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Effects of Hot and Cold Foods on Signals of Heart Rate Variability and Nail Fold Microcirculation of Healthy Young Humans: A Pilot Study

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Abstract

In traditional Chinese medicine, hot- and cold-attribute of food ingredients are a major part of dietary therapy. The aim of this study was to establish a suitable scientific methodology to define the attributes of food ingredients by investigating the relationship between food attributes and the physiological signals produced in healthy young subjects with different constitutions. Thirty subjects were grouped into hot and cold constitutions by Chinese medical doctors. Every subject took water, aged ginger tea and coconut water, which are well recognized as having neutral-, hot- and cold-attribute, respectively, on different visits. The different physiological signals induced by the samples were observed using skin and axillary temperature sensors, a heart rate variability analyzer and a laser Doppler anemometer. We found that the capillary red blood cell (RBC) velocity in nail fold microcirculation (NFM) of the subjects with hot constitution accelerated significantly after taking the hot-attribute aged ginger tea, which might be the result of elevated vagal activity leading to arteriole dilation in these subjects. In contrast, in subjects with cold constitution, capillary RBC velocity decelerated significantly and skin temperature decreased markedly after taking the cold-attribute coconut water, which might have been induced by sympathetic nerve activation causing the arteriole to be constricted. Accordingly, the use of capillary RBC velocity of NFM measured by laser Doppler anemometer may be a promising way to classify attributes of food ingredients commonly used in Chinese medicine dietary therapy in accordance with different personal constitutions.

Key Words: dietary therapy, food attribute, laser Doppler anemometer, capillary red blood cell velocity, personal constitution

Introduction

For more than 2000 years, Chinese people have believed that everything in the world follows the *yin-yang* theory. In this theory, *yin* and *yang* are relatively opposite (10) and represent cold and hot, respectively (17). From the perspective of traditional Chinese medicine (TCM), all constitutions, diseases, foods

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and drugs can be divided into these two major categories, *i.e.*, cold and hot (3, 13).

The true benefit of TCM is considered to be the reestablishment of a harmonious balance between cold (*yin*) and hot (*yang*) within the human body (2, 6). Generally, Chinese medical doctors identify whether the constitution of a person is cold or hot by integrating results of visual inspection, listening/smelling, inquiry and palpation. Physiological conditions like flushing, rough yellow tongue and rapid pulse are considered to indicate a hot constitution which exhibits heat in the body (2, 13, 19, 21). In contrast, the cold constitution, which exhibits coldness in the body, comprises conditions of cold hands and feet, smooth white tongue and slow pulse (2, 13, 19, 21). Although personal constitution does not cause disease, it can predispose a person to develop certain diseases more easily. Therefore, TCM dietary therapy claims that the attributes of foods should be used to oppose our constitutions in order to harmonize organ functions and maintain human vitality.

Attributes of food ingredients come from the physical responses of the eater to the food ingredient, not its temperature (2, 4). Recently, some researchers have hypothesized that cold/hot in TCM may be related to the concept of oxidation/antioxidation in modern Western medicine (17, 25). Huang and Wu (16) suggested that PGE_2 production by a macrophage cell line might be employed to identify food attribute. However, the scientific definition of food attribute as they relate to humans is still not very clear.

Body temperature, heart rate variability (HRV) and nail fold microcirculation (NFM) are quantitative and noninvasive methods for evaluating physiological and pathological conditions in the human body. In terms of the vasomotor tone of the cardiovascular system, sympathetic activation leads to increased heart rate, constriction of arterioles and augmentation of peripheral resistance in the body (11). In contrast, increased vagal activity, the most important parasympathetic activity, results in slow heart beat and vasodilation (11). Among the frequency-domain signals of HRV, low frequency (LF) and high frequency (HF) powers are generally believed to correlate with sympathetic and vagal activities (5, 23, 24, 26, 27). Currently, the normalized LF (nLF) and normalized HF (nHF) powers and the LF/HF ratio are considered reliable parameters for assessing the sympathovagal balance, which plays an important role in maintaining homeostasis (8, 15, 22-24).

The objective of this project was to establish a suitable scientific methodology to define the attributes of food ingredients by investigating the relationship between food attributes and the physiological signals produced in humans with different constitutions. We selected aged ginger tea and coconut water, which are well known as hot and cold foods, respectively, according to the principle of Chinese medicine dietary therapy (20). Physiological signals were then monitored with instruments, including skin and axillary temperature sensors, an HRV analyzer and a laser Doppler anemometer.

Materials and Methods

Subjects

This human experiment was approved by the institutional review board (DMR94-IRB-118) of China Medical University Hospital in Taiwan, and written informed consent was obtained from every subject. Patients diagnosed with cardiopulmonary diseases, such as upper respiratory tract infection, acute systemic disease, severe aortic stenosis, congestive heart failure, hypertension, angina pectoris or arrhythmia, were excluded from our experiment. In total, 30 healthy normal-weight subjects ranging from 21 to 31 years of age (mean, 22.8 ± 2.2 years) were recruited and grouped into hot and cold constitution groups by two Chinese medical doctors. All subjects were requested to eat light and absorbable foods, to avoid ice, pungent, roast or fried foods for two days before the experiment, and to refrain from smoking, alcohol drinking and medicine taking for eight hours before the experiment. Subjects were also required to fast for two hours before the experiment. Additionally, female subjects were asked not to participate in the study while in the menstrual period. The experimental procedure complied with the Declaration of Helsinki.

Samples Preparation

We prepared the aged ginger tea following the traditional method of preparation used in Chinese medicine. We added 18.75 g of sliced aged ginger into 800 ml of water, heated the mixture to boiling, then covered the boiler and let it stew on low heat for 20 min to obtain 500 ml of aged ginger tea. Besides, we collected coconut water from young coconuts purchased from the traditional market which were grown and harvested in Pingtung, Taiwan. One coconut contained about 450 ml of coconut water. No extra flavor was added to either of the samples. In addition, we selected water, considered to have a neutral-attribute, as the blank.

Experiment Design

The experiment was performed in a quiet room with a constant temperature (25 ± 1°C), and each subject rested for 10-20 min before the experiment (Fig. 1). At the beginning of the experiment, the

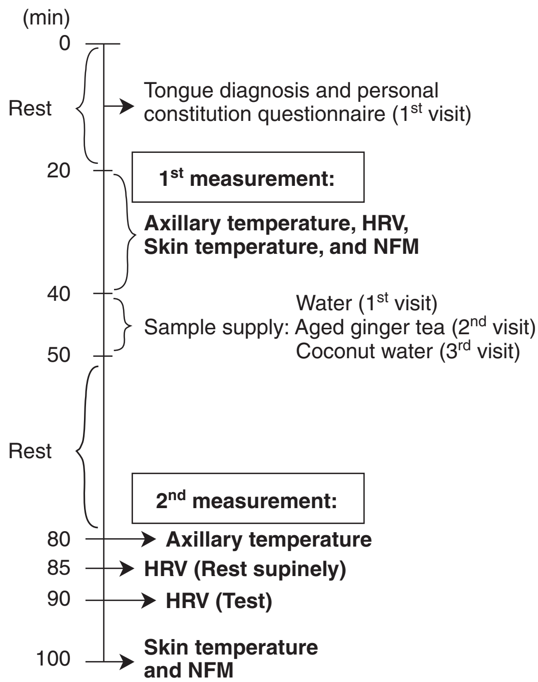

Fig. 1. The experimental procedure. The tongue diagnosis and personal constitution questionnaire of the subjects were determined by two Chinese medical doctors at the first visit. Measurements of axillary temperature, heart rate variability (HRV), skin temperature and nail fold microcirculation (NFM) proceeded for each subject before taking sample, and 30, 40 and 50 min after taking sample, respectively.

physiological status of each subject before taking the sample was measured. The measured items included tongue diagnosis according to Chinese medicine, skin and axillary temperatures, HRV time-domain and frequency-domain signals, capillary red blood cell (RBC) velocity of NFM and a questionnaire pertaining to the division of personal constitution. Subjects were then given the appropriate sample (250 ml of water, aged ginger tea, or coconut water at room temperature). Thirty minutes later, the skin and axillary temperatures, HRV time-domain and frequency-domain signals and the capillary RBC velocity of NFM were measured again. The timeline of physiological measurements after the subjects had consumed the samples was designed according to a preliminary experiment in which changes in each physiological criterion were monitored for one hour. Because of the color and flavor of our samples were too obvious to allow a double-blinded test, we compared the physiological status before and after each subject had taken the samples and observed for variations in physiological signals. Each subject repeated this procedure three times, drinking a different sample (water, aged ginger tea, or coconut water) each time, at one-week intervals. The personal constitution of each subject, diagnosed according to the tongue diagnosis and division of personal constitution questionnaire, was determined by two Chinese medical doctors.

Measurements

The electrocardiogram (lead II) was obtained with surface electrodes. The short-term time and frequency domains of HRV were measured simultaneously and analyzed afterward with HRV software developed by the Institute of Automatic Control Engineering of Feng Chia University in Taichung according to Western standards (8, 9, 18). LF and HF powers ranged from 0.04-0.15 Hz and 0.15-0.40 Hz, respectively. During the experiment, each subject was requested to rest supinely for 5 min, and the electrodes were then clipped onto the right hand, and the left and right feet for a 5-min HRV recording. This recording was obtained for each subject before and 40 min after taking the samples (Fig. 1). Axillary temperature was measured before every HRV recording.

The capillary RBC velocity of NFM was measured and analyzed using a laser Doppler anemometer (the capillaroscopy system CAM1, KK Technology, UK) connected to a personal computer. During the experiment, every subject was asked to keep quiet and sit on a comfortable chair. The height of the left hand was kept equal to the heart, and the middle finger of the left hand was fixed onto an attached pad with the palm facing down during NFM recording. This recording proceeded for each subject before and 50 min after taking the samples (Fig. 1). Skin temperature was measured before every NFM recording.

Statistical Analysis

The baseline physiological status of the subjects with different constitutions was analyzed by unpaired Student's *t*-test, and the data are expressed as means ± SEM. Variations in physiological signals were calculated using the following equation: Variation = $Signal_{after} - Signal_{before}$, where $Signal_{after}$ and $Signal_{before}$ were the signals measured after and before each subject took a sample, respectively. Variations in the physiological signals of aged ginger tea, coconut water and water were analyzed by one-way analysis of variance (ANOVA) and Duncan's multiple range test, and the data are expressed as means ± SEM. All statistics were performed with the SAS 8.1 software. The differences were considered significant at $P < 0.05$.

Results

Personal Constitution

Two Chinese medical doctors diagnosed 19 of

Table 1. Baseline status of subjects

Physiological status	Constitutions of subjects	
	Hot	Cold
Axillary temperature (°C)	36.14 ± 0.11	36.04 ± 0.08
Skin temperature (°C)	32.3 ± 0.5	31.6 ± 0.7
Time-domain of HRV		
Heart rate (bpm)	87.30 ± 4.19	74.75 ±2.63*
SDANN (ms^2)	59.18 ± 10.07	48.64 ± 6.27
Frequency-domain of HRV		
LF (ms^2)	1327 ± 776	750 ± 236
nLF (%)	45.30 ± 6.94	55.57 ± 4.16
HF (ms^2)	1,390 ± 637	786 ± 345
nHF (%)	54.70 ± 6.94	44.43 ± 4.16
LF/HF ratio	0.99 ± 0.28	1.46 ± 0.22
Capillary RBC velocity (mm/s)	0.60 ± 0.04	0.62 ± 0.04

Data are expressed as means ± SEM (hot constitution, n = 19; cold constitution, n = 11). HRV, heart rate variability; bpm, beats per minute; SDANN, standard deviation of the average NN interval; LF, low frequency component; nLF, normalized low frequency component; HF, high frequency component; nHF, normalized high frequency component; RBC, red blood cell. * indicates a significant difference ($P < 0.05$) between hot and cold constitutions using unpaired Student's *t*-test.

the subjects as having a hot constitution and 11 of the subjects as having a cold constitution according to the tongue diagnosis and division of personal constitution questionnaire. The comparisons of baseline physiological status between hot and cold constitution groups are shown in Table 1. No significant differences were observed between these two constitutions except that the average heart rate of the subjects with cold constitution (74.75 ± 2.63 bpm) was significantly lower than that of the subjects with hot constitution (87.30 ± 4.19 bpm, $P = 0.0233$).

Variations in Body Temperatures

No significant differences in variation in axillary temperature of the subjects were observed in either constitution groups (data not shown). However, the skin temperature of the subjects with cold constitution after taking coconut water was significantly reduced compared to their skin temperature after taking water or aged ginger tea (–10.1%, $P < 0.05$, Fig. 2B).

Variation in HRV

No significant differences in variation in HRV time-domain signals of the subjects in either constitution groups were observed (data not shown). However, the nLF (%) and LF/HF ratio of the subjects with hot constitution were significantly elevated after taking coconut water in comparison with the nLF and LF/HF ratio of these subjects after taking aged ginger tea (+35.4% and +89.8%, $P < 0.05$, Fig. 3, E and I). Moreover, both the HF (ms^2) and nHF (%) of the subjects with hot constitution increased significantly after taking aged ginger tea compared with taking coconut water (+25.1% and +5.9%, $P < 0.05$, Fig. 3, C and G). Although there were no significant dif-

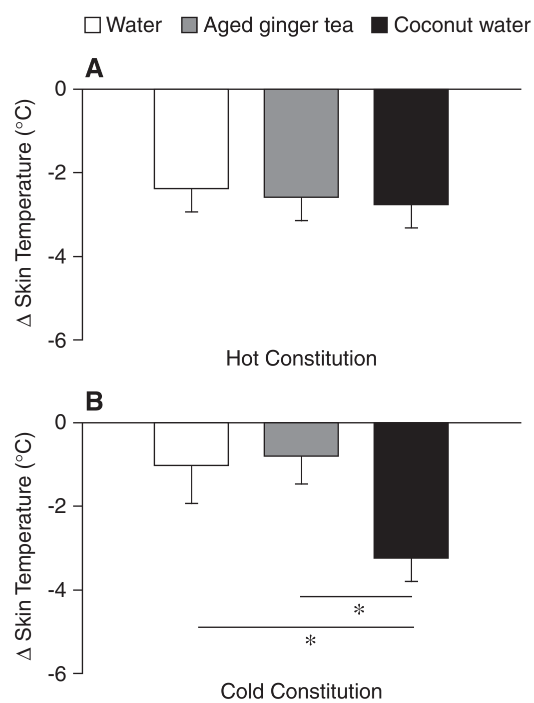

Fig. 2. Variation in the skin temperature of the subjects with hot (**A**) and cold (**B**) constitutions after taking water, aged ginger tea and coconut water. *$P < 0.05$ indicates a significant difference between responses to the samples using one-way ANOVA and Duncan's multiple range test.

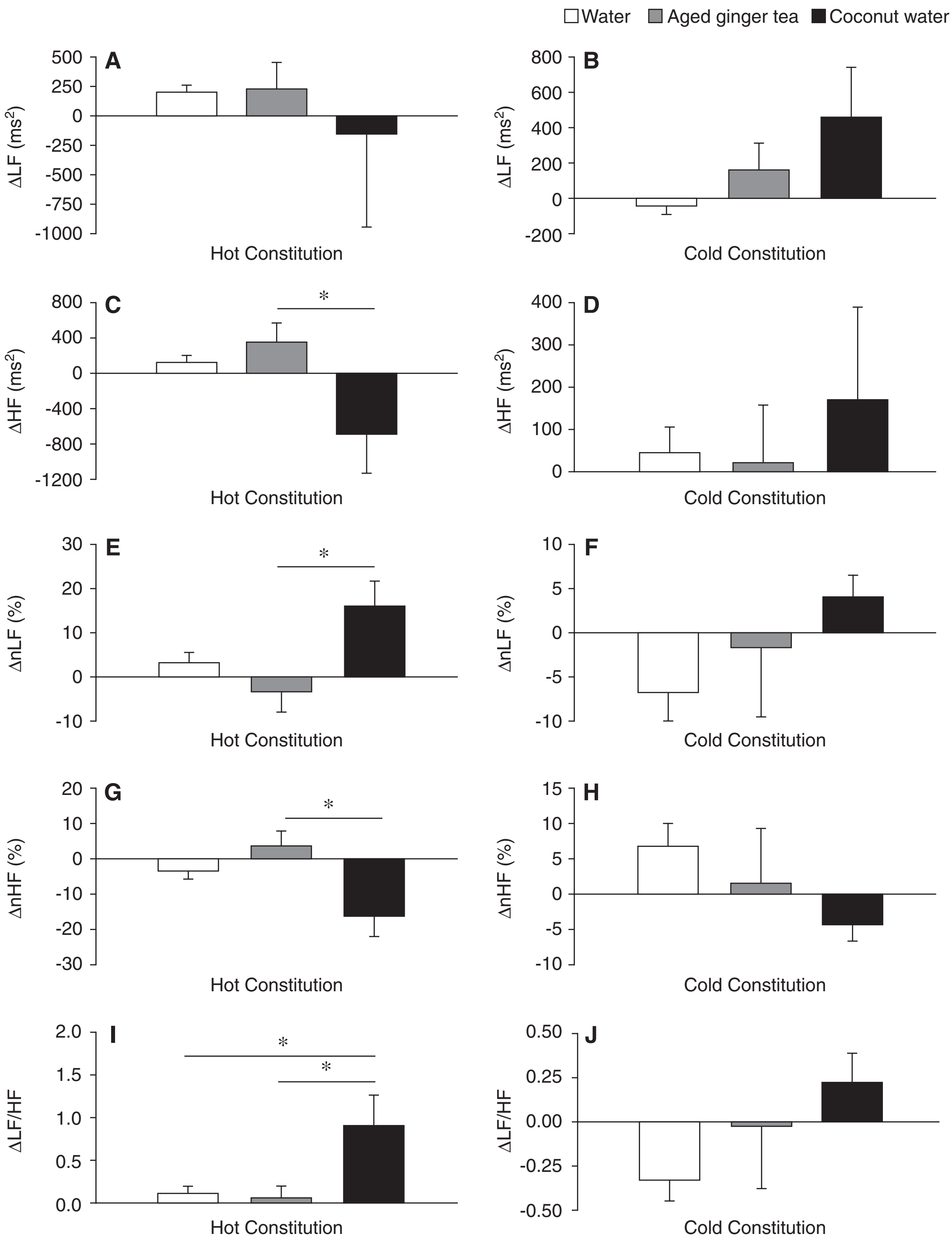

Fig. 3. Variation in the low frequency component (LF; **A**, **B**), high frequency component (HF; **C**, **D**), normalized low frequency component (nLF; **E**, **F**), normalized high frequency component (nHF; **G**, **H**), and LF/HF ratio (**I**, **J**) of HRV frequency-domain signals of the subjects with hot (**A**, **C**, **E**, **G**, **I**) and cold (**B**, **D**, **F**, **H**, **J**) constitutions after taking water, aged ginger tea, and coconut water. *$P < 0.05$ indicates a significant difference between responses to the samples using one-way ANOVA and Duncan's multiple range test.

ferences in variation in HRV frequency-domain signals of the subjects with cold constitution, the nLF and LF/HF ratio of these subjects after taking coconut water (+7.2% and +14.2%, Fig. 3, F and J) demonstrated a tendency toward elevation.

Variation in NFM

The variations in capillary RBC velocity of NFM of the subjects with different constitutions are shown in Fig. 4. The capillary RBC velocity of the

Table 2. Variation in physiological signal of total subject population

Physiological signal	Total subjects		
	Water	Aged ginger tea	Coconut water
Axillary temperature (°C)	-0.22 ± 0.09^{ab}	-0.02 ± 0.06^{a}	-0.26 ± 0.07^{b}
Skin temperature (°C)	-1.9 ± 0.5	-1.9 ± 0.5	-2.9 ± 0.4
Frequency-domain of HRV			
LF (ms^2)	$+62 \pm 50$	$+191 \pm 124$	$+210 \pm 364$
nLF (%)	-2.60 ± 2.55^{b}	-2.19 ± 4.82^{b}	$+9.00 \pm 3.28^{a}$
HF (ms^2)	$+75 \pm 49$	$+157 \pm 125$	-187 ± 251
nHF (%)	$+2.60 \pm 2.55^{a}$	$+2.19 \pm 4.82^{a}$	-9.00 ± 3.28^{b}
LF/HF ratio	-0.15 ± 0.10^{b}	$+0.00 \pm 0.21^{ab}$	$+0.49 \pm 0.20^{a}$
Capillary RBC velocity (mm/s)	-0.03 ± 0.02^{b}	$+0.08 \pm 0.03^{a}$	-0.07 ± 0.03^{b}

Data are expressed as means ± SEM (n = 30). HRV, heart rate variability; LF, low frequency component; nLF, normalized low frequency component; HF, high frequency component; nHF, normalized high frequency component; RBC, red blood cell. Variations within each signal not sharing the same letter are significantly different ($P < 0.05$) using one-way ANOVA and Duncan's multiple range test.

subjects with hot constitution accelerated significantly after taking aged ginger tea compared with taking water or coconut water (+16.6%, $P < 0.05$, Fig. 4A). The capillary RBC velocity of the subjects with cold constitution decelerated significantly after taking coconut water compared with taking water or aged ginger tea (–26.7%, $P < 0.05$, Fig. 4B).

Total Subject Population Regardless of the Constitution

As shown in Table 2, the axillary temperature of the total subject population was significantly reduced after taking coconut water compared with taking aged ginger tea ($P < 0.05$). Additionally, LF/HF ratio and nLF were significantly elevated, and nHF was significantly reduced in all subjects after taking coconut water in comparison to taking water or aged ginger tea ($P < 0.05$). Capillary RBC velocity was significantly accelerated in all subjects after taking aged ginger tea compared with taking water or coconut water ($P < 0.05$).

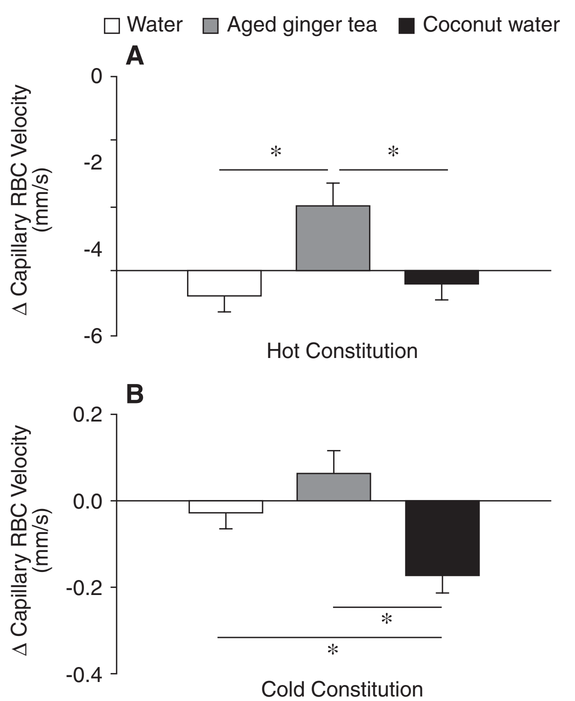

Fig. 4. Variation in the capillary red blood cell (RBC) velocity in NFM of the subjects with hot (**A**) and cold (**B**) constitutions after taking water, aged ginger tea, and coconut water. *$P < 0.05$ indicates a significant difference between responses to the samples using one-way ANOVA and Duncan's multiple range test.

Discussion

Personal Constitution vs. *Average Heart Rate*

In the present study, the average heart rate of the subjects with cold constitution was markedly lower than the subjects with hot constitution (Table 1). This corresponds to the *yin-yang* theory in TCM, which considers "stillness (*yin* excess or *yang* deficiency)" to cause slower pulses in the body and "activity (*yang* excess or *yin* deficiency)" to cause more rapid pulses (2, 19, 21). Therefore, we suggest that the subjects with cold constitution in the present study were calmer than those with hot constitution.

Capillary RBC Velocity vs. *Sympathovagal Balance and Skin Temperature*

The capillary RBC velocity of NFM of the subjects with hot constitution accelerated significantly after taking hot food, the aged ginger tea (Fig. 4A).

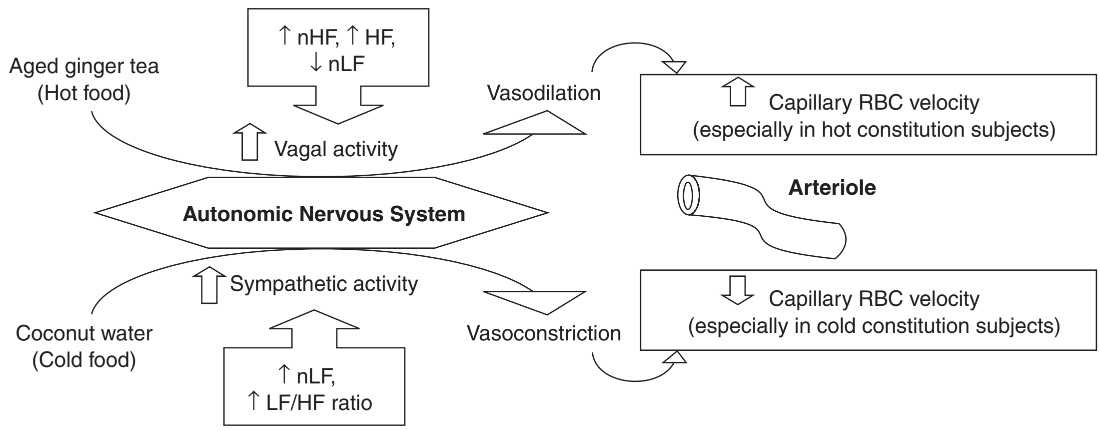

Fig. 5. Different attributes of food ingredients may affect the vasomotor tone of the cardiovascular system through the autonomic nervous system. LF: low frequency component; nLF: normalized low frequency component; HF: high frequency component; nHF: normalized high frequency component; RBC: red blood cell.

This indicated that the hot food raised the hot (*yang*) phenomenon in the subjects with hot constitution (2, 19, 21). The acceleration of skin blood flow has been shown to be related to vasodilation (14). Recent studies have suggested that the ginger aqueous extract and its phenolic compounds, 6-, 8- and 10-gingerol, could act as vasodilators through a dual effect mediated *via* endothelium-dependent and endothelium-independent pathways (1, 12). Therefore, aged ginger tea may have dilated the arterioles of these subjects and then accelerated their capillary RBC velocity on the basis of the phenolic compounds the tea contains.

In terms of the autonomic nervous system, vasodilation may be induced by increasing vagal activity (11). Of the variations in HRV frequency-domain signals, the vagal activity (HF and nHF) of the subjects with hot constitution significantly increased after taking aged ginger tea compared with taking coconut water (Fig. 3, C and G). In contrast, the sympathetic activity (nLF) of these subjects decreased simultaneously (Fig. 3E). The acceleration in capillary RBC velocity in these subjects after taking aged ginger tea may have been induced by vagal activation in the autonomic nervous system which causes arteriole dilation (Fig. 5). However, the effect of phenolic compounds in aged ginger tea on the autonomic nervous system requires further investigation.

In addition, the capillary RBC velocity of NFM of the subjects with cold constitution markedly decelerated after taking cold food, the coconut water (Fig. 4B). This finding may correspond to the significantly decreased skin temperature of these subjects that was also observed after taking coconut water in the present study (Fig. 2B). Our results are similar to those of House and Tipton (14) who found that both skin blood flow and skin temperature were reduced gradually during vasoconstriction. This also indicated that cold food would raise the cold (*yin*) phenomenon in the subjects with cold constitution (2, 19, 21).

Vasoconstriction may be induced by increasing sympathetic activity in the autonomic nervous system (11). According to our results, coconut water tended to increase sympathetic activity (nLF) and the sympathovagal ratio (LF/HF ratio) in the subjects with cold constitution (Fig. 3, F and J). The composition of young coconut water was mainly carbohydrate constituted mainly of fructose and glucose as the major components of total sugar (28). A recent study has reported that the cardiac interval LF component of healthy humans significantly increases after ingesting fructose or glucose drinks (7). Therefore, increasing sympathetic activity, which causes arteriole constriction, may have induced the deceleration in capillary RBC velocity of these subjects after taking coconut water (Fig. 5) which contains abundant fructose and glucose.

Personal Constitution vs. *Food Attribute*

Although we observed in the present study some significant variations in physiological signals in all subjects regardless of personal constitution (Table 2), we could not observe specific responses of people with different constitutions to food attributes until classifying them into hot and cold constitution groups, which also corresponds to the TCM concept of syndrome identification before treatment (21). Therefore, we consider personal constitution to be very important to the classification of food ingredient attributes.

In conclusion, the present study has demonstrated that [1] subjects with hot constitution exhibit a faster average heart rate (*yang* phenomenon) than subjects with cold constitution, [2] variations in capillary RBC velocity of NFM in our subjects with hot and cold constitutions seem to be sensitive to the hot and cold foods, respectively, and [3] variations in physiological signals across all subjects could not distinguish the different responses of subjects with different constitutions to food attributes.

Perspectives and Significance

The results obtained in this study provide us with preliminary evidences for a scientific approach to classify food attribute. The use of capillary RBC velocity of NFM measured by laser Doppler anemometer may be a promising methodology to classify the attributes of food ingredients in accordance with the different constitutions of people. We will further define the diversity of variations in capillary RBC velocity induced by different food ingredients and confirm that it is a suitable method to scientifically classify the attributes of all foods commonly used within the Chinese medicine dietary therapy in order to provide different individuals with more suitable diets.

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