FUKUOKA WOMEN'S UNIVERSITY

Comparative study of optimum flow rates for hot-water saving shower heads

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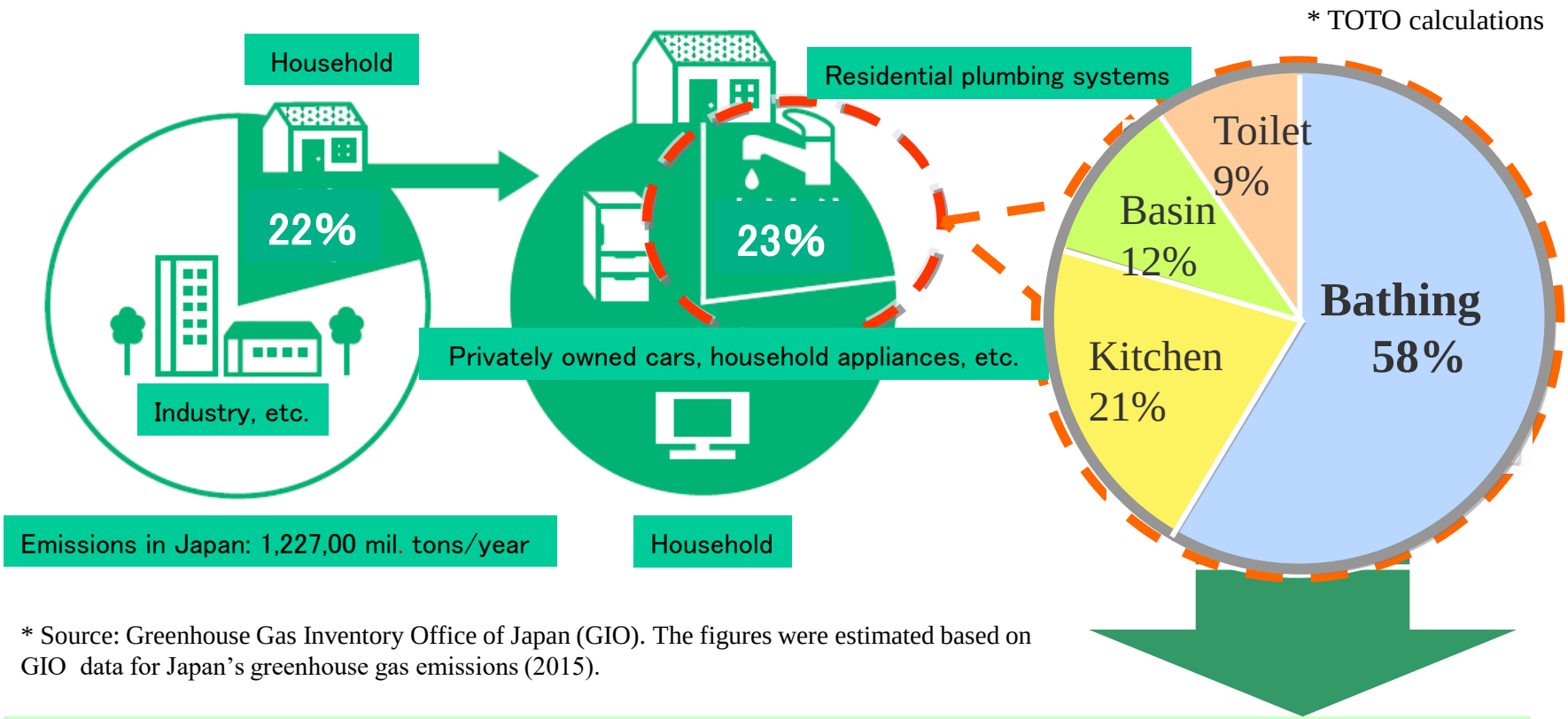
CO_2 Emissions from residential plumbing systems



* Source: Greenhouse Gas Inventory Office of Japan (GIO). The figures were estimated based on GIO data for Japan's greenhouse gas emissions (2015).

CO_2 Emissions from household water facilities ⇒ About 5% of total emissions in Japan

CO_2 emissions from household water related facilities constitute approximately 5% of Japan's total emissions.
About 60% of that is from bathing.

How hot water saving faucets are defined

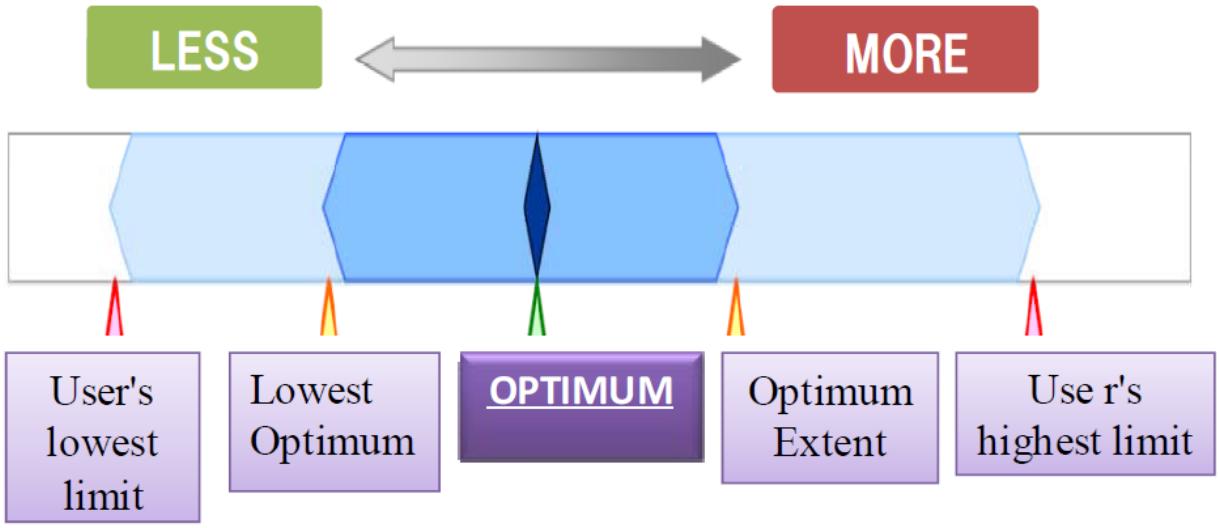
Standard Name		Energy-saving Standard for Household/building	Building Owners' Standard for Judgment
Water saving faucet definition		Products which meet the hot water saving faucet regulations	Products which meet the monitoring test for hot water saving faucets, decided by Japan Valve Manufacturers' Association.
Hot water saving types and effects	Temporary stop button	Hot Water Saving **A1** Kitchen faucets: 9% reduction Shower for bathing: 20% reduction	Hot Water Saving **A** Kitchen faucets: 9% reduction Shower for bathing: 20% reduction
	Low water flow	Hot Water Saving **B1** Shower for bathing: 15% reduction	Hot Water Saving **B** Kitchen faucets: 17% reduction Shower for bathing: 15% reduction
	Function to emit water preferentially	Hot Water Saving **C1** Kitchen faucets: 30% reduction Wash basin faucets: 30% reduction	
	All above	Hot Water Saving **A1** Hot Water Saving **C1** Kitchen faucets: 36% reduction	Hot Water Saving **AB** Kitchen faucets: 24% reduction Shower for bathing: 32% reduction

（Source: Japan Valve Manufacturers' Association）

For hot water saving B (showers for bathing) the optimum flow rate is less than 8.5L /min.

⇒"an effective wash and showering comfort" must be maintained.

Monitoring test method of showers for bathing（hot water saving B）



Conditions:
Spray the chest with shower water. The flow rate at each sensation is recorded.

Participants:
10 or more (equal number of male/female).

Optimum pressure

= The average of three optimum pressures, found after comparisons in one experiment.

<**Explanation**>

-Accounting for discrepancies, the optimum pressure is first calculated .

-It is then calculated again after finding the average maximum of bearable pressure, and then again after the finding the minimum extent.

（Source: Japan Valve Manufacturers' Association）

"Optimum Flow Rate" represents the flow rate felt to be optimum by the 10 participants – not too strong, not too weak.

Purpose of this study

To date, there are few studies that analyse the relationship between optimum flow rate and participant's age/sex.

Therefore, in this research, we examined the differences in "optimum flow rate" according to the attributes of participants and examined the relation between attributes and qualitative evaluations of "showering comfort" and "perceived spray strength".

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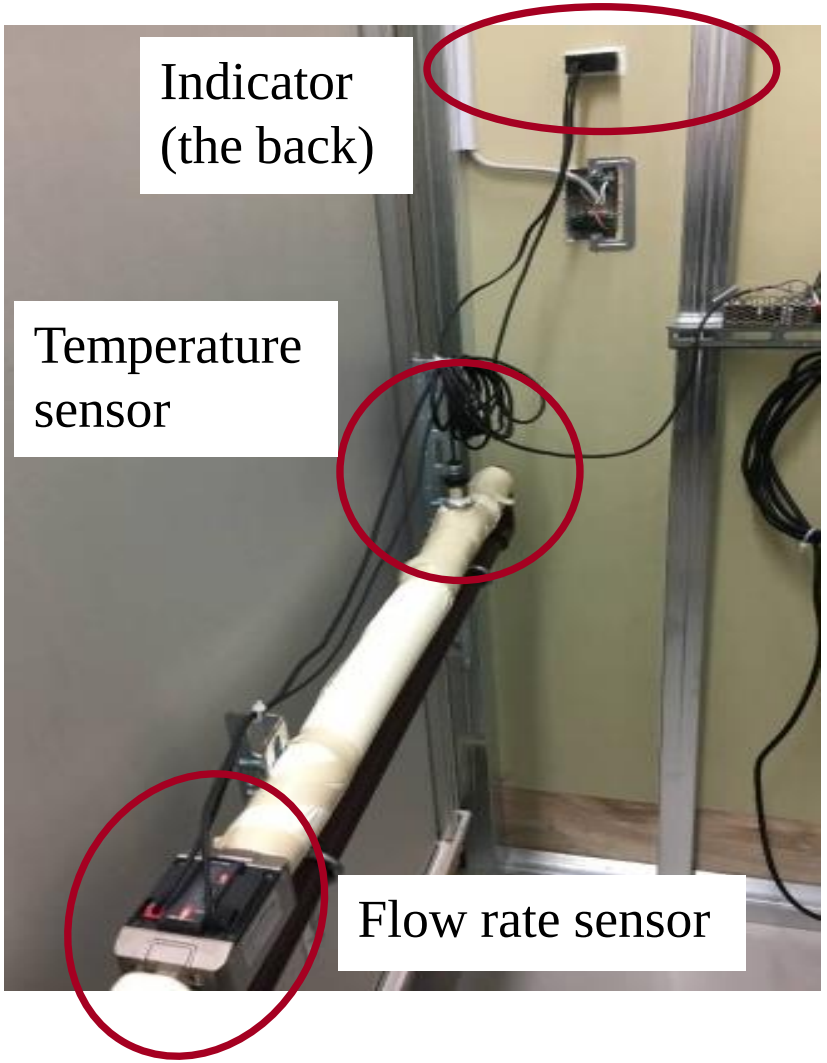
Test outline

Testing period	**5 December 2016 – 20 January 2017**
Site	Shower unit room in research building A, no. 203 (laboratory) Fukuoka Women's University
Participants	Men and women in their 20s and men and women aged 40-60 (each group of 10, total 40 participants)
Room temperature	26℃（inside the shower unit）
Items of measurement	For 4 showerheads, optimum flow rate, upper limit of comfort flow rate, maximum limit for usage, lower limit for comfort flow rate, minimum limit for usage, hot water temperature
Interview items	For each of the 4 shower heads, a 5-point evaluation on showering comfort and the perceived strength of the spray

Shower unit room (left) and the back (right)



Overview of tested showerheads

	A	B		C	D
Showerhead surface					
Hole diameter [mm]	1.2	0.5	1*3	0.85	1.2
Number of holes	40	60	4	48	60
Showerhead's sprinkler plate diameter [mm]	55	85		59	92
Water Pressure at 6.5L/min [MPa]	0.037	0.023		0.026	Under 0.020

Test method

Flow rate measurement	(1) The faucet thermostat in the shower unit is set to the participant's desired hot water temperature. (2) The participant holds the first shower head in their hand, 30 cm from their chest and they adjust the flow rate valve. (3) For the second shower head, perform the measurements of section 2, above. (4) For the third shower head, perform the measurements of section 2, above. (5) For the fourth shower head, perform the measurements of section 2, above.
Rest	Rest for 20 minutes.
Qualitative evaluation	(1) Flow rate is set at 6.5L/minute. (2) The faucet thermostat in the shower unit is set to the participant's desired hot water temperature. (3) The 4 shower heads in order are evaluated by pointing at the chest and evaluating showering comfort and strength of spray based on a 5-point scale. 【Showering comfort】 1：Extremely bad 2：Bad 3：Average 4：Good 5：Extremely good 【Spray strength】 1：Weak 2：Quite weak 3：Not sure 4：Quite strong 5：Strong

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Optimum flow rate（no shower head distinction）

（L/min）

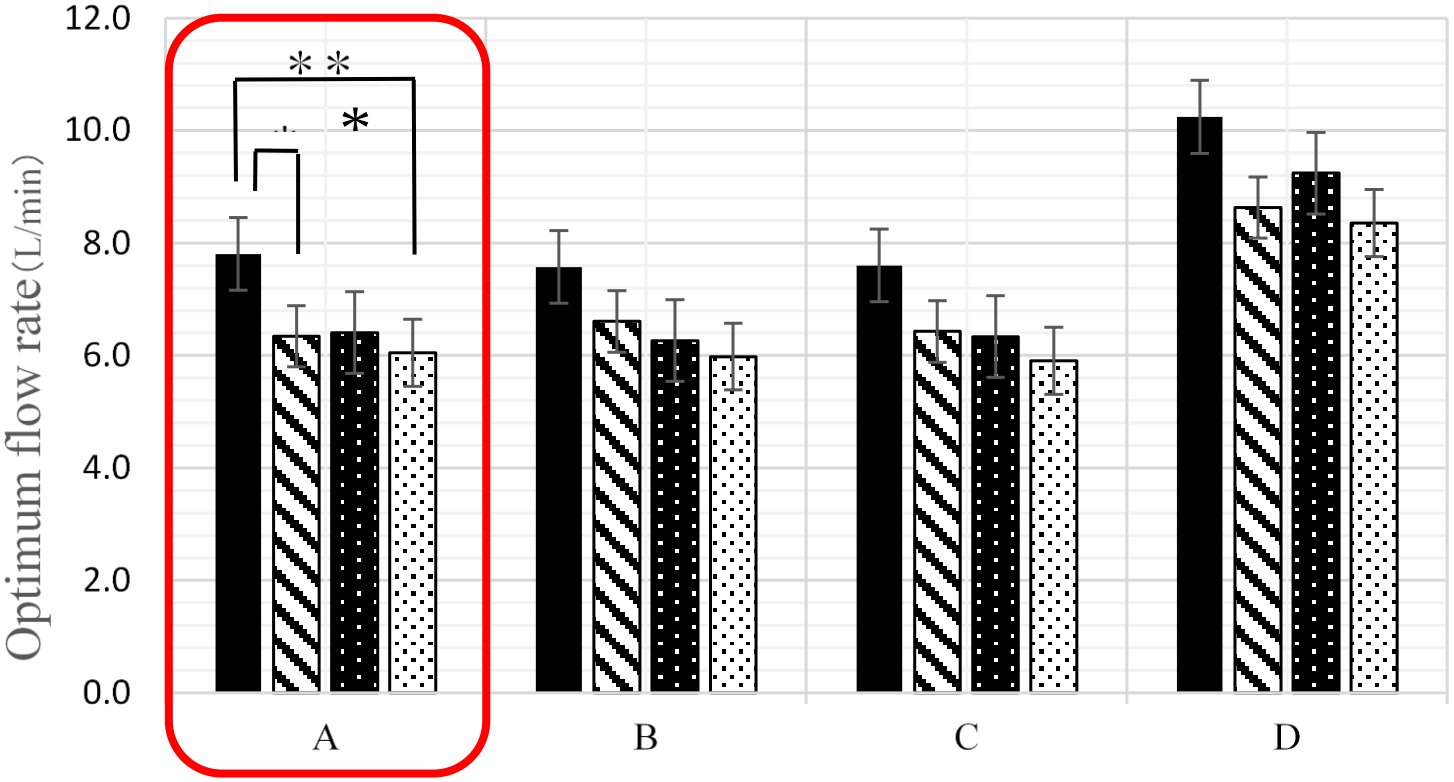
	Average value	Standard error
All	7.24	0.17
Men in 20s	8.31	0.39
Men in 40s 50s	7.00	0.33
Women in 20s	7.06	0.28
Women in 40s 50s	6.57	0.29

Results of variance analysis of optimum flow rate (no shower head distinction)

Groups		Standard error	Significance probability (p)
Men in 20s	Men in 40s and 50s	0.4617	0.027
	Women in 20s	0.4617	0.039
	Women in 40s and 50s	0.4617	0.001
Men in 40s and 50s	Women in 20s	0.4617	0.999
	Women in 40s and 50s	0.4617	0.789
Women in 20s	Women in 40s and 50s	0.4617	0.713

(P<0.05：Significant difference, 0.05≦P<0.1：Significant trend)

Results from testing significant difference by each showerhead's optimum flow rate and participant's attributes



A

Optimal flow average（L/minute）			
A	B	C	D
6.7	6.6	6.6	9.1

＊＊：P<0.05(significant difference)
＊：0.05≦P<0.1：significant trend

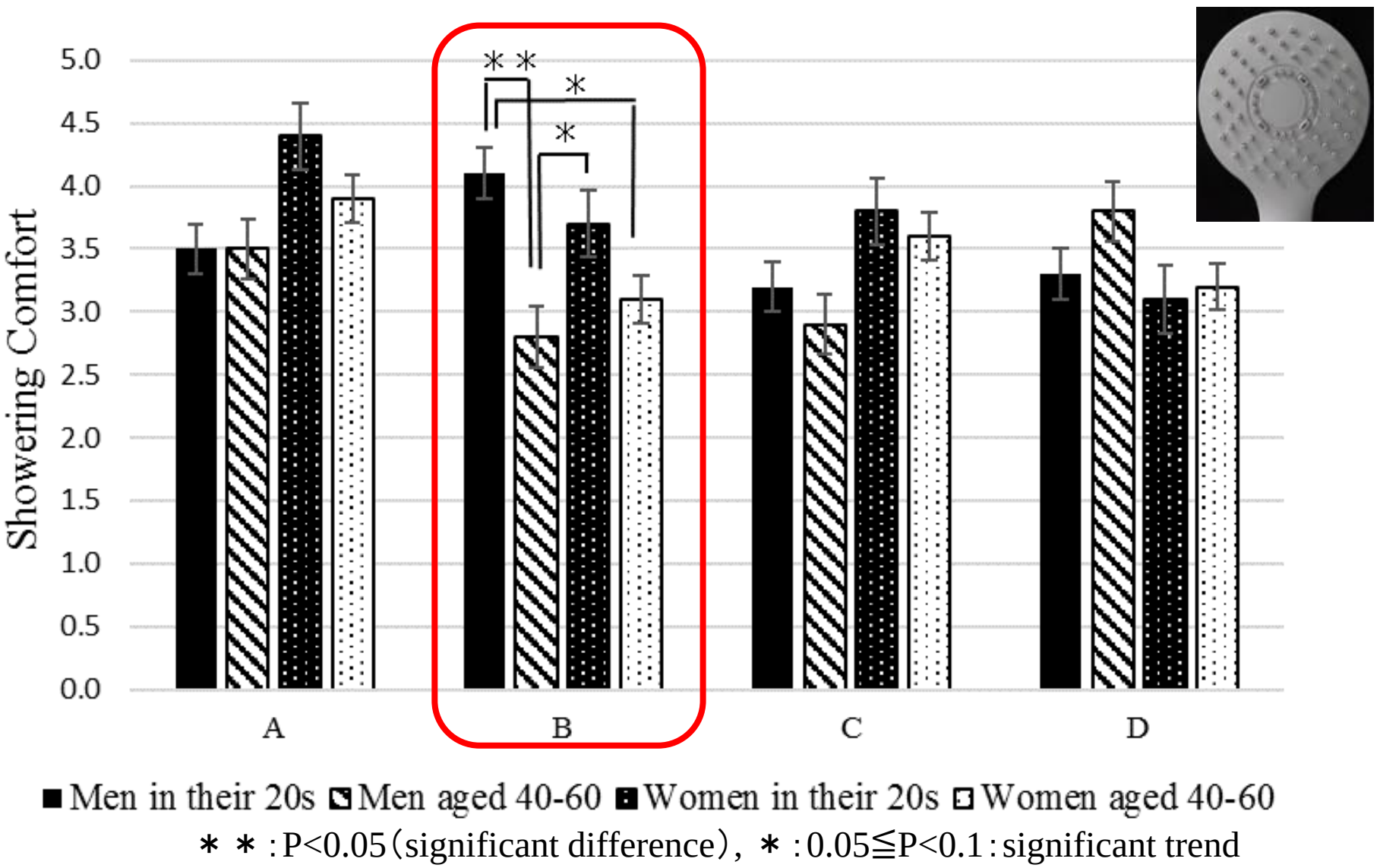
Qualitative evaluation of showerheads

Showerhead	Showering comfort	Perceived strength of spray
A	3.8	3.1
B	3.4	3.4
C	3.4	3.4
D	3.4	2.0

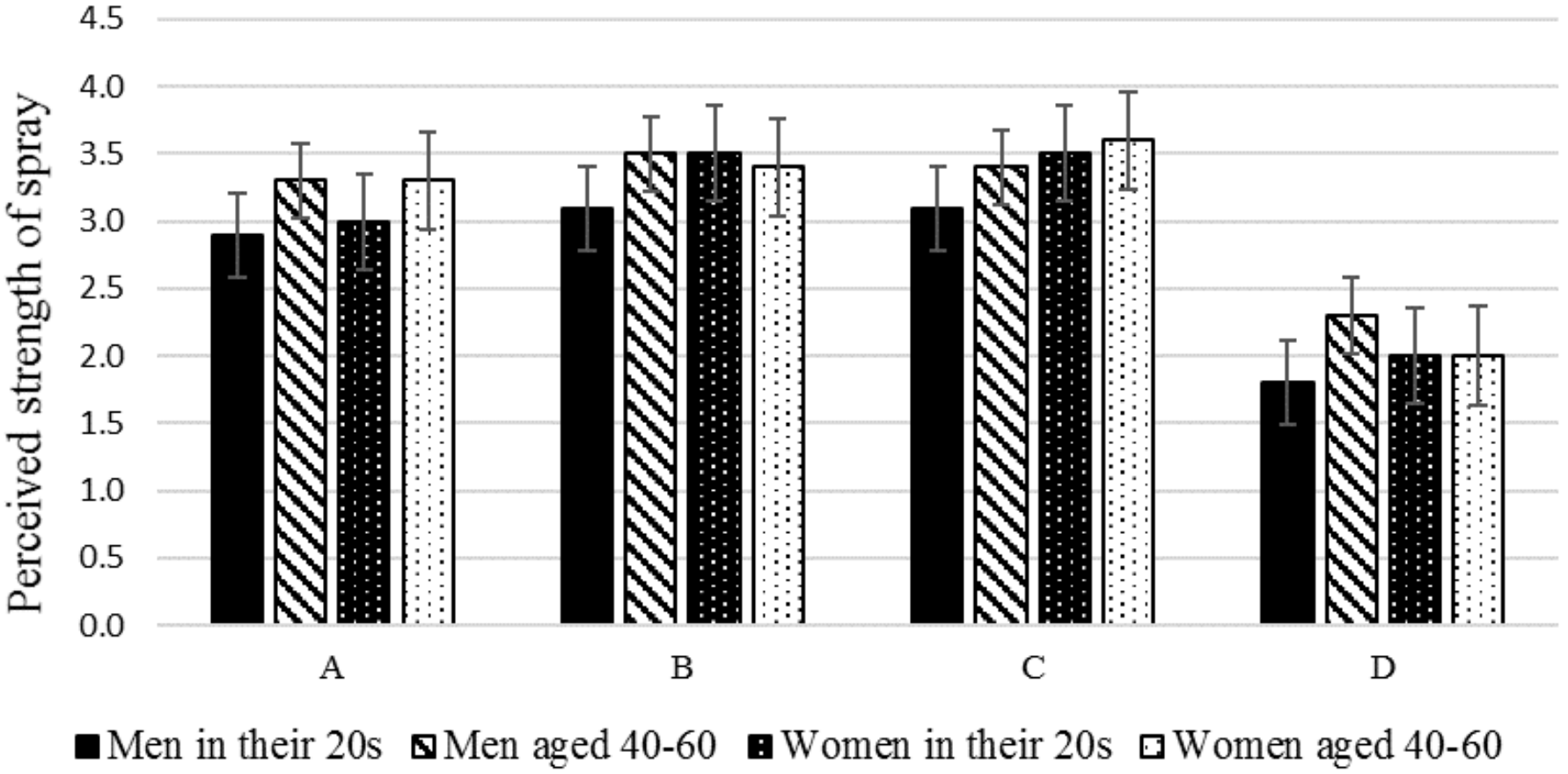
For showering comfort, A was highly rated.
For perceived strength of spray, D was rated low.
（Because the evaluation of D occurred at 6.5L/min, less than the optimum flow rate.）

Optimal flow average（L/minute）			
A	B	C	D
6.7	6.6	6.6	9.1

Significance test results based on participants' group and evaluation of each shower head's showering comfort



Significance test results based on participants' group and evaluation of strength of spray sensation

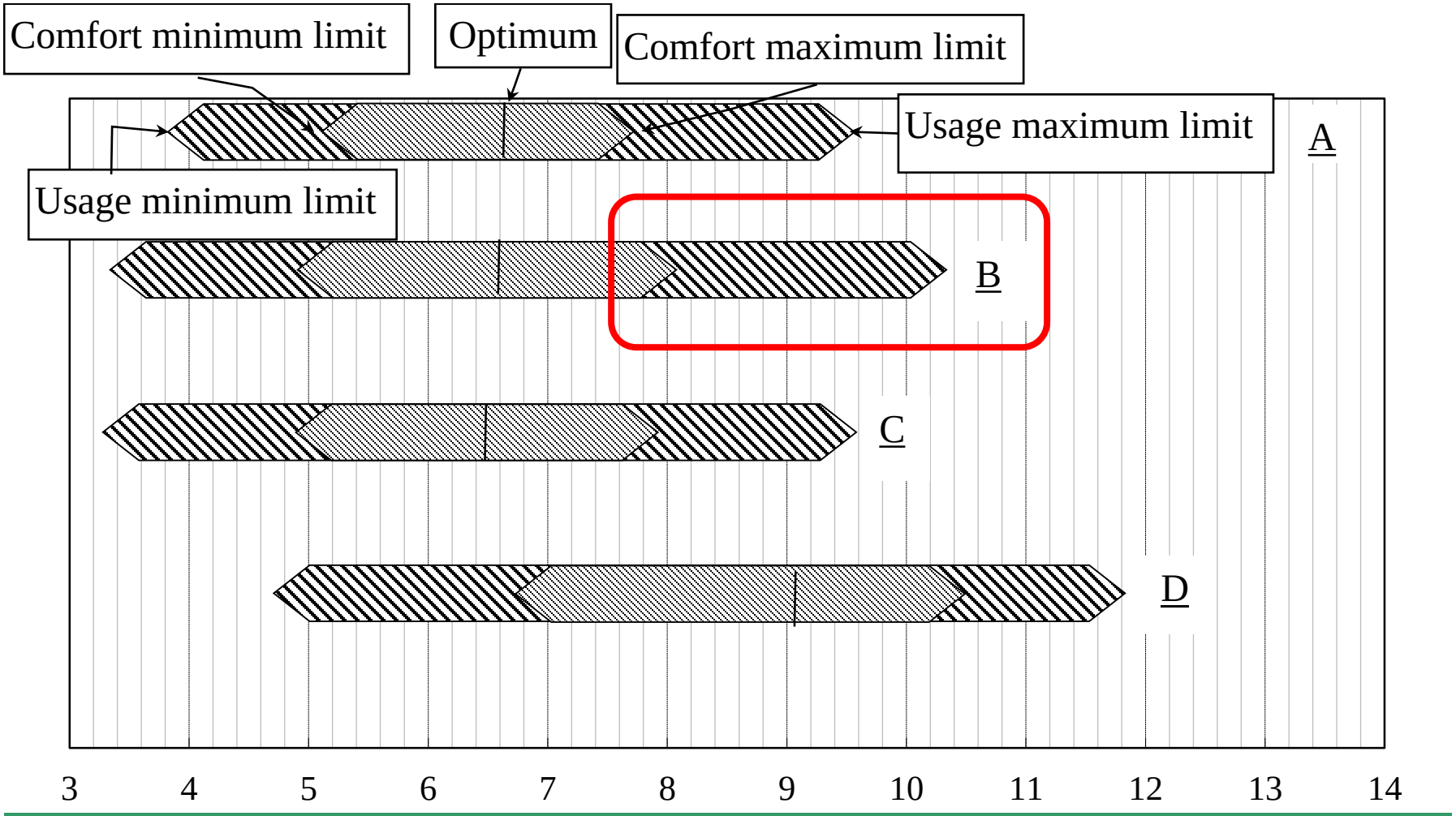


Conclusion

In this study, the experiments showed the differences in "optimum flow rate" based on participants' attributes, and conducted qualitative evaluations of "showering comfort" and "strength of spray".

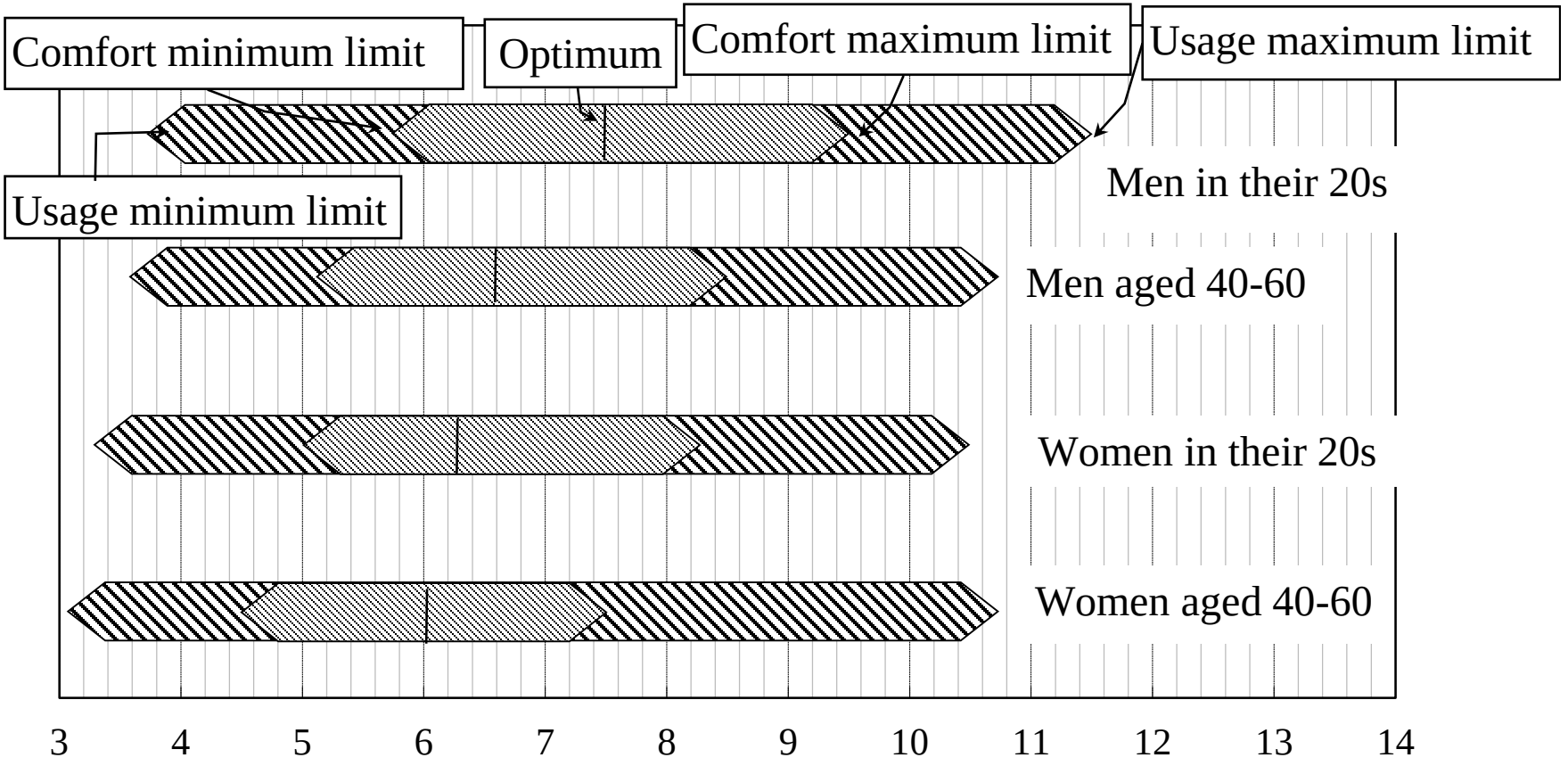
As a result, it was found that, by gender, the flow rates rated by men were larger and, by age, those in their 20s preferred larger flow rates.
Further, the optimum flow rate for men in their 20s was found to be significantly larger than that of women in their 20s, and men in their 40s and 50s.
Particularly, in the shower head comparison, the difference in optimum flow rate for the different groups was most pronounced for shower head A, which had the feature of air in the water droplets.

Average flow rate for each shower head



シャワーヘッドA～Cの中では、Bの上限流量が大きい

The average flow value for showerhead B for each participant group



シャワーヘッドBで、20代男性の使用上限流量が大きい