisfaction and physical properties between showerheads with a high level of satisfaction and those with a low level of satisfaction, as well as between normal showerheads that use a high volume of water and low-flow showerheads that use smaller volumes of water. When creating these four groups, the threshold for water flow for low-flow showerheads and normal showerheads were set 7.5 L/min based on the ASME A112.18.1-2012/CSA B125.1-12. [16] and AS/NZS6400:2005 [17]. In addition, as a seven-level method was used for sensory evaluations to measure satisfaction, the threshold was set at 4 (neutral) and the grades were divided into a high satisfaction group and a low satisfaction group. Through this, the showerheads were divided into Group I—Low flow-high satisfaction group (three showerheads), Group II—Low flow-low satisfaction group (three showerheads), Group III—Normal flow-high satisfaction group (three showerheads), and Group IV—Normal flow-low satisfaction group (zero showerheads). As there were no showerheads that fit into Group IV, in actuality the showerheads were divided into three groups. Table 2 indicate the groups of showerheads.

Table 2. Groups of showerheads.

Group	Taiwan	Vietnam
Ⅰ Low Flow—High Satisfuction	S1, S3	S1, S2, S3, S6, S8
Ⅱ Low Flow—Low Satisfuction	S2, S5, S6, S8	S5
Ⅲ Normal Flow—High Satisfuction	S4, S7, S9	S4, S7, S9
Ⅳ Normal Flow—Low Satisfuction	--	--

In order to analyze the difference in satisfaction between these three groups, the satisfaction grades for the showerheads in each group were averaged and a one-way variance analysis and multiple comparisons (Tukey b method) were conducted. The results are shown in Table 3.

Compared to the low flow-high satisfaction group (Group I) and the normal flow-high satisfaction group (Group III), the low flow-low satisfaction group (Group II) had significantly lower values in satisfaction in the result of Taiwan and Vietnam. On the other hand, significant differences in satisfaction could not be observed for the low flow-high satisfaction group (Group I) and the normal flow-high satisfaction group (Group III). This result may show that high level of satisfaction can be achieved with low flow rate showers if other factors are optimized.

Table 3. Result of ANOVA and multiple comparisons (satisfaction).

Satisfaction		I	II	III	F-Value	Multiple Comparison
		Low Flow	Low Flow	Normal Flow	** $p <$	
		High Satisfuction	Low Satisfuction	High Satisfuction	0.001	
Taiwan	AVERAGE	5.0	3.7	4.6	9.176 **	I, III > II
	SD	0.3	0.2	0.2		
Vietnam	AVERAGE	4.9	3.7	4.8	5.096 **	I, III > II
	SD	0.2	0.3	0.2		

Next, In order to analyze the difference in Spray Force, Spray Pattern, Temperature Drop and Spray Angle between these three groups, the measurement values for the showerheads in each group were averaged and a one-way variance analysis and multiple comparison (Tukey b method) were conducted. The results are shown in Table 4.

Table 4. Result of ANOVA and multiple comparisons (physical properties).

Countries	Physical Properties		I	II	III	F-Value	Multiple Comparison
			Low Flow	Low Flow	Normal Flow	** $p < 0.001$	
			High Satisfuction	Low Satisfuction	High Satisfuction	* $p < 0.005$	
Taiwan	Spray Force [N]	AVERAGE	1.0	1.0	1.2	68.671 *	III > I, II
		SD	0.2	0.1	0.1		
	Spray Force (per-hole) [N]	AVERAGE	0.01	0.025	0.018	31.495 **	II > II, I> I
		SD	0.01	0.010	0.004		
	Spray Pattern φ 100 [%]	AVERAGE	46	42	29	72.756 **	I, II > III
		SD	9	20	4		
	Spray Pattern φ 150 [%]	AVERAGE	87	74	54	333.253 **	I, II > III
		SD	2	27	4		
	Temperature Drop [°C]	AVERAGE	1.9	1.9	1.5	6.993 **	I, II > III
		SD	0.4	0.9	0.3		
	Spray Angle [deg]	AVERAGE	5	5	5	0.222	--
		SD	1	2	2		
Vietnam	Spray Force [N]	AVERAGE	1.0	0.9	1.2	71.552 **	III > I > II
		SD	0.2	0.0	0.1		
	Spray Force (per-hole) [N]	AVERAGE	0.020	0.027	0.018	6.733 **	II > I, III
		SD	0.011	0.000	0.004		
	Spray Pattern φ 100 [%]	AVERAGE	49	15	29	109.868 **	I > III > II
		SD	13	0	4		
	Spray Pattern φ 150 [%]	AVERAGE	87	31	54	519.096 **	I > III > II
		SD	10	-	4		
	Temperature Drop [°C]	AVERAGE	1.6	3.4	1.5	150.792 **	II > I, III
		SD	0.5	0.0	0.3		
	Spray Angle [deg]	AVERAGE	5	4	5	0.872	--
		SD	2	0	2		

After investigating the relationship between Spray Force and usage water flow, compared to the two low flow groups (Groups I and II), the spray force value for the normal flow-high satisfaction group (Group III) was significantly higher in Taiwan. Although, a significant difference was not recognized, the spray force value of Group III was also higher in Vietnam. It is generally understood that spray force is proportional to flow velocity and water volume, and from this, it can be presumed that spray force also has an influence on usage water flow.

Next, no significant difference could be observed in the relationship with satisfaction between the low flow-high satisfaction group (Group I) and the low flow-low satisfaction group (Group II). This suggests that spray force does not influence satisfaction in both countries.

The relationship of Spray Force-per-Hole with usage water flow, satisfaction of showers was investigated. Spray Force-per-Hole value was calculated as a spray force value per hole obtained by dividing the force received by the entire water receiving plate by the number of holes in the showerhead.

First, for the relationship between usage water flow and Spray Force-per-Hole, the Spray Force-per-Hole value was significantly higher for the normal flow-high satisfaction group (Group III) when compared to the low flow-high satisfaction group (Group I) in both countries. As with the spray force, it is understood that Spray Force-per-Hole is also proportional to the flow rate per hole or the velocity of spray. As the water flow per hole is higher when usage water flow is higher, it is believed that the Spray Force-per-Hole influences usage water flow.

Next, from the relationship with satisfaction, compared to the low flow-high satisfaction group, the low flow-low satisfaction group had significantly higher values in result of Vietnam, and it was shown that lower Spray Force-per-Hole values increases satisfaction. On the other hand, in the result of Taiwan, in contrast to the low flow-high satisfaction group (Group 1), the Spray Force-per-Hole value was significantly higher for the normal flow-high satisfaction group (Group III), and a difference in Spray Force-per-Hole value could be seen within the high satisfaction group where there was no difference in satisfaction. These results suggest that, in Taiwan although the Spray Force-per-Hole value influences satisfaction, this influence no longer applies when a certain level of satisfaction is reached.

The spray pattern measurement results are shown in Figure 1. Because particular difference in water volume ratio among showerheads could be seen with the 100 mm and 150 mm diameters, a comparison was made with each group of the ratio between the total water volume and the water volume distributed within 100 mm and 150 mm.

Results from studying the relationship between usage water flow and water volume ratio showed that the normal flow -high satisfaction group (Group III) had significantly higher values for both 100 mm and 150 mm values compared to the low flow-high satisfaction group (Group I) in the results of Taiwan and Vietnam. On the other hand, spray pattern can be controlled to a certain degree through spray hole angle, allowing for designs independent of usage water flow. As such, it is difficult to assume that there is a relationship between spray pattern and usage water flow. These results led to the belief that, compared to normal flow showerheads, low flow showerheads were designed so that spray pattern is concentrated in the center.

Next, in the comparison between the two high satisfaction groups (Groups I and II) and the low flow-low satisfaction group (Group II), no significant difference could be observed in the result of Taiwan. On the other hand, when focusing on the sample spray pattern for the low flow-low satisfaction group (Group II), there was different trend compare with others, as seen in Figure 1, which has spray with distributed spray pattern (S5). From this, it was assumed that satisfaction is lost when the spray is either too distributed. Although there is a need for further analysis in the future with a larger sample size, there is a possibility that spray pattern influences satisfaction in Taiwan. In the result of Vietnam, compared to the two high satisfaction groups (Groups I and III), the spray pattern value for the low flow-low satisfaction group (Group II) was significantly lower. So, satisfaction reduces with spray distribution in both countries. This result suggests that the water ratio of 100 mm and 150 mm values influence satisfaction in Vietnam.

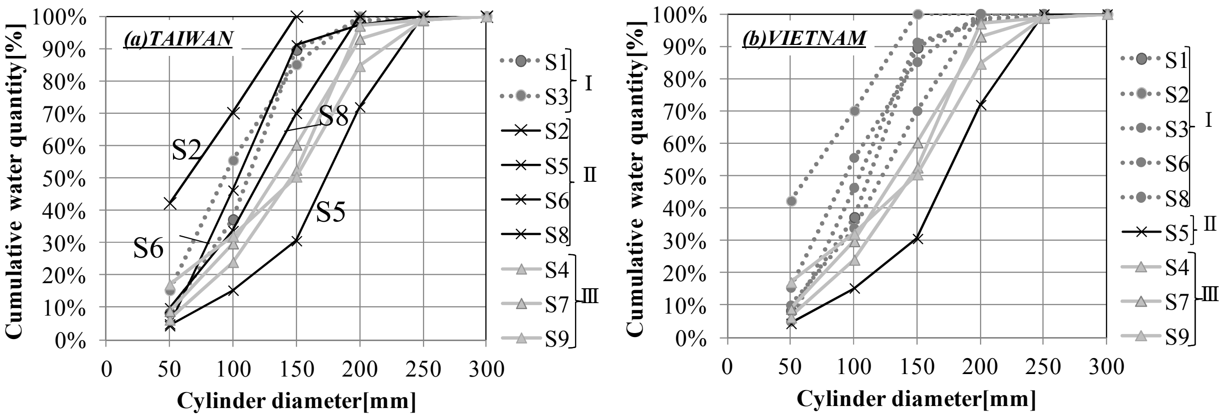

Figure 1. Spray Pattern (**a**) Taiwan; (**b**) Vietnam.

The relationship between Temperature Drops and the usage water flow was compared between the low flow-high satisfaction group (Group I) and the normal flow -high satisfaction group (Group III). The result of Taiwan showed significant differences within each group. The result suggests that usage water flow is low when the value of the Temperature Drop is high. The results of Vietnam showed no significant differences within each group and so there was no indication of the relationship between usage water flow and Temperature Drops.

It is assumed that Temperature Drop depends on the heat quantity of flow line and droplets of shower spray. Heat quantity of flow line and droplets increase with water flow, and Temperature Drop decreases, which means that water flow can be assumed to correlate with Temperature Drop. However, no significant differences were found between low flow-high satisfaction group (Group I) and the normal water flow-high satisfaction group (Group III) in the result of Vietnam in this experiment. We studied the reason for this phenomenon. The average hole diameter for each groups can be found on Table 5. Because some showerheads had two or more different hole diameters, we calculated the average hole diameter by dividing the total surface area of all the holes with the total number of holes on the showerhead. Comparing the low-flow-high satisfaction group (Group I) and the normal water flow-high satisfaction group (Group III), the average hole diameter of the normal water flow-high satisfaction group (Group III) was 0.9 mm in the results of Taiwan and Vietnam. In contrast, the average of diameter of the low-flow-high satisfaction group (Group I) was 0.7 mm in the result of Taiwan, and 0.8 mm in the result of Vietnam. From the above fact, It is speculated that what caused the lack of difference found in the Vietnamese result was the fact that the droplets of the low flow-high satisfaction group (Group I) were big in size, reducing the amount of temperature loss despite less water being used.

The relationship between Temperature Drops and satisfaction was compared between the low flow-high satisfaction group (Group I) and the low flow-low satisfaction group (Group II). The results of Taiwan showed no significant differences within each group and so there was no indication of the relationship between satisfaction and Temperature Drops. The results of Vietnam showed significant differences within each group and the result suggests that Temperature Drops influence satisfaction.

Table 5. Average of spray hole diameters.

Countries	I	II	III
	Low Flow	**Low Flow**	**Normal Flow**
	High Satisfuction	**Low Satisfuction**	**High Satisfuction**
Taiwan	φ 0.73	φ 0.78	φ 0.93
Vietnam	φ 0.79	φ 0.6	φ 0.93

Regarding the relationship between spray angle, usage water flow and satisfaction, there were no significant differences and so there were no indication of the relationship.

From these results, it is believed that Spray Force, Spray Force-per-Hole and Temperature Drop are physical properties that influence usage water flow. It was also shown that Spray Force-per-Hole and Spray Pattern are physical properties that influence satisfaction. Also, there is a possibility that water volume ratio of 100 mm and 150 mm is a physical property that influences satisfaction for both countries. In additions, it was assumed that Temperature Drop influences satisfaction in Vietnam.

3.2. Comparison of the Results in Japan, Taiwan and Vietnam

The results from analyses in Taiwan and Vietnam were added to the results of the analysis conducted in Japan shown in [4] above, and the results of the three countries compared and considered.

First, three factors; Spray force, Spray force per hole, temperature drop were extracted as physical properties which affect usage water flow in all three countries. This relationship can also be theoretically explained, and it is believed that there is no difference between countries.

Next, in regards to physical properties that have a proportional relationship to satisfaction, a comparison was conducted in Japan, Taiwan, and Vietnam. Table 6 shows the average sample value for the low flow-low satisfaction group (Group II) in each country. Physical properties that were thought to have no influence on satisfaction are indicated with a "-". Differing trends could be seen for Spray Pattern values within Group II in Japan and Taiwan. As such, for Japan, the average values have been indicated for S2 and S6, where more concentrated spray patterns could be seen compared to other groups, as well as that for S5, for which a diffused value was seen. For Taiwan, the value for S5, for which a more diffuse pattern was seen compared to other groups, has been indicated.

First, for Spray Force-per-Hole, the trend in all three countries was a decline in satisfaction when Spray Force-per-Hole became too great. When comparing average values, the largest was Japan with 0.030 N, followed by 0.027 for Vietnam, and 0.025 N for Taiwan. It is believed that the difference in these values possibly indicates a difference in tolerance values for localized loads. In previous research that may have a relationship with tolerance values for localized loads, there is research on the differences between races regarding tolerance to pain. There has been research conducted on threshold and tolerance to mecanically applied stimuli comparing Danish Caucasians and South Indians [18], and betweeen Belgians and Japanese [19]. In the research, the threshold for pain was higher for Asians compared to Caucasians, but with lower tolerance. Although there was no reseach found comparing Japanese with Taiwanese and Vietnamese, because the threshold for pain differs, it can be inferred that localized load is associated with low satisfaction levels, in other words, a difference could be seen in the average value for load per hole.

Table 6. Comparison of Group value among three countries.

Physical Properties	Japan	Taiwan	Vietnam
Spray Force [N]	--	--	--
Spray Force-per-hole [N]	0.029	0.023	0.023
Spray Pattern φ 100 [%]	--	--	20
Spray Pattern φ 150 [%]	--	35	34
Temperature Drop [°C]	2.1	--	3.2
Spray Angle [°]	5	--	--

Spray Pattern measurement results showed a trend in all three countries where satisfaction decreased if the water volume ratio within φ 100 and φ 150 was low. Only in Japan was there a trend where satisfaction decreased when the water volume ratio was too large. However, because the average value for the low satisfaction sample was 96%, this was deemed to be nearly 100%. Because the average value for water volume ratio that was seen to provide low satisfaction was practically the same for all three countries, it can be inferred that the water volume ratio within φ 100 and φ 150 that increases satisfaction remains the same regardless of country.

The Temperature Drop measurement results showed a trend in Japan and Vietnam where satisfaction decreased when the Temperature Drop was large. No relationship could be observed in Taiwan. When comparing the average values for samples in Japan and Vietnam for which satisfaction was evaluated as being low, the value was 2.3 °C for Japan and 3.4 °C for Vietnam. The differences in these values indicate a difference in tolerance for temperature drops, and it is believed that the Japanese may have a stricter tolerance for temperature drops. There is previous research relating to this where it has been reported that there are differences between races when it comes to human body temperature adjustment response [20,21]. For example, when exposed to heat, rectal temperatures for Malays, who live in tropical regions, do not rise as easily as the Japanese, who live in mesodermal climates, and because there is a large rise in temperature of the extremities for the Malays, they have a greater ability to effectively stabilize their internal body temperature, giving them abilities appropriate for tropical climates [22,23]. The average temperature in Japan (Fukuoka Prefecture) is 17.0 °C [24], a temperate zone, while Taipei, Taiwan has an average temperature of 23.0 °C [25], a subtropical zone, while Hanoi, Vietnam has an average temperature of 24 °C [26], a tropical zone. From this, there is a high possibility that compared to the Japanese, the Taiwanese and Vietnamese have abilities appropriate for high temperatures. In addition, According to the result of survey regarding shower water temperature, the average temperature for Japan was approximately 39.0 °C while the average temperature for Taiwan was approximately 36.1 °C. In previous research [27], it was reported that no changes in heart rate were observed when bathing in still water with a temperature of 36 °C, which is close to the average temperature for Taiwan, while heart rate increased when bathing in still water with a temperature of 38 °C, close to the average for Japan. It is believed that compared to the Taiwanese who use showers while trying not to warm up their bodies as this leads to increased blood circulation around the entire body, increasing heart rate, the Japanese use showers to warm up their bodies. From the above, it is believed that it may be that receiving heat is felt as satisfying for the Japanese who live in a temperate area, while the Taiwanese and Vietnamese, who live in subtropical and tropical areas feel satisfaction in releasing heat from their bodies in order to cope with the high temperature environment. Perhaps this is why there was no indication for the Taiwanese of a relationship with satisfaction even when the water temperature dropped, and that tolerance values were lower in Japan than in Vietnam.

In regards to Spray Angle, a relationship with satisfaction could only be indicated for Japan, and there was a trend of lower satisfaction evaluations when spray angles were too great. Although various factors can be suggested as to why indications could be seen of a relationship between spray angle and satisfaction that exists only in Japan, this paper focused on differences in bathing habits. According to the result of survey regarding bathing habit, only 3% of the Japanese subjects responded that they do not bathe in the bathtub at all, while the numbers were 66% for the Taiwanese subjects and 61% for the Vietnamese. This is believed to indicate that while Japanese bathing habits mainly involve bathing in a bathtub, the Taiwanese and Vietnamese only shower. It is believed that in Japan, the Japanese shower using the washing area next to a bathtub filled with hot water. Compared to shower sprays with small spray angles, those with larger angles have a shallower angle of incidence when hitting the body, making it easier for water that bounces off the body after hitting the skin to spray all around the surrounding area. It is believed that because there is a conscious effort to avoid getting water that bounces off when showering from falling in the bathtub, the Japanese feel a lower level of satisfaction when the spray angle is large.

In this study, we speculated that these differences are affected respectively by ethnic differences in pain tolerance, thermoregulatory response, bathing habit. However, there is a possibility that these differences are affected by many factors; age or gender of people, geography, socioeconomic factors. For instance, Berardi [28] reports that the gender differential affects water usage and amount of showering. This further analysis is an issue for the future.

4. Conclusions

The purpose of this study was to construct a scheme that makes it possible to compare the relationship between usage of water, satisfaction, and physical properties in several countries. In this paper, we analyzed the result from Taiwanese and Vietnamese subjects and compared them to that of Japanese subjects analyzed in the previous study. From these results, it is believed that Spray Force, Spray Force-per-Hole and Temperature Drop are physical properties that influence usage water flow. It was also shown that Spray Force-per-Hole, water volume ratio of Spray Patterns 100 mm and 150 mm are physical properties that influence satisfaction for both countries. In addition, Temperature Drop also was shown to influence satisfaction in Vietnam.

Next, we compared the physical properties of shower assessed low in satisfaction by Taiwanese, Vietnamese and Japanese subjects. It was assumed that spray pattern tends to decrease satisfaction when the water volume ratio within 100 mm and 150 mm is low, and that, because all three countries showed the same value, it was imagined that there were no differences in the water volume ratio of high-satisfaction showerheads among three countries. On the other hand, the values of Spray Force-per-Hole, Temperature Drop, and Spray Angle were different among three countries. We speculated that these differences are affected respectively by ethnic differences in pain tolerance, thermoregulatory response and bathing habit.

To promote reduction of water use through the popularization of high efficiency showerhead, a guideline of physics value to guarantee satisfaction feelings of showering needs to be established. In the future, we will investigate this guideline.

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Author Contributions

Minami Okamoto designed and performed the experiment, analyzed and interpreted the data and wrote the draft of the manuscript. Ryohei Yaita performed the experiment, analyzed and interpreted the data. Minoru Sato participated in study designed and interpreted the results. Masayoshi Kamijo analyzed, interpreted the data and helped to draft the manuscript. Kanako Toyosada, Yasutoshi Shimizu and Kyosuke Sakaue participated in study design and coordination and helped to draft the manuscript. Wan-Ju Liao, Meng-Chieh Lee and Cheng-Li Cheng participated in study design, performed the experiment and interpreted the result. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Shimizu, Y.; Dejima, S.; Toyosada, K. The CO_2 Emission Factor of Water in Japan. *Water* **2012**, *4*, 759–769.
2. Hakket, M.J.; Gray, N.F. Carbon Dioxide Emission Savings Potential of Household Water Use Reduction in the UK. *J. Sustain. Dev.* **2009**, *2*, 36–43.
3. Gidding, D. Low Flow Showerheads as a Regional Energy Savings Measure. RTF Meeting 2010. Available online: http://rtf.nwcouncil.org/meetings/2010/02/Measure%20Assessment%20-%20 Showerheads%20-%2020100125.docx (accessed on 30 March 2015).
4. Okamoto, M.; Sato, M.; Shodai, Y.; Kamijo, M. Identifying the physical properties of showers that influence the satisfaction of shower feeling for the purpose of developing water-saving showers. *Water* **2015**, *7*, 4054–4062.
5. Water and Energy Efficient Showers: Project Report 2007. Available online: http://www. allianceforwaterefficiency.org/assets/0/28/142/48/88/C86DEB33-2463-4795-BE5E-A66EA64CAB3E.pdf (accessed on 28 March 2015).

6. Okamoto, M.; Sato, M.; Shodai, Y. Analysis of factors affecting showering comfort—Comparison between Japan and Taiwan. *J. Affect. Eng.* **2015**, *14*, 173–180.
7. Woolf, D.; Pau, I.; Shouler, M. Shower head design: Increasing performance at lower flow rates. In Proceedings of the 32nd International Symposium on Water Supply and Drainage for Buildings, Taipei, Taiwan, 18–20 September 2006; pp. 18–20.
8. Alkhanddar, A.R.; Phipps, D.; Karci, B.; Hordessuex, J. Saving water in showers. *J. Phys. Conf. Ser.* **2007**, *76*, doi:10.1088/1742-6596/76/1/012064.
9. High-Efficiency Showerhead Performance Study: Final Report 2010. Available online: http://www.map-testing.com/assets/files/Showerhead%20Final%20Dec%202011.pdf (accessed on 28 March 2015).
10. Kondo, T.; Hanao, M.; Takasu, N.; Otuka, M.; Kamata, M. Study on methods of designing showerheads: The effects on optimum flow rate and comfort condition resulted from difference in size and angle of shower heads' hole. *J. Arch. Plan.* **2003**, *563*, 61–67. (In Japanese)
11. Murakawa, S.; Nishina, D.; Inoue, K. A Study on the Design Requirements of Equipment for Taking a Shower: Part 2-Evaluation of Shower Heads Based on the Subject's Feeling for Uses. *J. Soc. Heat. Air Cond. Sanit. Eng. Jpn.* **1995**, *58*, 119–131. (In Japanese)
12. Kiyono, A.; Inoue, T.; Mae, M.; Iwamoto, S.; Kurafuchi, T.; Otuka, M.; Sato, M.; Yatsuzuka,H.; Hirosawa, S.; Mori, Y.; *et al.* Study on properties and feelings of hot water saving faucet and showerhead: Part 1 Study on properties of showers by an experiment of force of flow, Summaries of technical papers of annual meeting. *Arch. Inst. Jpn.* **2013**, *2013*, 621–622.
13. Okamoto, M.; Sato, M.; Yamazaki, H.; Shodai, Y.; Cheng, C.L.; Sakaue, K. Study on relationship between the subjective shower feeling and the criteria for low-flow showerhead. In Proceedings of the International Symposium on Water Supply and Drainage for Buildings CIB062, Nagano, Japan, 17–20 September 2013; pp. 645–655.
14. Yaita, R.; Okamoto, M.; Sato, M.; Shodai, Y.; Lee, M.C.; Cheng, C.L.; Sakaue, K. Study on Comfort of Hand Shower in Vietnam. In Proceedings of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Akita, Japan, 3–5 September 2013; pp. 33–36.
15. Australian Standard. *Performance of Showers for Bathing*; AS3662:2013; SAI GLOBAL: Sydney, Australia, 2013.
16. ASME Standard, CSA Standard. *Pumbing Supply Fittings*; American Society of Mechanical Engineers (ASME) A112.18.1-2012/CSA B125.1-12; CSA Group: Toronto, ON, Canada, 2012.
17. Australian/NewZealand Standard. *Water Efficient Products-Rating and Labelling*; AS/NZS6400: 2005; SAI GLOBAL: Sydney, Australia, 2005.
18. Gazerani, P.; Arendt-Nielsen, L. The impact of ethnic difference in response to capsaicin-included trigeminal sensitization. *Pain* **2005**, *117*, 223–229.
19. Nayak, S.; Shiflett, S.C.; Eshun, S.; Levine, F.M. Culture and gender effects in pain beliefs and the prediction of pain tolerance. *Cross Cult. Res.* **2000**, *34*, 135–151.
20. Nigel, A.S. Taylor, N. Ethnic differences in thermoregulation: Genotypic *vs.* phenotypic heat adaptation. *J. Ther. Biol.* **2006**, *31*, 90–104.
21. Marino, F.E.; Lambert, M.I.; Noakes, T.D. Superior performance of African runners in warm humid but not in cool environmental conditions. *J. Appl. Physiol.* **2003**, *96*, 124–130.

22. Mohamed, S.; Yutaka, T.; Nobuko, H.; Sirisinghe, R.G.; Mizuho, F.; Chin, M.C. Effects of Exercise in the Heat on Thermoregulation of Japanese and Malaysian Males. *J. Physiol. Anthropol. Appl. Hum. Sci.* **2005**, *24*, 267–275.
23. Lee, J.Y.; Wakabayashi, H.; Wijayanto, T.; Hashiguchi, N.; Saat, M.; Tochihara, Y. Ethnic differences in thermoregulatory responses during resting, passive and active heating: Application of Werner's adaptation model. *J. Appl. Physiol.* **2011**, *111*, 2895–2905.
24. Japan Meteorological Agency. Available online: http://www.data.jma.go.jp/obd/stats/etrn/view/nml_sfc_ym.php?prec_no=82&prec_ch=%95%9F%89%AA%8C%A7&block_no=47807&block_ch=%95%9F%89%AA&year=&month=&day=&elm=normal&view= (accessed on 19 March 2015).
25. Central Weather Bureau 1981–2010. Available online: http://www.cwb.gov.tw/V7e/climate/monthlyMean/tx.htm (accessed on 19 March 2015).
26. Hydro-Meteorological Service of Vietnam. Available online: http://worldweather.wmo.int/082/c00308.htm (accessed on 19 March 2015).
27. Kishino, T.; Nagahama, A.; Sasagawa, K.; Matsuda, M. Heart rate variability during the bathing in still water and flowing water. *J. Jpn. Soc. Balneol. Climatol. Phys. Med.* **1996**, *59*, 175–183. (In Japanese)
28. Berardi, U.; Alborzfard, N. Water consumption in dormitories: InsIghts from a survey in the United States. In *Sustainable Water Use and Management*; Springer International Publishing AG: Cham, Switzerland, 2015.