RELATION BETWEEN CONSTITUTION AND THERMAL CONTROL USE DURING SUMMER

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ABSTRACT

Relations between thermal control use in summer and respondents' reported constitution, such as heat and cold resistance, tendency to catch a cold, and poor vascular circulation, were assessed using questionnaire surveys administered to Osaka apartment residents. Results show the following. 1-a) Men reporting a strong constitution avoid using air conditioners (AC), set the highest temperatures, and open windows the most. 1-b) Women reporting a weak constitution do not use fans. 1-c) Employed younger women who report themselves as heat intolerant use AC and fans the most. 1-d) Employed younger men who are heat intolerant use AC, close windows the most, and set the lowest temperatures. 1-e) Employed younger women who report poor circulation do not use AC much, and set the temperature high when they do. 2) Women who are heat intolerant report the highest payments for AC, whereas women who report having a weak constitution also report the lowest payments. 3) The AC use frequency is related to heat tolerance and age. Younger respondents use AC frequently. The reported tendency to catch a cold exhibits no relation to thermal control use.

Keywords: Constitution; Thermal control use during summer; Air conditioner; Cluster analysis

1. INTRODUCTION

Recently, it is commonplace in Japan for a family to own two or more air conditioners (AC) because climate change and urban heat island phenomena have made it difficult to bear summer heat without AC. Usually, AC has been used personally in private rooms. Personal assessments of attributes related to thermal regulation ability such as sensitivity to heat or cold, resistance to catching cold, perspiration, and poor vascular circulation might affect the use of AC, electric fans, and natural ventilation.

Earlier studies found relations between personal attributes and thermal control use. Kakitsuba (1999) conducted a questionnaire survey of susceptibility to warmth and coldness and lifestyles. Results show that individuals who feel that they are unusually sensitive to warmth and cold relied more on AC devices than others. Ohnaka (2013) found in a field study conducted during summer that the preferred room temperature was 27.9 ℃ for a subjectively assessed heat sensitive group and 28.5 ℃ for a non-heat-sensitive group. Sassa (2009) showed that people who are sensitive to heat preferred lower temperatures. People who are sensitive to cold preferred higher temperatures in climate chamber experiments. Iwasaki et al. (2013) found from questionnaire survey results that respondents with poor circulation set lower cooling temperatures and had higher cooling payments.

This study analyzes the relations between self-reported physical constitution and thermal control use during summer from results of five surveys conducted during 2004 and 2014 for 1,616 apartment residents in Osaka, Japan. First, residents were classified into seven categories based on age, sex, occupation and constitution. Peculiarities of respective categories were analyzed for 1) the frequency

of air conditioner use and setting temperature of AC, 2) the frequency of window opening, 3) the frequency of electric fan use, and 4) the cooling payment.

2. METHODS

2.1 Analyzed Data

Table 1 presents data used for this study. Data of five questionnaire surveys of family apartments in Osaka were used. Purposes of those earlier studies differed, but the questionnaire items and formats of questionnaire sheets were common for some questions related to attributes of the respondents and apartments, consciousness about AC use, and thermal control use. Health conditions were reported in four categories. Also, 347 respondents who reported themselves as 'in a bad health condition' were excluded from the analyses. Table 2 presents survey items that are common among the five former surveys. Respondents' basic attributes, lifestyles, environmental consciousness, subjective evaluations of living environment, apartment attributes, and thermal control use in summer were elicited.

Table1. Analyzed data

Survey	Surveyed year	Number of respondents	Reference
A	2004	290	Lin et al. (2007)
B	2006	297	Umemiya et al. (2008)
C	2011	314	Sakane et al. (2012)
D	2012	363	Nakayama et al. (2015a)
E	2014	352	Nakayama et al. (2015b)

Table 2. Survey items

Classification	Questionnaire items (number of categories)
Respondents attributes	age, sex, occupation (3), tolerance to heat (3), tolerance to cold (3), tendency of catching cold (3), health condition (3)
Lifestyle and Environmental consciousness	regularity of living time, chronotype, habit of sports, habit of drink, smoking (2), habit of bathing, air conditioner use outside home, environmental consciousness {10 items}(4), energy-saving consciousness {12 items}(4)
Subjective evaluation of living environment	ventilation, sunshine, the view from the veranda, sight from the outside, outside air, security, noise, draft, moisture and smell, insects such as flies, mold and condensation of windows and walls, solar heat, sunshine , summer heat, effectiveness of the air conditioning, degree of satisfaction of the apartment (3)
Apartment attributes	floor plans, number of stories in the building and the number of dwelling unit, residence date, building age, the structure of the building, window orientation, awning way, dwelling unit area, ownership, collection form
Thermal control use	frequency of air conditioner use (daytime and sleeping time), air conditioning setting temperature (lower and higher limits), satisfaction and thinking of air conditioning, electric bill (May and August), frequency of electric fan use, frequency of window opening (daytime and sleeping time)

2.2 Definitions

The lower and upper limits of the air conditioner setting temperatures were asked of survey participants. The mean of the two limits was defined as the setting temperature. The value was defined as the setting temperature if only one temperature was reported on the questionnaire sheets. The cooling payment was defined as the difference between electric payments in August and May. May is presumed to be a natural ventilation season when AC is not used. Electricity payments in August became the highest of the entire year because of air conditioner use.

3. CLASSIFICATION OF THE RESPONDENTS

3.1 Respondents' Basic Attributes

Figure 1 presents basic attributes of the respondents. There were slight differences in the distributions of basic attributes among the five surveys. Of the respondents, 59.5% were women, 40.5% were 50–69 years old, and 67.2% were full time workers or part time workers. Almost all unemployed respondents were retired elderly people.

Figure 2 shows respondents' self-reported constitutional attributes related to *heat sensitivity*, *cold sensitivity*, *tendency to catch a cold*, and *poor vascular circulation*. No statistically significant difference in constitution related responses was found among surveys. In total, 18.9%, 55.5% and 25.6% respectively reported themselves as 'strong', 'normal' and 'weak' in their resistance against heat. Also, 20.9%, 50.5%, and 28.5% respectively regarded themselves as 'strong', 'normal' and 'weak' in their resistance against cold. Of respondents, 54.4% 'rarely catch a cold'. 'Bad', 'normal' and 'good' circulation were respectively reported by 33.6%, 30.9% and 35.5% of respondents.

Figure 3 shows apartment attributes. The most frequently reported planning type was 70–80 m^2 of floor area, two or three bedrooms with family room, dining room, and kitchen. More than 80% of residences were privately owned. The apartments were evaluated as having 'good ventilation' and 'sunny' by 65.4% and 73.3% of respondents.

Figure 4 portrays the relative frequency distributions of air conditioner setting temperatures in summer and the cooling payments. The mean lower setting temperature was 26.4 °C. The mean higher setting temperature was 27.6°C. The mean cooling payment was 1,847 yen.

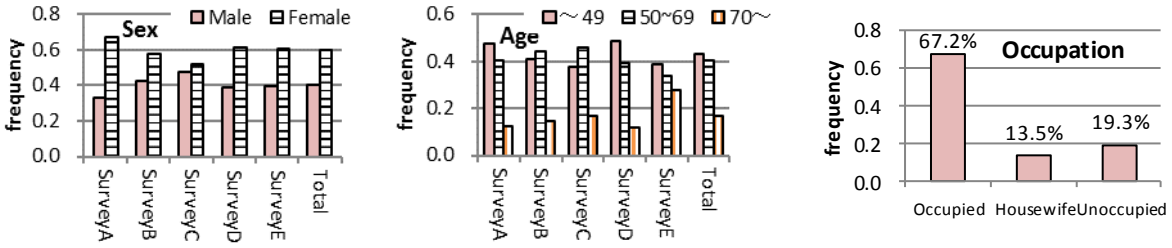

Figure 1. Basic attributes of the respondents

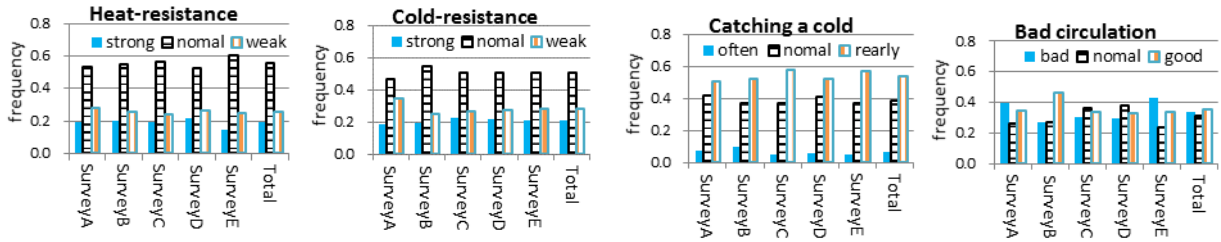

Figure 2. Constitution

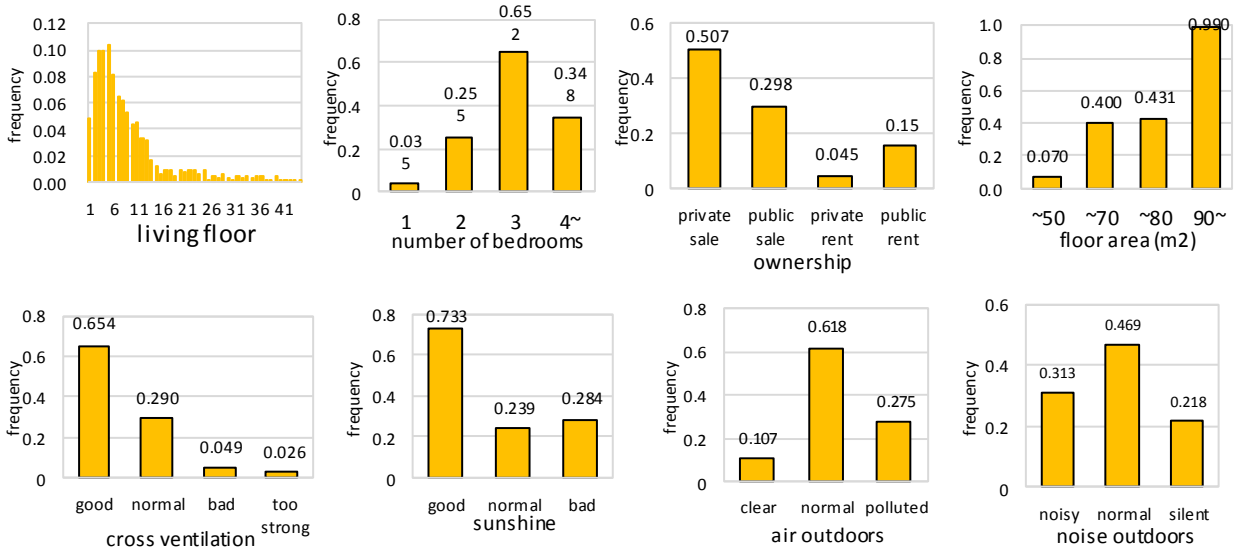

Figure 3. Attributes of the apartments

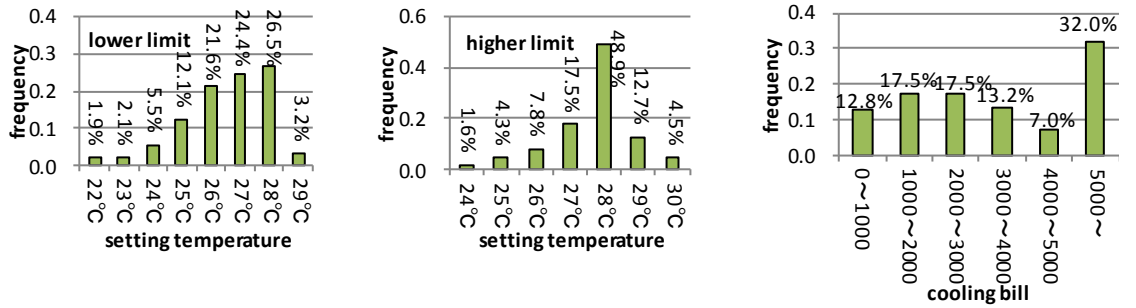

Figure 4. Setting temperatures of air conditioner and cooling bill

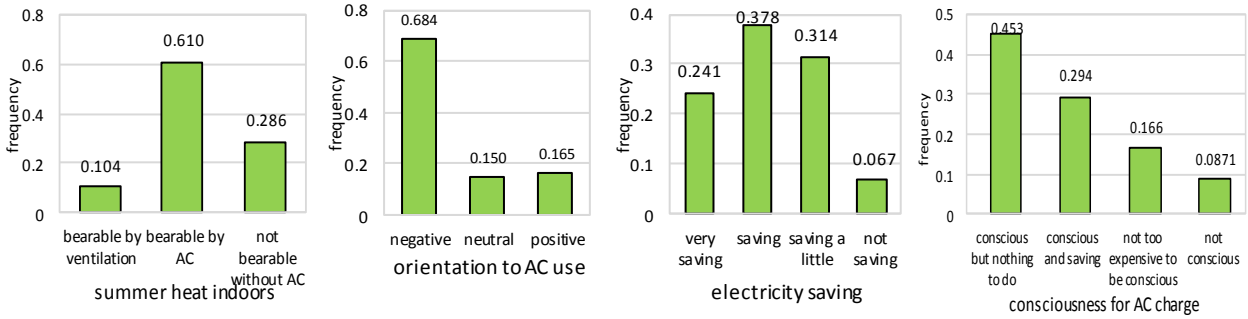

Figure 5. Consciousness about air conditioner use and habits of saving electricity

Figure 5 shows respondents' consciousness about AC: In using AC, 68.4% were negative, but 16.5% were positive. Results show that 61.9% were saving electricity; 74.7 were conscious about electricity payments for AC.

3.2 Classification

The 1,269 respondents were classified according to age, sex, occupation, health condition, and subjective constitution. Ages were classified as under 50, 50–70, and over 70 years. Health conditions were classified as 'good' or 'normal'. The number of clusters was examined as between 4 and 8. Seven was chosen as the best classified number because distributions of constitutions were separated into

clusters. Clusters' features were clear. Respondents were classified into nearly even sample numbers for seven clusters.

3.3 Cluster features

Table 3 presents distributions of the basic attributes and constitutions of the seven clusters. Differences of health condition were not found. Distributions of health condition were similar among clusters. Cluster features and sample numbers of the respondents are the following.

CL#1 (*n*=186): 91.0% were men. Constitutions were rather stronger.

CL#2 (*n*=116): 89.5% were women. Constitutions were rather weaker.

CL#3 (*n*=182): 87.0% were women. Constitutions were stronger except for heat resistance.

CL#4 (*n*=191): Constitutions were weaker except for catching a cold. Basic attributes were distributed rather uniformly, with higher relative frequency of 'employed' respondents.

CL#5 (*n*=182): 85.0% were men, 95.1% were under 70 years old, and 98.2% were 'employed'.

CL#6 (*n*=300): 98.0% were women, 98.5% were under 70 years old. Frequency of 'employed' was 89.7% and higher. Constitutions were stronger except for 'poor circulation'.

CL#7 (*n*=131): 78.7% were men. Respondents were younger (76.0% were under 50 years old and 22.5% were 50–70 years old). Frequency of 'employed' was 81.9%. Constitutions were weaker except for heat resistance.

Clusters over 70 years was not found. Sex, age and occupations were often key features of the clusters. Constitutions were also key features but clusters of single constitution were not extracted. Basic attributes and constitutions were combined to form the cluster features.

4. CLUSTERS AND THERMAL CONTROL USE DURING SUMMER

4.1 Air Conditioner Use

Figure 6 depicts the frequency distributions of air conditioner use for seven clusters. Stronger constitution men, CL#1, used AC least frequently. Employed younger men reporting stronger constitutions except for heat resistance, CL#5, used AC most frequently. Employed younger women

Table 3. Frequency distributions of basic attributes and constitutions of seven clusters

CL	Age	Sex	Occupation	Heat resistance	Cold resistance	Catching a cold	Circulation
①	70～ 27.5 50～69 50.6 ～49 22.0	female 9.0 male 91.0	unoccup. 31.5 h. wife 4.0 occupied 64.5	weak 0.6 normal 53.0 strong 46.4	weak 10.4 normal 55.8 strong 33.7	rarely 87.2 normal 12.8 often 0	good 76.9 normal 20.9 bad 2.2
②	70～ 30.0 50～69 39.5 ～49 30.7	female 89.5 male 10.5	unoccup. 31.5 h. wife 48.0 occupied 20.6	weak 45.2 normal 53.9 strong 0.9	weak 46.5 normal 51.5 strong 2.0	rarely 2.6 normal 68.4 often 29.0	good 5.3 normal 29.8 bad 64.9
③	70～ 36.1 50～69 40 ～49 23.9	female 87.0 male 13.0	unoccup. 53.8 h. wife 25.5 occupied 20.8	weak 57.5 normal 42.0 strong 0.6	weak 6.0 normal 46.4 strong 47.6	rarely 86.2 normal 13.8 often 0	good 57.5 normal 35.4 bad 7.2
④	70～ 21.8 50～69 48.9 ～49 29.3	female 36.0 male 64.0	unoccup. 24.0 h. wife 9.1 occupied 66.9	weak 45.5 normal 51.9 strong 2.7	weak 53.1 normal 46.4 strong 0.6	rarely 60.3 normal 39.7 often 0	good 7.3 normal 42.4 bad 50.3
⑤	70～ 5.0 50～69 37.6 ～49 57.4	female 15.5 male 84.5	unoccup. 0 h. wife 1.8 occupied 98.2	weak 34.4 normal 60 strong 5.6	weak 6.4 normal 56.7 strong 36.8	rarely 20.7 normal 71.0 often 8.4	good 74.3 normal 25.7 bad 0
⑥	70～ 1.7 50～69 38.2 ～49 60.2	female 98.0 male 2.0	unoccup. 1.1 h. wife 9.2 occupied 89.7	weak 4.7 normal 67.2 strong 28.1	weak 18.2 normal 65.1 strong 16.7	rarely 74.7 normal 25.3 often 0	good 8.7 normal 31.7 bad 59.6
⑦	70～ 1.6 50～69 22.5 ～49 76.0	female 78.7 male 21.3	unoccup. 1.4 h. wife 16.7 occupied 81.9	weak 3.1 normal 51.2 strong 45.7	weak 92.6 normal 6.6 strong 0.8	rarely 0.8 normal 72.9 often 26.4	good 16.2 normal 25.4 bad 58.5

reporting weaker constitutions except for heat resistance, CL#7, also used AC frequently. The tendency was similar for air conditioner use during sleep: CL#1 used AC least frequently and CL#5 used AC most frequently during sleep.

Figure 7 shows mean setting temperatures for respective clusters. Lower limits of setting temperatures were higher for CL#1 and CL#6, who were employed younger women reporting stronger constitutions except for 'poor circulation'. Mean settings were lower for CL#3, who were women reporting stronger constitutions except for heat resistance, and were lower for CL#5. The upper limit of setting temperature was highest for CL#7 and lowest for CL#3. Mean setting temperatures were highest for CL#2, who were women reporting weaker constitutions, and CL#6. Mean setting temperatures were lower for CL#3, CL#4, who were respondents reporting weaker constitutions except for catching a cold, and for CL#5, all of which were clusters reporting weaker resistance against heat. Figure 8 presents a comparison of cooling payments among clusters. Cooling payments of CL#2 were the lowest, presumably because of the highest setting temperature. The cooling payments were highest for CL#3, who set air conditioner temperatures lower. Higher ratios of unemployed respondents might also lead to higher cooling payments because of longer stays at home. Figure 9 presents the mean cooling payments for different setting temperatures. Cooling payments were lower for higher setting temperatures, but cooling payment of CL#3 were higher than for other clusters for the same setting temperature.

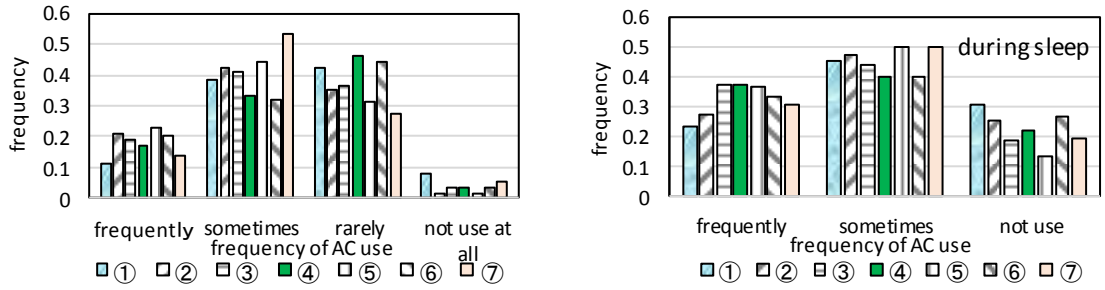

Figure 6. Frequency distributions of air conditioner use

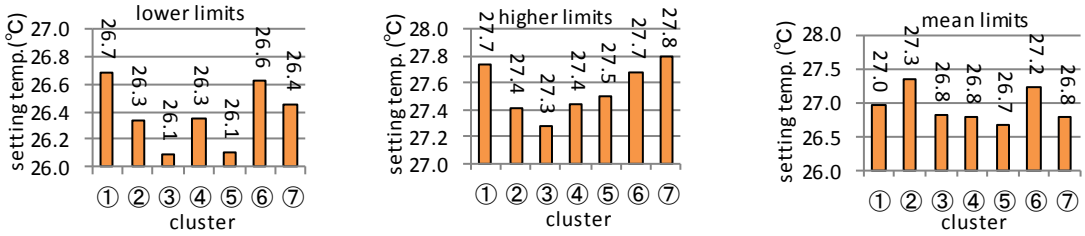

Figure 7. Mean setting temperatures for clusters

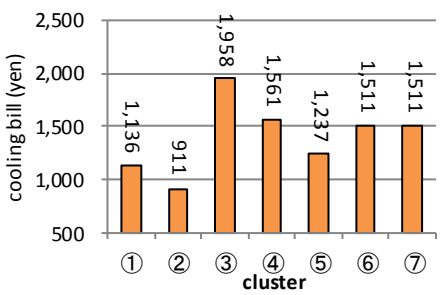

Figure 8. Cooling bill

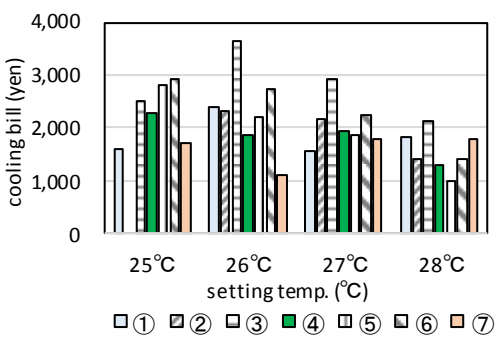

Figure 9. Setting temperature and cooling bill

4.2 Window opening and Electric Fan Use

Figure 10 shows frequency distributions of window opening behaviors for seven clusters: CL#1 opened windows most frequently during daytime; CL#5 closed them least frequently during daytime; CL#1 opened windows most frequently during sleep; and CL#3 closed windows most frequently during sleep.

Figure 11 shows frequency distributions of electric fan use: CL#2, women reporting weaker constitutions, used fans least frequently; and CL#7 used fans most frequently.

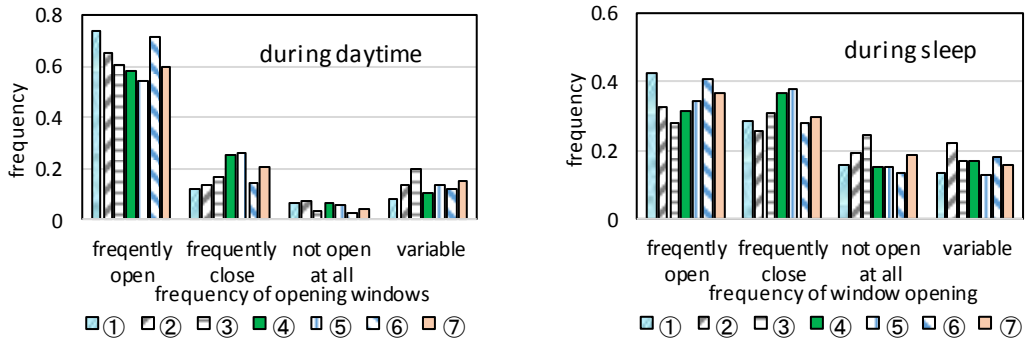

Figure 10. Frequency distributions of window opening

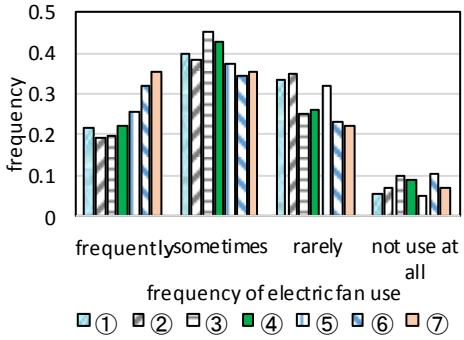

Figure 11. Frequency distribution of electric fan use

5. CONCLUSIONS

Relations between thermal control use during summer and attributes were investigated for 1,269 respondent residents of apartments in Osaka. Respondents were classified into seven clusters by their sex, age, occupation, and self-reported constitution. Investigated constitution attributes were heat resistance, cold resistance, tendency to catch cold, and poor circulation. Results were the following.

1-a) A cluster of men reporting stronger constitutions uses AC least frequently, sets the highest cooling temperatures, and opens windows most frequently.

1-b) A cluster of women reporting weaker constitutions use electric fans least frequently.

1-c) A cluster of employed younger women reporting weaker constitutions, except for heat resistance, use AC and electric fans most frequently.

1-d) A cluster of employed younger men reporting stronger constitutions, except for heat resistance, closes windows most frequently, and use AC most frequently with the lowest setting temperatures.

1-e) A cluster of employed younger women reporting poor circulation rarely use AC and set temperatures higher.

2) The cooling payment is highest for a cluster of younger women reporting weaker heat resistance and is lowest for clusters of women reporting weaker constitutions.
3) Age and reported resistance against heat are factors related to air conditioner use. Younger respondents use AC more frequently. A reported tendency to catch a cold is unrelated to thermal control use in summer.

6. REFERENCES

Iwasaki, S., Umemiya, N., Tokuda, M., Sakane, T. 2013. Factors related to 'bad circulation' – Questionnaire survey in summer, Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, 42, pp.217-220 (in Japanese).

Kakitsuba, N. 1999. Analysis on susceptibility to hot and cold temperatures and its relation to lifestyle, The 23rd Symposium on Human−Environment System, pp.192-195 (in Japanese)

Lin, X. and Umemiya, N. 2007. Bearing the summer heat in urban Osaka apartments: Analysis by age, Proceedings of the 6th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings, Ⅲ, pp.83-90.

Nakayama, Y., Umemiya, N., Sakane, T., Arai, J., Kobayashi, T., Tachibana Y. 2015a. Questionnaire survey of air-conditioner effects on sleep quality in summer -Analyses of falling asleep, maintaining sleep factor and fatigue recovery factor, Proceedings of the 6th International Building Physics Conference, No.862, pp.1-6.

Nakayama, Y., Umemiya, N., Sakane, T., Arai, J., Kobayashi, T., Tachibana Y. 2015b. Air-Conditioner Use Effects on Sleep Quality in Summer -Residential Performance and Sleep Maintenance and Fatigue Recovery Factors, Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, 44, pp.181-184 (in Japanese).

Ohnaka, T. 2013. People susceptible to heat and their residential thermal environments in summer, Journal of Human and Living Environment, 20(1), pp.1-6 (in Japanese).

Sakane, T., Umemiya, N., Lin, X., Naotsuka, T. 2012. Changing sleep condition and energy saving action under power saving during the summer -Survey of Osaka-, Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, 41, pp.263-266 (in Japanese).

Sassa, N. 2009. Study on thermal environmental regulation of the sensitive to the heat and the cold in summer, Summaries of Technical Papers of Annual meeting of Architectural Institute of Japan, pp. 343-344.

Umemiya, N., Nomura, Y., Okura, R., Lin, X. 2008. Relationship between the resident floor and the thermal control use in summer in super hi-rise apartments, Proceedings of the 9th International Symposium on Building and Urban Environmental Engineering, pp.116-122.