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Effects of Mild Hyperthermia Treatment Using Nano-Mist Sauna on Blood Gas Parameters and Skin Appearance

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Abstract

Physicians often observe patients' complexion (their natural skin color) as an indicator of health. The complexion may depend on the internal environment, however, very few researchers studied its evidence. We previously reported various benefits of a mild hyperthermia treatment on human health using the nano-mist sauna (NMS), including acceleration of gas exchange (O_2 and CO_2) in the venous blood, enhancement of immunity, and the modulation of autonomic nervous system. However, the effects of NMS on skin appearance are unknown. There is a historical and widespread belief that mild hyperthermic treatments such as hot springs are good for improving skin appearance. However, the effect of NMS on the skin appearance has not been examined. In the present study, we examined the color of venous blood using the CIELAB (a color space specified by the French Commission *internationale de l'éclairage*) method, and then compared the color changes before and after NMS stimulation. Next, we examined correlations of blood gas parameters with color elements of the venous blood, which are highly dependent on oxygen. Our results suggest that the colors and appearance of the face depend on the internal environment, because there are numerous vessels under the skin. Thus, the color of the venous blood may provide medical evidence of changes in complexion. This new method may be useful for assessment of medical complexion by physicians, for use in determining internal health based on skin color information.

Keywords

Nano-Mist Sauna, Hyperthermia Treatment, Medical Complexion, Blood Gas, Color, Commission *Internationale de L'éclairage*

1. Introduction

Numerous studies have examined the health effects of mild hyperthermia, including bathing, saunas, or hot springs [1]-[6]. We previously reported the effects of conventional bathing with high temperature (>42˚C) [7] [8] and (≤42˚C) hyperthermia treatment with lower temperatures on internal health [9]. We also found that mild hyperthermia using the nano-mist sauna (NMS), a new hyperthermia (40˚C) treatment system, can provide beneficial health effects using indicators such as body temperature, autonomic nervous system function, and innate and adaptive immunity [10] [11]. For example, NMS treatment was associated with: 1) elevated body temperature, and increased PO_2 (partial pressure of oxygen) and decreased PCO_2 (partial pressure of carbon dioxide) of venous blood, resulting in alkalization; 2) decreased lactate levels, suggesting a mild parasympathetic nerve dominant (relaxed) condition; 3) a retention effect on body temperature; 4) a female-, patient-, and elderly-friendly hyperthermic stimulation (such patients may have difficulties in conventional bathing, which can also have a negative physiological effect); and 5) activation of leucocytes, and enhanced immunity and parasympathetic nerve activity [10] [11]. Nevertheless, the effects of NMS on skin appearance are largely unknown, although there is a long historical belief of beneficial effects of mild hyperthermia treatment on health and beauty.

In the present study, we examined the color elements (brightness, red, and yellow) of the venous blood and the face (as an indicator of beauty/appearance) in subjects before and after NMS stimulation. Further, we examined the relationship of venous blood gas parameters [pH (hydrogen-ion exponent), PO_2 (partial pressure of oxygen), and SO_2 (oxygen saturation)] as an indicator of internal health with the outside appearance of the body.

2. Materials and Methods

2.1. Subjects

In this study, participants were limited to office workers (20 - 60 years old) to avoid any factors other than the mild hyperthermia. Female of possibility of pregnancy or lactating were excluded. At the result, ten healthy male volunteers, aged 35 - 55 years (average 44.0 ± 8.8 years), participated in this study. All subjects were Japanese (Mongoloid race). Written informed consent was obtained from all subjects, and the study was approved by the institutional review board of Niigata University (Niigata, Japan). Subjects received a mild hyperthermic stimulation (20 min) using the NMS (40˚C, 100% relative humidity; CORONA Co., Niigata, Japan). NMS provides a mild stimulation without stressors such as water pressure. All subjects rested for more than 20 min before they received NMS stimulation. Subjects in the control group (no NMS) sat down in a work room (24.3˚C ± 0.3˚C, 70.0% ± 3.0% relative humidity) (**Figures 1(a)-(d)**).

2.2. Mild Hyperthermic Stimulation with the NMS

The NMS produces ultra-small fog-shaped hot water termed a nano-mist, which barely condenses to dew in the air. For generation of the nano-mist, the cone rapidly rotates and centrifugally lifts water in the tank (**Figure 1(a)**, **Figure 1(b)**). The water then escapes from small holes in the upper part of the cone, and passes through the metal mesh above the cone. This generates very fine water drops (nano-mist) that are negatively charged and released into the air. Relatively large drops fall back into the tank (**Figure 1(a)**). To activate the NMS, water is heated to approximately 45˚C by the sheath heater, the nano-mist is generated as described, and it is then sent into the sauna room by a cross flow fan (**Figure 1(a)**, **Figure 1(c)**). The heated air with the nano-mist comes from the air outlet on the lower side, and is sucked into the upper duct, which circulates the air in the nano-mist sauna room (40˚C, 100% relative humidity) (**Figure 1(a)**, **Figure 1(c)**). The diameter range of the nano-mist water droplets is approximately 10 to 500 nm [11]. Additionally, it provides a non-wet feeling, different from typical steam or mist [10].

2.3. Assessment of Blood Parameters

Fresh venous blood obtained from the median antebrachial vein before and after NMS stimulation was used to measure pH (hydrogen-ion exponent), PO_2 (partial pressure of oxygen), and SO_2 (oxygen saturation) using an i-STAT 1 analyzer (Abbott Point of Care Inc., Princeton, NJ, USA), as previously described [12] [13] [14]. Those parameters are collected within 10 minutes before the experiment and within 10 minutes after the experiment (**Figure 1(d)**).

2.4. Assessment of Venous Blood Color

The color of venous blood was assessed with the CR-400 (Konica Minolta, Inc., Tokyo, Japan) using the CIE L*a*b* (CIELAB) (a color space specified by the French Commission *internationale de l'éclairage*) method. This method is a color space specified by the International Commission on Illumination that describes all the colors visible to the human eye, and was created as a device-independent model to be used as a reference (**Figure 2**).

The three coordinates of CIELAB represent the lightness of color (L* = 0 indicates black; L* = 100 indicates diffuse white; specular white may be higher), its position between red/magenta and green (a*, negative values indicate green, positive values indicate magenta), and its position between yellow and blue (b*, negative values indicate blue, positive values indicate yellow) [15].

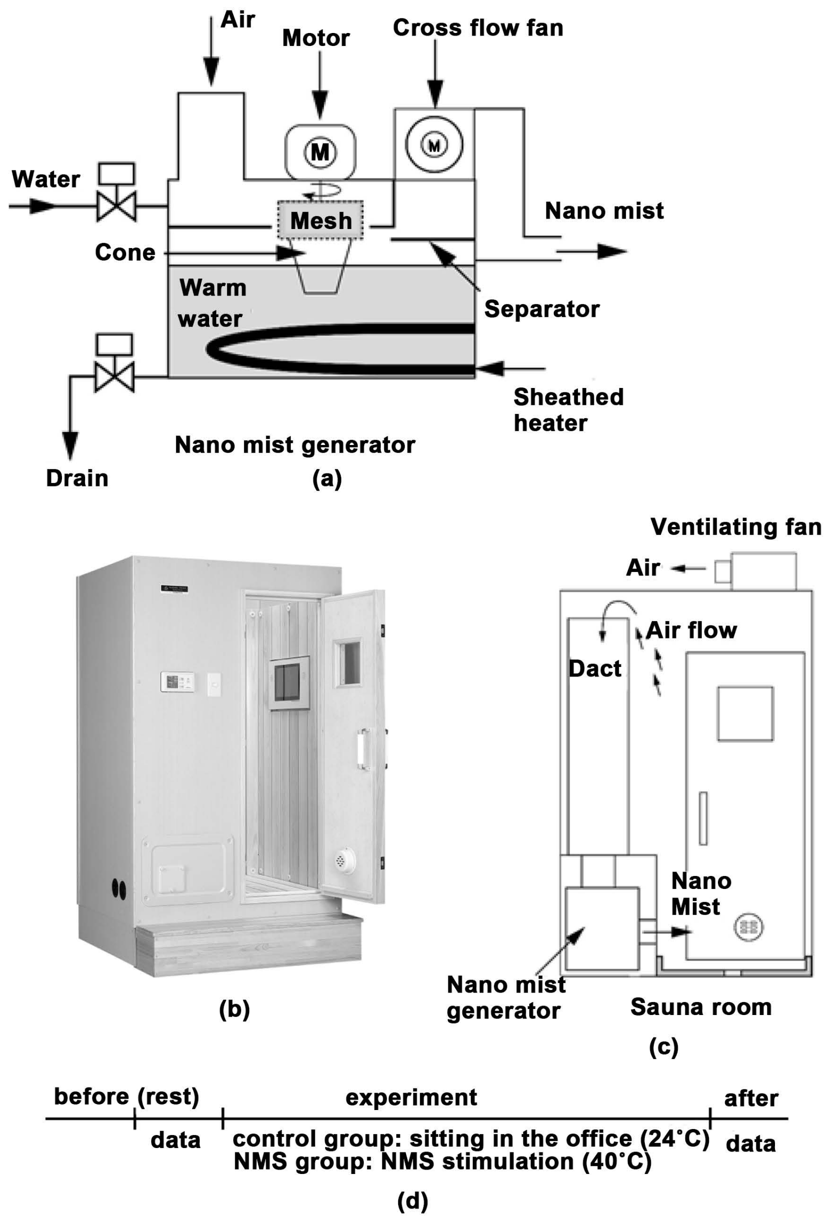

Figure 1. Nano-mist sauna (NMS) is filled with nano-mist. (a) Nano-mist is produced in NMS. Its diameter is approximately 10 to 500 nm, and it hardly condenses to dew in the air; (b) The appearance of NMS; (c) Nano-mist circulates in the NMS (40˚C, 100% relative humidity); (d) The protocol and difference of two groups of this study.

2.5. Assessment of Facial Color

The color elements of the face (at the top of cheek bones) were also measured using the same method as for the blood.

2.6. Statistical Analysis

Statistical differences between the groups were analyzed by the Wilcoxon signed rank test and the Mann-Whitney U test. Regression analyses of the relationship of blood parameters with the color of the venous blood, and of the color of

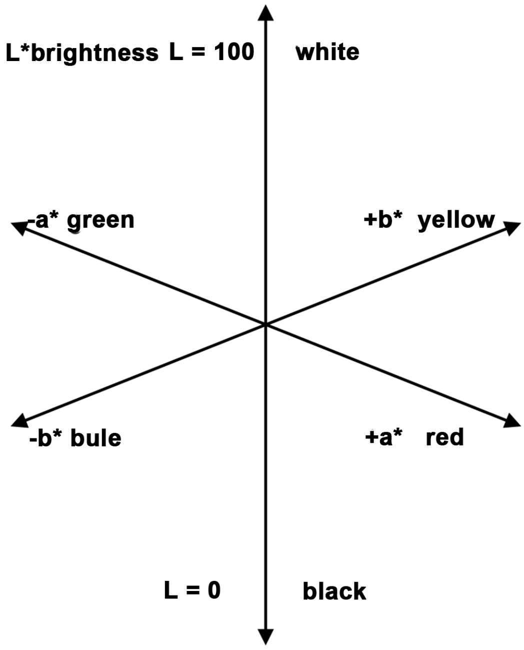

Figure 2. The conception of CIELAB. 1. brightness L* = 0 (black) to L* = 100 (white), 2. red and green (a*), negative values (green) positive values (red) and 3. yellow and blue (b*), negative values (blue) positive values (yellow).

venous blood with color of the face, was also examined. All statistical tests were performed using statistical software (Statcel 2; OMS Publishing, Saitama, Japan), which is written in Visual Basic for Applications. A P-value < 0.05 was considered statistically significant.

3. Results

3.1. Blood Gas Parameters

We previously reported that an increase in heart rate may affect blood circulation and the oxygen content of venous blood induced by the NMS stimulation. Therefore, in the present study we examined the changes in various blood gas parameters, including pH, PO_2, and SO_2, after NMS. There was a significant increase in blood pH (baseline: 7.35 ± 0.01 vs. NMS: 7.40 ± 0.02; $P < 0.05$), PO_2 (baseline: 33 ± 9 mmHg vs. NMS: 47 ± 15 mmHg; $P < 0.05$), and SO_2 (baseline: 57% ± 19% vs. NMS: 76% ± 19%; $P < 0.05$) after NMS stimulation. There were no changes in these parameters in the control group (**Figure 3(a)**).

3.2. Changes in Venous Blood Color

Visually, the color of the venous blood changed from dark red to vivid red after mild hyperthermic stimulation with the NMS. Using the CIELAB method, there was a significant increase in the blood brightness (brightness = L*; baseline: 32.4 ± 0.8 vs. NMS: 33.4 ± 1.1), red values (a*; baseline: 7.7 ± 3.7 vs. NMS: 12.0 ± 4.6; $P < 0.05$), and yellow values (b*; baseline: 1.3 ± 1.1 vs. NMS: 2.7 ± 1.3; $P < 0.05$)

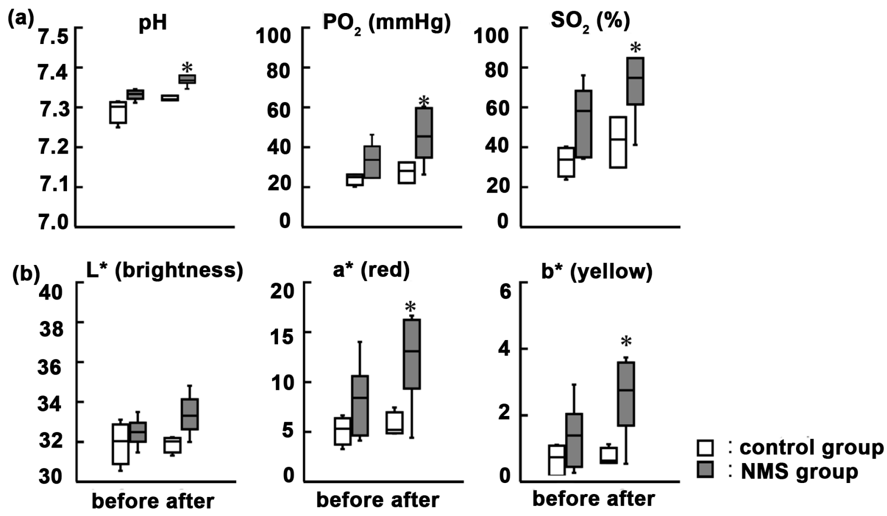

Figure 3. (a) Various blood Gas. pH, the partial pressures of oxygen (PO_2) and oxygen saturation (SO_2). Statistically increased after NMS while the control group did not. (b) The color of venous blood changed from dark red to vivid red. Although increased the value of brightness (L*) did not show significant increase, those of the red (a*) and yellow (b*) elevated (*$P < 0.05$).

following NMS treatment. Thus, visually the color of the venous blood became brighter (from dark to white) after hyperthermic stimulation, while the red and yellow values increased, and the green and blue values decreased. There were no changes in these parameters in the control group (Figure 3(b)).

3.3. Changes in Face Color

Simultaneous measurement of color elements of the face showed no significant differences with NMS treatment (data not shown).

3.4. Correlations of Blood Gas Parameters with Blood Color Elements

There were positive correlations of all color elements with venous blood parameters (pH, PO_2, and SO_2), with particular strong correlations with PO_2 and SO_2 (Figure 4).

3.5. Correlations of Blood Color Elements with Complexion

The regression analyses of blood color with complexion (color of the face) are shown in Figure 5. Although there were no significant changes, the b* value (yellow) showed trend towards a negative correlation, while the a* (red) and L* values showed trend towards a positive correlation.

4. Discussion

In the present study, we found a change in face color in all subjects (from pale to red) during and after NMS stimulation, as we previously demonstrated [8] [9] [10] [11]. Red blood cells contain hemoglobin (Hb), which transports oxygen

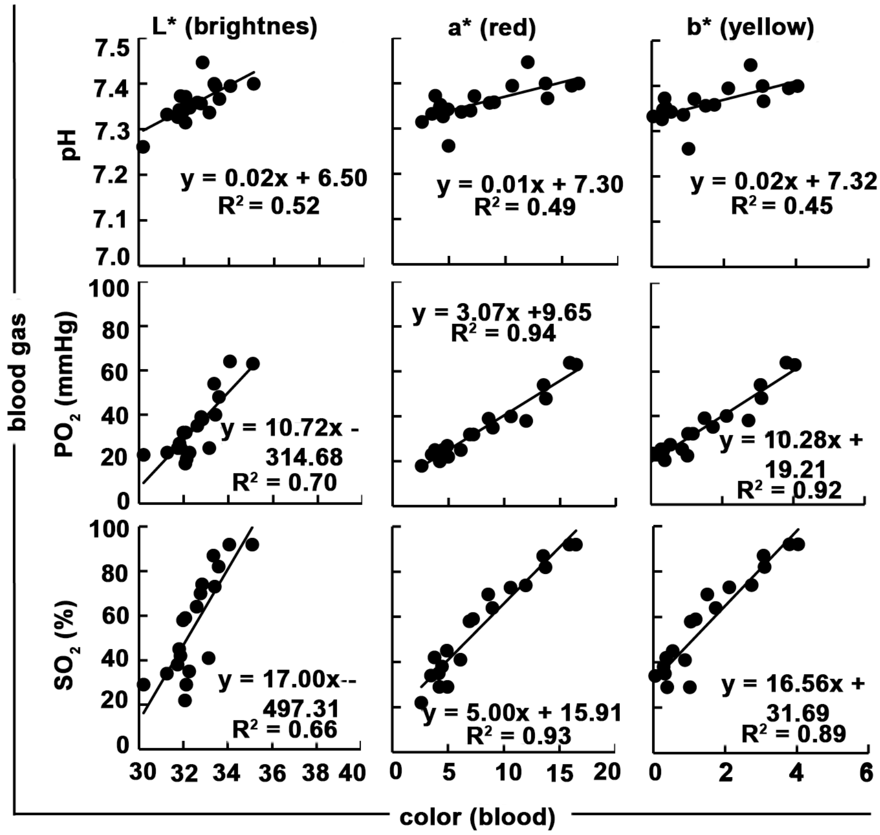

Figure 4. Positive correlations between blood gas parameters and color elements of blood correlations between all color elements of venous blood (brightness = L*, red = a* and yellow = b*) and its parameters (PO_2 and SO_2) positive and high.

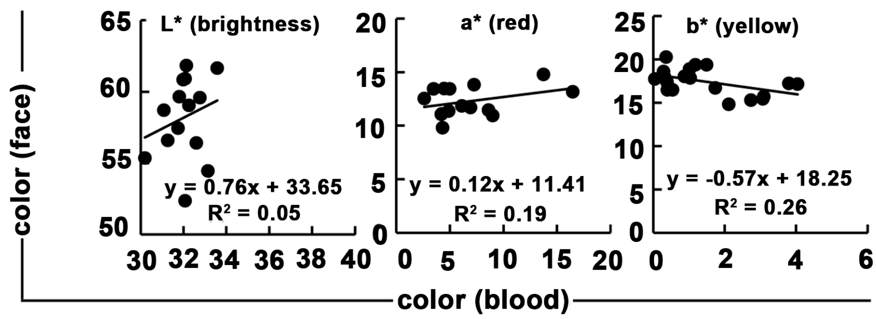

Figure 5. The color of blood and the complexion (color of the face). The value of b* (yellow) was the highest and followed by a* (red) and L* (brightness). Only b* showed a negative correlation.

throughout the body. Hb contains a haem prosthetic group that has an iron atom at its center. When Hb is rich in oxygen, the iron is bound to oxygen, and the haem group produces a vivid red color. By contrast, lower Hb saturation is associated with a darker red color. In the preset study, we confirmed this change in blood color using the CIELAB method. Further, we found positive and strong correlations of all color elements (e.g., brightness [white/black], red, and yellow) with blood gas parameters (e.g., pH, PO_2, and SO_2) (**Figure 4**).

We previously reported that hyperthermic stimulation accelerated internal gases exchange [8] [9] [10] [11]. Indeed, in the present study, the PCO_2 (baseline: 52 ± 6 mmHg vs. NMS: 45 ± 5 mmHg) and total CO_2 (baseline: 30 ± 2 mmHg vs. NMS: 29 ± 2 mmHg) decreased after NMS [8] [9] [10] [11]. The NMS also increased respiratory rate (baseline: 15.7 ± 5.8 vs. NMS: 16.7 ± 6.3 per minute) and heart rate (baseline: 72.2 ± 10.1 vs. NMS: 74.2 ± 11.3 per minute) (data not shown). Thus, these data support the change of venous blood color from dark red to vivid red. These findings may be explained by the Bohr Effect, whereby the reduction in blood CO_2 and corresponding increase in pH causes a shift in the oxygen-dissociation curve [16].

The specific position of the yellow color may also support the findings of a change in blood color from dark red to vivid red with NMS, as yellow is located at the opposite end of the scale from blue (**Figure 2**) [15]. In other words, with improving blood circulation following NMS, there is a decrease in the blue color and an increase in the yellow color, which can result in a change in the skin complexion (from pale to red).

The rich network of capillary blood vessels in the face may also allow assessment of blood condition by measurement of the face color (complexion). Our study provides suggestive evidence for a correlation of complexion (red and yellow) with blood parameters (**Figure 5**), while the red color in the face likely reflects the level of blood oxygen. We also found that the yellow color in the blood showed a strong negative correlation with that in the face. All our subjects were of Mongoloid race. Therefore, the yellow color element of the venous blood was not as strong as being able to reflect through the facial skin. However, further studies with more subjects of different backgrounds are required to examine this hypothesis. Further, these studies should minimize interpersonal differences of the facial skin including suntan or age.

Physicians often observe the appearance of a patient's complexion to help with diagnosis (e.g., anemia or blood circulation). However, this requires time and experience, and sometimes medical testing equipment. Our findings provide support for the use of medical complexion as a diagnostic tool, as it can reflect changes in the blood color, which is dependent on blood circulation and oxygenation. This technique may be particularly useful in the ambulatory setting or primary care, as it is minimally invasive and easy to perform. Nevertheless, further studies examining the correlation of complexion with health (internal environment) are required to confirm the clinical utility of this method. There are also a number of limitations of this study, including the small number of subjects. Thus, additional larger scale studies using age-matched groups, in various occupations, in different seasons, genders, and in different countries are required to further support our findings.

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Competing Interest

The authors have no competing interests to report.

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