Influence of cold footbath to appetite in morning

国際社会系(渡邊ゼミ)

S118060

田中怜奈

Rena　Tanaka

Abstract

Influence of cold footbath to appetite in morning

The purpose of this experiment was to reveal the influence of cold footbath on autonomic nervous system, sensitivities of sugar and satiety in the morning. Seven male and female college students undertook footbath at 36℃ and 10℃ for 15 each on two separated days. We compared autonomic nervous activity based on heart rate variability. Also, we measured satiety with visual analogue scale (VAS) before and after the footbath and after eating rice. About Sensitivity of sugar was measured with Taste disc. There were no significant differences on autonomic nervous activity and sensitivities of sugar and satiety between footbath of 10℃ and 36℃. These results suggest that cold footbath is not effective on Autonomic nervous system and appetite of the morning.

朝食時の冷水による足浴の食欲に対する影響

本研究の目的は異なる水温を用いた水浴による食欲増進作用の有無を明らかにすることである。中京大学の学生 7 人対象とし別日に 2 回の測定を実施した。 1 日目は 10℃、２日目は 36°の水に足を 15 分間つけた。心拍変動をもとに自律神経の変化を比較した。また足の冷水浴の前後と白米実食後の空腹（満腹）度をＶＡＳ方式のアンケートを実施した。そして糖分の枯渇度を見るために甘味の味覚感受性のテストを行った。10 度と 36 度間の水に足をつける事による自律神経・甘味感受性・空腹（満腹）度に統計学的に有意な差は認められなかった。これらの結果から朝食時における水温 10 度の足水浴は自律神経活動の活発化やそれに伴う食欲の増進を引き起こさないことが明らかとなった。

El efecto del baño frío por la parte en pie para apetite por la mañana.

El objeto de este estudio es aclarar influencia del baño frío por la parte en pie para nervio autonómico, sensibilidad de azúcar y satisfecho en la mañana. Siete alumnos del Universidad del Chukyo metieron sus piernas en agua con la temperatura 36℃ y 10℃ por 15 minutos cada dos días. Comparamos la variabilidad del ritmo cardíaco (HRV) para ver el cambio de nervio autónomo. También, preguntamos el satisfecho a los participantes con la encuesta de escala visual analógica (VAS) antes, después del baño y después desayuno. La sensibilidad de azúcar fue midieron con Taste Disc. No había tanta diferencia en autonómico, sensibilidad de azúcar ni satisfecho entre baño frío por la parte en pie con la temperatura 10℃ y 36℃. Estos resultados significan q baño frío de pies no es efectivo para autonómico y apetite de la mañana.

Introduction

Recent years in Japan, energy shortage has become a social problem. According to survey by Ministry of Health, Labour and Welfar, the percentage of skinny level of BMI of women between 20 to 29 years is 21.5% and that is highest in all generations (Ministry of Health, Labour and Welfar, 2013). This is because they have a small appetite especially among young people (20 to 29 years old). The rate of skip breakfast is increasing (Ministry of Health, 2008). 13.2% of Japanese skip breakfast (Ministry of Health, 2008). Young people aged between 20 and 29 showed largest number of skipping breakfast (27.9%) comparing with other age groups (Ministry of Health, 2008).

Breakfast is essential opportunity for energy intake because it is first meal and became energy to active. If we skip breakfast, number of meals increases, and this leads the possibility of overeating. (John,2007). Also, children have low caloric intakes are significantly more likely to report hunger and have significantly worse grades in school, higher rates of absenteeism, and more psychological problems in comparison to children with more adequate dietary intakes. (Kleinman et al., 2002)

The studies of autonomic nervous have shown that heart rate of non-obese subjects was changed, and standard deviation (SD) raised after the cold exposure of 10℃. This result shows that the autonomic system was affected by cold exposure (Tamaki et al., 2001). The regulation of body temperature is one of the most critical functions of the nervous system (Chan & Zachary, 2018).

On the other hand, when temperature down, our body use glucose to preserve body temperature. (Zhichao et al., 2020). With these three previous studies, we can see the connection between temperature, autonomic nervous system and the regulation of body temperature. This means that when the temperature down, autonomic nervous system works to adjust the body temperature appropriate degree. And this brings up the consume of sugar as energy. Moreover, there is animal study reported that fall of air temperature induces increase of the amount of meal. In this report, they used seventeen male Sprague Dawley rats and put them to the room with temperature of 20℃, 33.5℃, 8℃, 30℃, and 20℃. As a result, the food intake increased during the week at low temperature (8℃) (Cormarèche-Leydier, 1984).

There is a study that it has been clarified that autonomic nervous system is also affected by water temperature. Footbath with 42℃ changes in the measured autonomic responses, indicating a shift to increased parasympathetic and decreased sympathetic activity. (Saeki, Nagai, & Hishinuma, 2006)

The purpose of this study was to reveal the influence of cold footbath on autonomic nervous system and sensitivities of sugar and satiety in the morning.

We hypothesized that cold footbath effect on autonomic nervous system and the HRV will show variance (Tamaki et al., 2001; Saeki, Nagai, & Hishinuma, 2006). Then the level of sensitivity of sweetness will improve because the sugar of one's body will consume to keep their body temperature

from cold stimulus (Zhichao et al., 2020). Consequently, we assumed that cold stimulus improves the level of hunger through VAS questionnaire.

Methods

Pre-experiment

We conducted a simple pre-experiment on 12 subjects. This is the experiment aiming to determine the detection place of sense of taste by using Taste Disc (Mikawa Chemical Laboratory company, Japan) on the tongue in experiment 2 (Fig.1). We used five level of sweetness solution and put on tip and center from weaker to stronger sweetness levels gradually (S-1 to S-5) and the filter paper with a diameter of 5mm. Then, put it on tip and center of the tongue. The participants tested from level1(S-1) to level5(S-5) gradually. The experiment was finished when the participants sense the sweetness. During each inspection, the participants rinse their mouth to wash their mouth and tongue in order to reset from the sweetness solution.

Experiment1: Pilot study

The participant is only one university student. This experiment was designed to investigate whether cold footbath has influence on autonomic nervous activity as much as cold exposure. The experiment started at 8 am following the previous study of cold exposure (Matsumoto, et al., 2001). First day, we reproduce with same environment (25° & 10°) to see the change of heart rate, SD. We used the

Fig.1 Taste Disc

thermometer to monitor the temperature of the room (Fig.2A).

Second day, we repeat the process with water (25° to 10°) and recorded the same as first day to confirm if there is same change on heart rate, SD as first day. To monitor the temperature, we used water thermometer (Fig.2B). In this case, we used outside temperature to reproduce the circumstances of chamber because it was difficult to use chamber. About 25°, we used heating and closed the door to keep the temperature.

Heart rate variability (HRV)

The participants dressed in T-shirts and shorts and instrumented with ECG electrodes. Then, rest for 20 minutes in order to keep stable heartrate. After this process, the subject entered the room that controlled the temperature at 25° by heater for 15 minutes. We took the room temperature by the remote control and thermometer (Fig.2A). In first process we recorded the heart rate during the participant was in the room with temperature 25°. During the test, the heart rate was continuously recorded by ECG for 5 minutes and subjects breathed in synchrony with a metronome at 15 beats ・ min^{-1} (0.25 Hz) (Smart Metronome & Tuner) (Fig.2C). We took rest for 2 hours as written in the preceding studies and repeated the first process with the room with temperature of 10° (Matsumoto, et al., 2001). Second day, we did the same process as first days only changed cold exposure, from room temperature to water temperature. First, heart rate was measured following 20 minutes of rest of period. Then, the participant take footbath with water temperature of 25° for 15 minutes. We monitor

Fig.2A Thermometer

Fig.2B Water thermometer

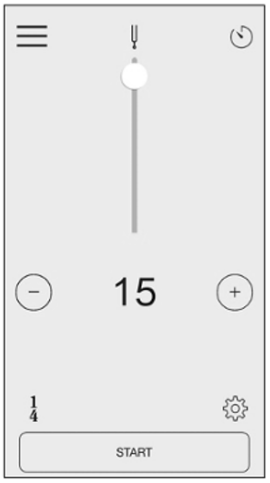

Fig.2C Metronome of application(Smart Metronome & Tuner)

the water temperature by water thermometer (Fig.2B). After the rest of 2 hours, the first process was repeated with water temperature of 10°.The participant wore a jacket so that the participant wouldn't be exposed to the cold. Through this consideration, the participant affected the influence of temperature only from her foot. The depth of water was set about 25cm to immerse the participant's ankle.

Experiment 2: Main study

Participants

Seven university students (BMI:19.1±1.1kg/m2) who are non-smokers participated in this experiment. All participants had been weight-stable for at least 1 year. Also, they hadn't had any disease of high blood pressure, diabetes, and cardiovascular diseases. They were instructed to avoid any food or beverage containing alcohol and caffeine after 21:00 of the day preceding the study. That is because these affect to autonomic nervous system（Matsumoto,2001）.All participants were fasted since 21:00 before experiment day to avoid the excessive fullness of the morning.

Procedure

The experiment were two consecutive days. Each day started at 8:00 or 7:00 and finished at 8:00 or 9:00. This study was conducted in the laboratory of Chukyo university. First, we recorded heart rate and sensitivities of sugar and level satiety before the foot bath. It is to know those basic lines of each participant. The volume of water is the same as pilot study. During the footbath, we recorded heart

rate. After that, the participants took a test of Taste disk and answered to the VAS of satiety. Finally, they ate rice and repeat the procedure that did after the footbath.

The effect of cold footbath on autonomic nervous system leads to sugar consumption to maintain body temperature from cold stimulation. Then we will prove that sugar was used for body temperature retention by the test before and after the experiment with the sweetened aqueous solution of the Taste disk. After of all, we will judge whether the increase in the food intake by the cold footbath by using hunger (satiety) VAS.

Heart rate variability (HRV)

The procedure of recording heart rate is same as pilot study. In this case, 25° and 10° of the temperature changed to 36° and 10° of water temperature. 36° is set as normal temperature of human as the water temperature that don't have an influence on the body temperature. This is because to remove the possibility that there is effect on the autonomic nervous system only by footbath.

Taste Disk

We used Taste Disk to examine the sensitivity of sweetness (Fig.1). The place to put filter paper was decided at the tip of the tongue according to pre-experiment and previous study (Xiaoke et al., 2012) (Fig.4).

VAS

We prepared VAS to measure the level of satiety（Fig.3）. The left end is level 0 of hunger. That

means “feel full”. On the other hand, the right is level 10 of hunger. That means “very hungry”. The VAS was measured at before, after of the footbath and at the end of all measurements. We referred “Japanese Food Guide Spinning Top” according to each participant’s active and divided the amount of food of one day by three to serve as an amount of the breakfast (Ministry of Agriculture, Forestry and Fisheries).

Statistics

All statistical analyses were performed using a commercial software package (SPSS version 7.5 for Windows, SPSS). The non-parametric analysis was used for non-normally distributed data. SD of HRV, sensitivity of sweetness and Satiety level were compared between footbath of 25° and 10° using Wilcoxon test. We compared the Percentage of change between pre and post of the footbath in SD of HRV and sensitivity of sweetness between day of 25° and 10° using Wilcoxon test. About sensitivity of fullness, we compared percentage of change between pre, post of the footbath and at the end of the experiment between day of 25° and 10°.

Result

Pre-experiment

From the graph of average of sensitivity of sweetness between center of tongue and tip, it can be said that the tip of the tongue is more sensitive to sweetness than the center (Fig.4).

Experiment 1

The SD of HR increased by the cold footbath as much as cold exposure (Fig. 7). SD of HRV with cold exposure changed 1.8 to 3.0 and the value with cold footbath changed 1.4 to 3.0.

Experiment 2

In main study, SD of heart rate changed from2.9±0.8 to 3.0±1.6 at footbath of 36° and from 2.6±1.0 to 3.1±0.8 at 10° respectively. There were no significant differences in HRV between 36° and 10° respectively ($p > 0.05$) (Figure 8). The level sensitivity of sweetness changed from 2.5±1.0 to 2.4±0.9 at footbath of 36° and from 2.0±1.9 to 1.8±0.7 at footbath of 10° respectively. There was no significant difference percentage of change in sensitivity of sweetness between pre and post of footbath in the day of 36° and 10° respectively ($p > 0.05$) (Fig.7). The average of level hunger (satiety) level VAS changed 6.9±1.2 to 6.8±1.5 at footbath of 36° and 6.6±1.9 to 6.4±1.2 at 10° respectively. About the final value of hunger were 2.1±1.1 to 2.7±1.7 for footbath of 36° and 10°. There was no significant difference in average of hunger level between 36° and 10° between pre and post ($p > 0.05$) (Fig. 8). Also, there was no significant difference in average of hunger level between 36° and 10° between pre and post ($p > 0.05$) (Fig. 8).

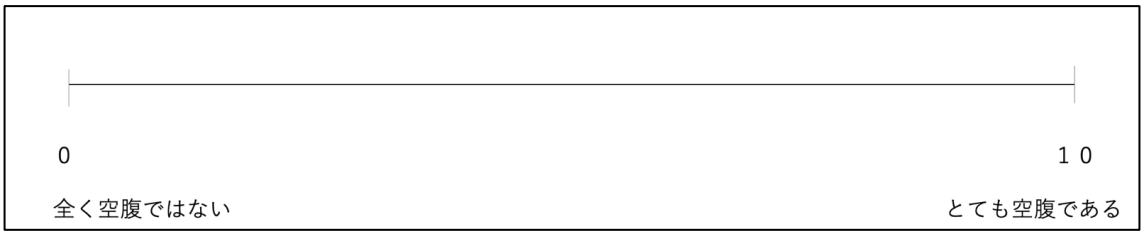

Fig.3 Questionnaire of VAS (A Visual Analogue Scale)

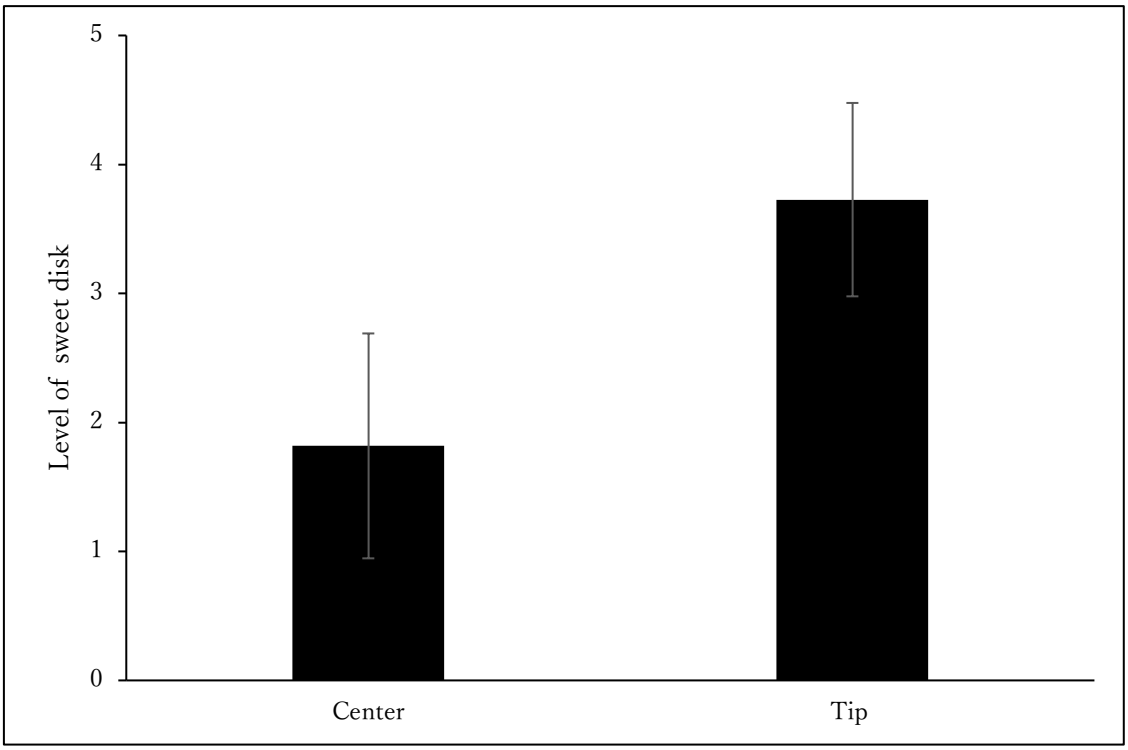

Fig.4 Average of sensitivity of sweetness between center of tongue and tip.

Discussion

In experiment 2, the influence by footbath of 10° on the autonomic nervous system wasn't observed. ($p < 0.05$) (Fig.5). That means the footbath of 10° is not sufficient to affect on the autonomic nerve system. However, in experiment 1, the SD of heart rate of 10°at footbath and cold exposure was same (3.0). We started experiment 1 at 8:00 and soaked at footbath of 10° at 10:40 following the previous study (Matsumoto, et al., 2001). On the other hand, experiment 2 was started 8:00 or 9:00 and the participants soaked their foots in footbath at 8:20 or 9:20. There is possibility of diurnal change between 8:20 and 9:20 because the autonomic nervous system changes a day (Raffaello, et al., 1990). In this previous study there is no reference about change of each hour. However, there was difference in average of SD of heart rate between the group of 8:20 and 9:20 (Fig. 11). The value of group 9:20 increased more than group 8:20. Moreover, the CV of 8:20 is 40.6 and 30.4 before cold footbath and after cold footbath. On the other hands, the CV of 9:20 is 18.6 and 9.2 before cold footbath and after cold footbath. This means that the group that soaked late, may have more influence. This makes sense because in previous study's result support that during early morning parasympathetic nerve system is active and sympathetic activity is passive (Raffaello, et al., 2009). As time go on, sympathetic activity becomes active and parasympathetic nerve system. Temperature is one of the environmental factors affecting the autonomic nervous system (Matsumoto, et al., 2001). Previous studies referred in experiment 1 have revealed that cold exposure of 25° to 10° affected the autonomic nervous

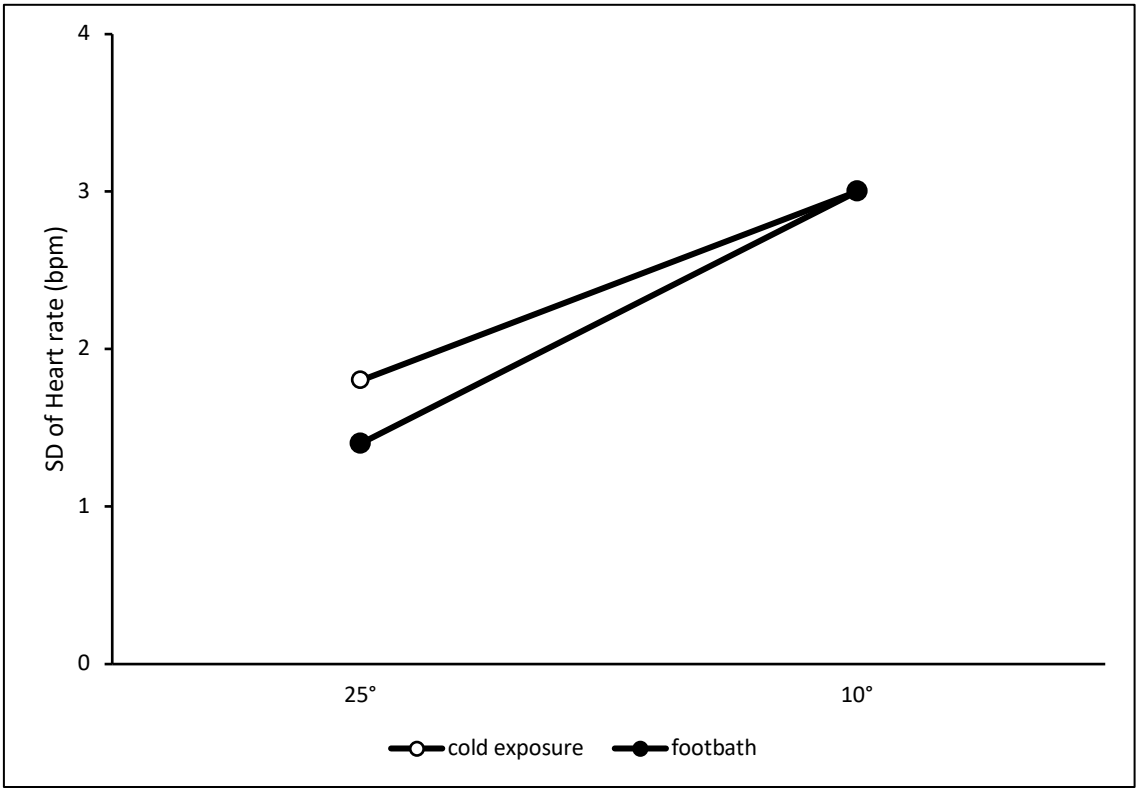

Fig.5 Standard variation (SD) of heart rate with cold exposure and footbath.

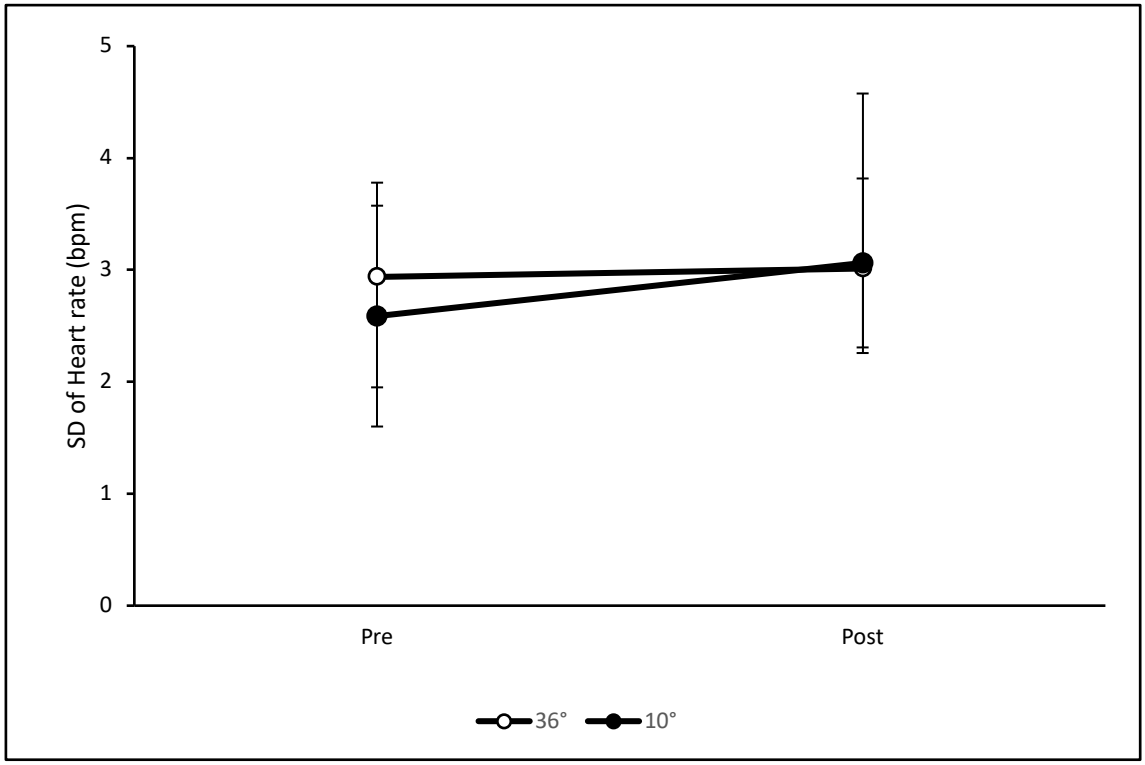

Fig.6 Standard deviation (SD) of heart rate before and after with footbath of 36° and 10°.

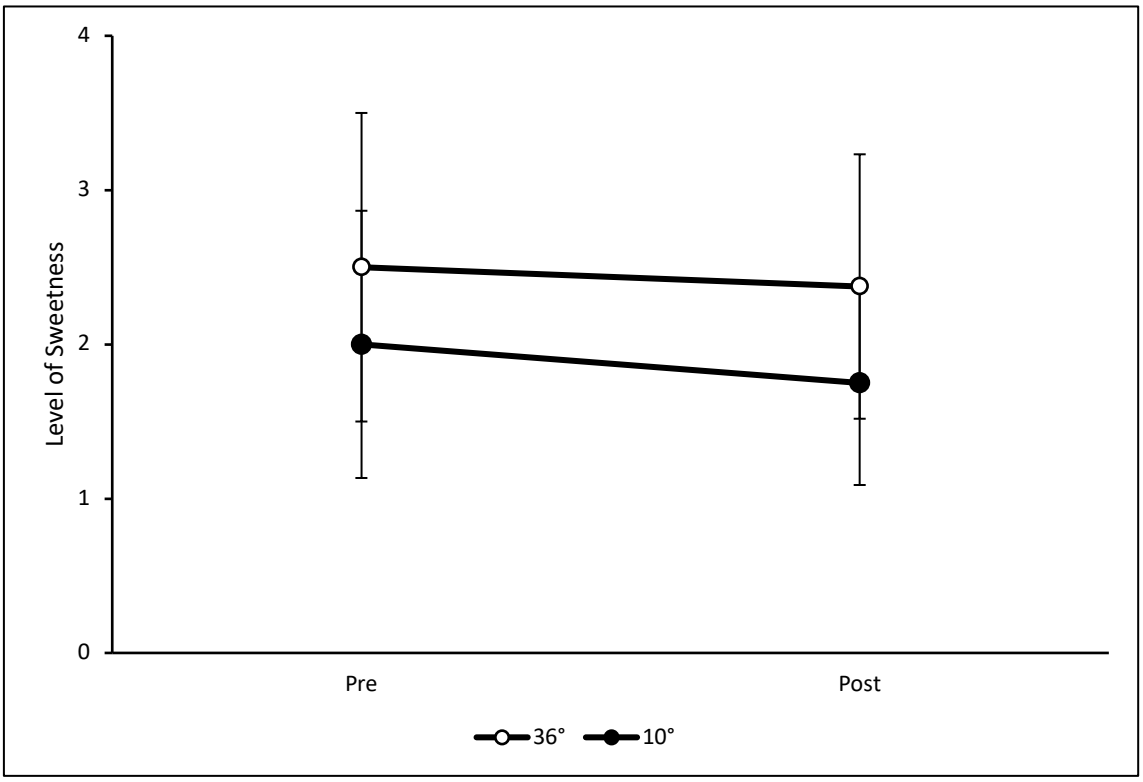

Fig.7 Average of sensitivity of sweetness before and after of footbath at 36° and 10°.

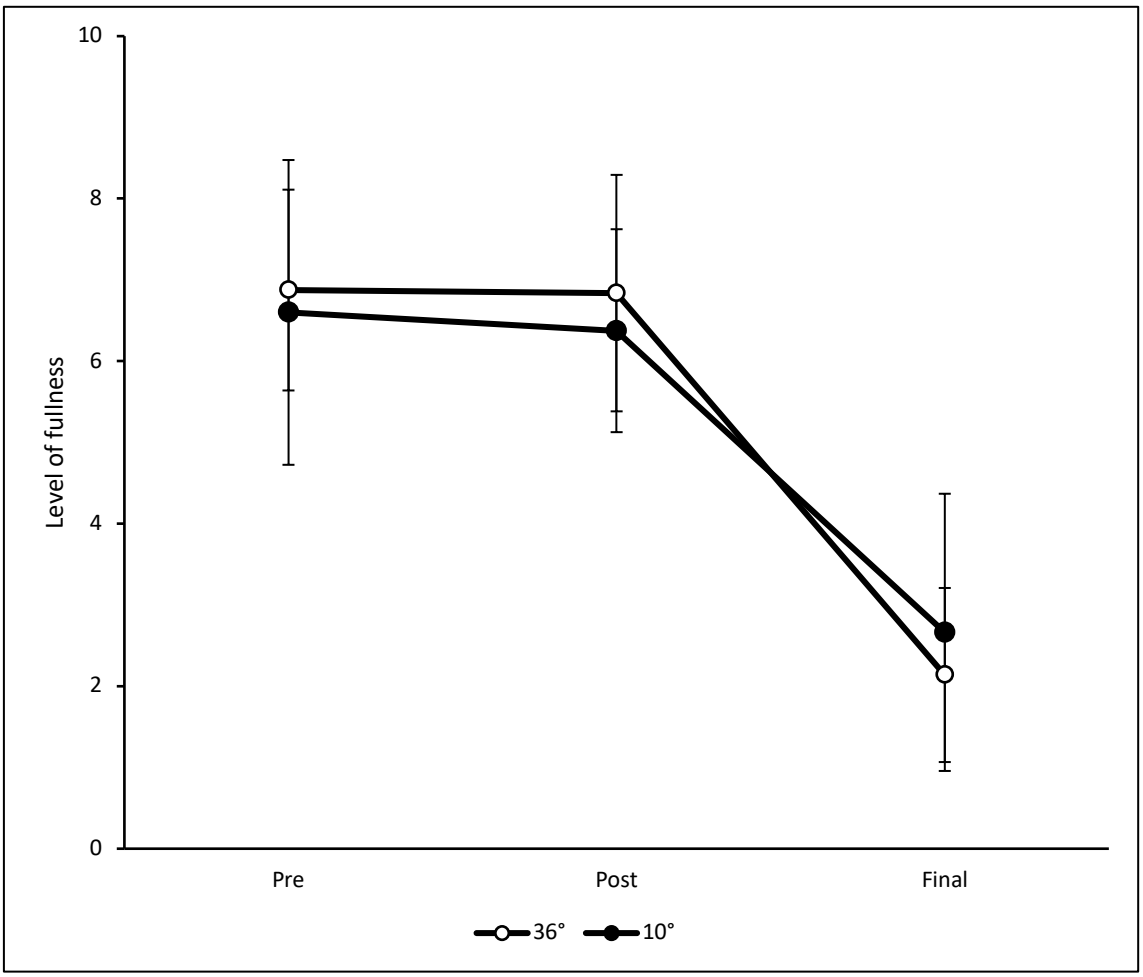

Fig.8 Average of hunger by VAS questionnaire.

system (Matsumoto, et al., 2001). Since the pre-experiment was carried out by one subject, the chamber room could be reproduced using heating in the closed room and the temperature could be kept constant. However, in this experiment, there were two or more people, and two windows were always opened because corona countermeasures were necessary. From this, the temperature change of about 2 degrees during the experiment was seen. According to previous studies, autonomic nervous system is affected even during comfortable temperature (Matsumoto, et al., 2001). However, there was not any previous study that reveal the effect on heart rate every degree. Therefore, we can declare about the influence of temperature change of few degrees.

The temperature of cold water was enough as a cold stimulus to effects on the autonomic nerve system and change HRV significantly (Fig.6). The temperature of the cold water was set same temperature as the preliminary experiment conducted based on the previous research on cold exposure (Matsumoto, et al., 2001). In other experiments using cold water to effect on the autonomic nerve system used water of 10°-12° or 12° (Geert, et al., 2016; Maxime et al., 2020). Previous studies have shown that cold stimulation produces dizziness and discomfort due to muscle tension caused by hypotension after peripheral vasoconstriction (Romain, et al., 2018). In other words, excessively low temperature or long-term inundation put a heavy load on the participants' bodies. There is a previous study that suggest the difference effect of HRV change of cold exposure between obese and non-obese young women (Matsumoto et al., 1999). However, the average of participants' BMI was 19.1±1.09.

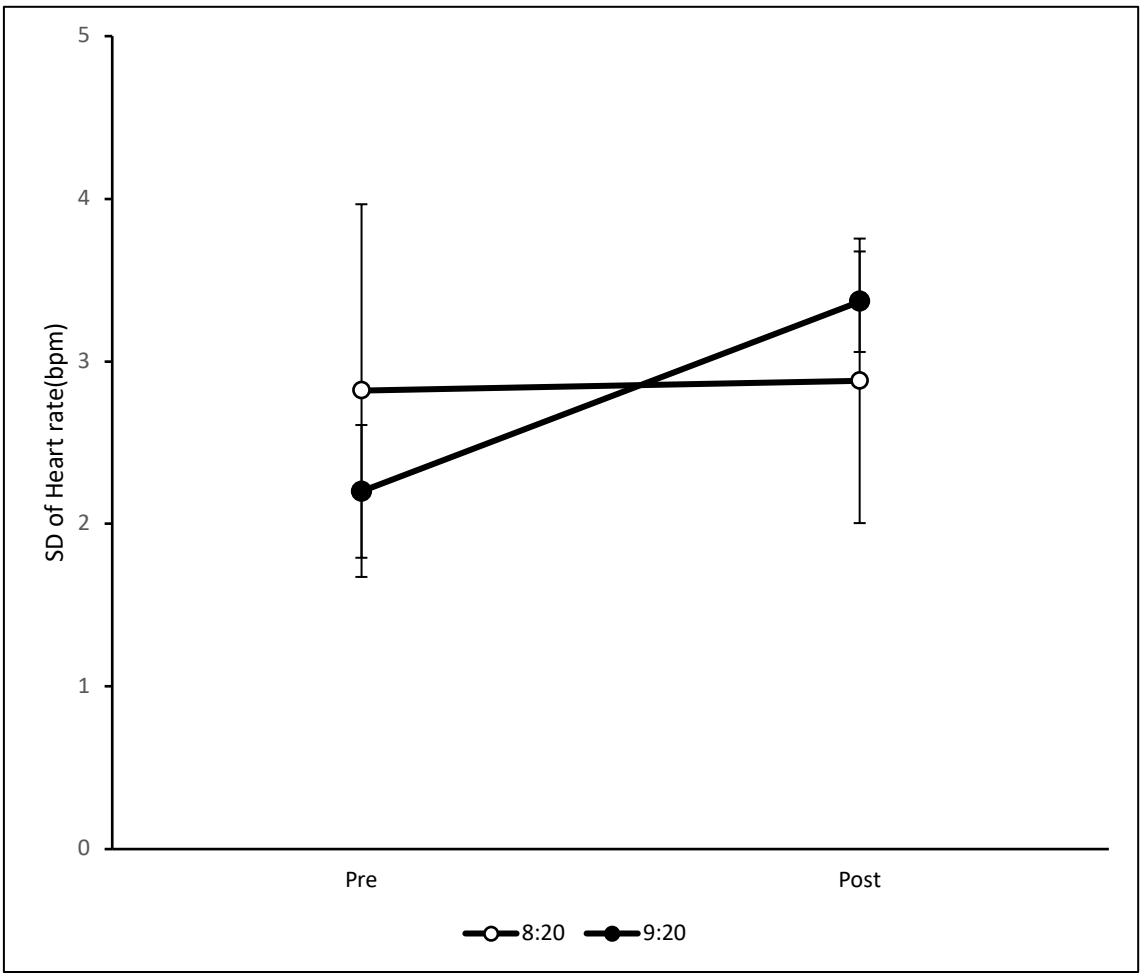

Fig.9 Standard deviation of heart rate of 8:20 and 9:20.

In the previous study, average of participants' BMI was 18.5±0.18 and 26.3±0.74 for non-obese and obese women (Matsumoto, et al., 2001). The average of participants' BMI of main study, was close to non-obese woman group's than obese ones. This means, it is extremely difficult that there was influence by variation of participants' BMI.

Next, about the fact that no significant change in sweetness sensitivity was observed ($P > 0.05$) (Fig.7).

During the experiment, there were several subjects who felt sweetness with the same level of solution but answered that they felt sweeter than before the water temperature was 10°. In other words, if we prepared a sweet aqueous solution with a concentration between 1 and 2, it might have been possible to record a slight difference in the sensitivity threshold as data. In hypothesis, we expected that the level of satiety will down by effect of cold-water irritation through autonomic nervous system. However, footbath of 10° of the experiment 2 was not sufficient to decrease the level of satiety.

In conclusion, we compared the change of SD of HR sensitivity of sweetness and satiety with footbath of 36° and 10°. In experiment 1, there is difference between the footbath of 10° and 25° as same as cold exposure in SD of heart rate as expected. However, there were no significant differences between footbath of 36° and 10°, SD of heart rate and sensitivities of sweetness and satiety. From these results, we suggested that the footbath with 10° was not effective on autonomic nervous system and appetite.

Acknowledgement

This research was supported by the full support of Watanabe Lab. The authors are sincerely grateful to associate Professor Kohei Watanabe (Chukyo University).

References

Geert,A., Inger N, Bas, C., Marcel,G. & Monique,H., (2016), The Effect of Cold Showering on Health and Work: A Randomized Controlled Trial, PLoS One, 11(9).

Xiaoke, C., Mariano, G., Yueqing, P., Nicholas, J. & Charles S. (2011), A Gustotopic Map of Taste Qualities in the Mammalian Brain: Science, 333(6047):1262-6

Raffaello, F., Stefano, G., Wilma, C., Simonetta, D., Mauro, T., Giuseppe, B., Sergio C., Federico, L., Massimo, P., & Alberto, M., (2009), Continuous 24-hour assessment of the neural regulation of systemic arterial pressure and RR variabilities in ambulant subjects, Circulation, 81(2), 537-47

Cormarèche-Leydier, M. (1984) The effect of long warm and cold ambient exposure on food intake water intake and body weight in the capsaicin desensitized rat, Pflugers Arch, 400(2):183-187.

John, M., (2007), The time of day and the proportions of macronutrients eaten are related to total daily food intake, British journal of nutrition, 98 (5), 1077–1083

Larson, M., Ader, R. &Moynihan, J., (2001), Heart rate, neuroendocrine, and immunological reactivity in response to an acute laboratory stressor, Psychosom Med, 63(3), 493-501.

Kleinman,R., Hall,S., Green,H., Korzec-Ramirez, D., Patton, K., Pagano, M. & Murphy, J. (2002), Diet, Breakfast, and Academic Performance in Children, Ann Nutr Metab, 46 (01), 24-3

Matsumoto, T., Miyawaki, T., Ue, H., Kanda,T., Zenji,C., Moritani, T.(1999) Autonomic responsiveness to acute cold expose in obese and non-obese young women, International Journal of Obesity , 23 (8), 793–800.

Rajendra, U., Paul, K., Kannathal, N., Choo, M. & Jasjit, S. (2006) Heart rate variety: a review, Med Biol Eng Comput, 44(12), 1031-51.

Zhichao, W., Tinglu, N., Anying, S., Jared, R., Qiong, A. & Lei, J., (2020), Chronic cold exposure enhances glucose oxidation in brown adipose tissue, EMBO Rep, 21(11)

Saeki, Y., Nagai, N. & Hishinuma, M., (2006), Effects of footbathing on autonomic nerve and immune function, Complementary Therapies in Clinical Practice, 13 (3), 158-165

Ministry of Health, rate of skipping breakfast, National Health and Nutrition Survey, 2008. https://www.mhlw.go.jp/bunya/kenkou/eiyou/dl/h20-houkoku-02.pdf

Ministry of Health, Labour and Welfar, National Health and Nutrition Survey, 2013. https://www.mhlw.go.jp/bunya/kenkou/eiyou/dl/h25-houkoku-05.pdf