Analysis of effects of aroma foot care using functional near-infrared spectroscopy

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Abstract

Foot care is attracting attention as a medically effective treatment of the foot lesions caused by diabetes or aging. In this study, we experimentally examined how aromatherapy affects the functions of the human brain during foot care by using functional near-infrared spectroscopy (fNIRS). Four female subjects received foot care massages and aroma oil massages. We analyzed the changes in their oxygenated hemoglobin (oxy-Hb) concentrations based on their brain activity by t-tests, and the t-test results showed significant differences between the foot and aroma oil massages. Our questionnaire results obtained from our subjects showed that they felt more comfortable and relaxed while receiving foot care with aroma oils. These results suggest that aroma oil massages are an effective foot care tool.

Keywords: foot care, aroma oil massage, function near-infrared spectroscopy;

1. Introduction

As a countermeasure against foot lesions caused by aging and diabetes, interest in foot care is growing as an effective medical means, especially combining aromatherapy with foot care\textsuperscript{1,2}. Aroma oils relax the mind and the
body and increase the intrinsic self-healing power of humans. In this study, we measure the influence of the blood flow in the human brain during foot care with aroma oils using a functional near-infrared spectroscopy (fNIRS) device to confirm the relaxation caused by the aroma oils. This fNIRS device measures the relative alterations in the oxygenated hemoglobin (oxy-Hb), in the deoxygenated hemoglobin (deoxy-Hb), and the total hemoglobin (total Hb) changes in the blood flow in the human brain and specifies the part that is being activated.

Previous studies reported the effects of stimulation by smell using fNIRS on the human brain, which is the area that corresponds to the orbitofrontal cortex to the activation. Differences in the quality of the smell and the activated state of the human brain have also been reported. However, little research has examined the effect of foot care using aroma oils. We examined the effect of aroma oils by measuring with fNIRS the changes of the blood flow within the brain during aroma oil massages and analyzed the results.

2. Experiment

In our experiments, three female nurses who specialize in foot care performed four sets of foot care: a footbath, a massage, a footbath with aroma oils, and an aroma oil massage. Our subjects were four women over the age of 65. We obtained aroma oils from essential oils by blending Lavandula angustifolia, Tea tree, Ravensara, Palmarosa, and Chamomile. We measured the prefrontal cortex area (from the 1st to 22nd channels) and the somatosensory cortex area (from 23rd to 46th channels). We used the fNIRS system developed by the Shimadzu Co. (FOIRE-3000, 46 channels) to observe and record the hemoglobin concentrations in every subject’s brain.

The probe holder included 46 optical source-detector channels to monitor the relative changes in the hemoglobin concentration in the brains of the subjects. The channels covered the brain’s frontal association area and its somatosensory area. To assess the activation of the human brain functions in these areas, we observed the blood hemoglobin concentration of each subject from the beginning to the end of the massage. The relative changes in the oxy-Hb, deoxy-Hb, and total-Hb concentrations from the 46 channel points were simultaneously measured and recorded for each subject. After finishing the measurements, the subjects completed questionnaires on a five-point scale, where 1 = very weak and 5 = very strong, to determine the following: their relaxation levels, feelings of comfort and smell, and like and dislike of the smell.

2.1. Experimental design

Our experiment used the block design shown in Fig. 1. Rest 1 is just touching the subject’s foot (20 seconds). Task A is a massage of the subject’s right foot with aroma oils (60 seconds). Rest 2 does nothing (rest) (20 seconds). Task B is a massage of the subject’s left foot with aroma oils (60 seconds). These were repeated three times.

![Fig. 1. Block design of experiment with aroma oil massages.](image-url)
Fig. 2 shows the setup of the brain function measurement and the massage performance in this experiment. Fig. 2. (a) shows a subject wearing the probe holder. Fig. 2. (b) shows a subject receiving an aroma oil massage from a foot care nurse.

3. Result

3.1. Trend graph of hemoglobin concentration changes

We graphically compared the hemoglobin concentration of the blood changes in the human brain from the foot and aroma oil massages. Fig. 3 shows subject A’s trend graph, which represents the temporal changes of the Hb concentration of all the channels. The red line shows the oxy-Hb concentration, the blue line shows the deoxy-Hb concentration, and the green line shows the total Hb concentration. The left half of the figure corresponds to the frontal association area, and the right half corresponds with the somatosensory area.

From the graph in Fig. 3(a), the oxy-Hb concentration in channel 13 corresponding to the untitled frontal association area increased and the total Hb concentration also increased. With a corresponding increase of the oxy-Hb concentration, the deox-Hb concentration rapidly decreased in the second half of each task. On the whole, the deoxy-Hb concentration gradually decreased. In channel 33, which corresponds to the somatosensory area, the Oxy-Hb concentration did not change much in task 1, but it rapidly declined in task 2; the de-Oxy-Hb concentration only slightly changed in the first task, but it abruptly increased in task 2.

From the graph of Fig. 3(b), the oxy-Hb concentration of channel 13 corresponding to the frontal association area increased as did the total-Hb concentration. The oxy-Hb concentration gradually decreased in task 3. The deoxy-Hb concentration also gradually decreased. The oxy-Hb concentration of channel 33 corresponding to the somatosensory area did not change, but it increased in the second half. The deoxy-Hb concentration greatly decreased first and then returned to the level of zero in the second half.
3.2. Smoothing of data

We calculated the moving average to smooth the data of subject A. In Fig. 4. (a) in each task period, oxy-Hb concentration tended to increase slightly after the later task began, and the oxy-Hb concentration decreased; the opposite phenomenon occurred in each rest period. The oxy-Hb concentration shows an increasing tendency, and the deox-Hb concentration shows a tendency to return to the level zero.

In Fig. 4. (b) in each task period, the oxy-Hb concentration shows a remarkable change: increases in the first half and a gradual downward tendency. The deoxy-Hb concentration shows a gradual downward tendency, although no remarkable change is seen compared with the oxy-Hb concentration. The deoxy-Hb concentration increased at the beginning of task 3, but decreased rapidly from the four rests and maintained its state until task 6.
3.3. Differences between feet

We analyzed the data of the changes in the oxy-Hb concentration in the brain among tasks and the rest task with aroma oil and foot massages. Here, the amount of change in the oxy-Hb concentration reduced the average value of the amount of the change of the period of each rest (just touching the foot) from the amount of change of each task period.

We averaged the measured changes in the oxy-Hb concentration of our four subjects and compared the foot and aroma oil massages by t-tests (p < 0.05). Channels where significant changes occurred in the oxy-Hb concentration are shown by shading with diagonal slashes (Fig. 5). In the right foot, channels 9, 14, 27, 34, and 37 show significant differences. In the left foot, channels 6, 8, 13, 16, 23, 33, 35, 38, and 43 show significant differences. We found no differences between the feet and no big differences between the somatosensory and frontal association areas. But the somatosensory area had more significant difference channels.
3.4. Differences between foot and aroma oil massages

Figure 6 shows the moving averages of the channels that showed a significant change in the oxy-Hb concentration. Channels 8 and 9 correspond to the frontal association area. The aroma oil massages show a relatively big range of the change in the oxy-Hb concentration, which greatly decreased in the task, and the massage shows a smaller decrease than the aroma oil massages in channel 8. The massage shows a relatively large range of change in the oxy-Hb concentration, and the aroma oil massages repeat the increases and decreases for every task and show a big change in the second half. The massage decreases in the beginning, increases after that, and shows a downward tendency from the middle of the period in channel 9.

Channels 33 and 35 correspond to the somatosensory area. From the graph, we found that the oxy-Hb concentration changed in both the foot and aroma oil massages. The aroma oil massages show a tendency to gradually increase, repeating increases and decreases, and the massage tends to decrease gradually, repeating increases and decreases in channel 33. The aroma oil massages repeated their increases and decreases without showing a larger range of changes, and the massage decreased in the beginning, increased after that, and shows a big downward tendency in the second half of the period in channel 35.

![Graphs showing differences between foot and aroma oil massages](image-url)
3.5. Results of questionnaire investigation

We summarize the questionnaire results of our investigation as follows.

(1) Massage strength:
   - One subject felt that the massage was slightly too strong, but the other three felt the strength was appropriate.
   - The four subjects felt the strength of the aroma oil massage was appropriate.

(2) Comfort:
   - The four subjects felt the foot and aroma oil massages were very comfortable.

(3) Relax:
   - One subject slightly relaxed in both the foot and aroma oil massages.
   - Two subjects greatly relaxed in both the foot and aroma oil massages.
   - One subject slightly relaxed in the massage.
   - One subject greatly relaxed during the aroma oil massage.

(4) Smell:
   - Three subjects clearly detected a smell, and one only slightly detected a smell. Three subjects liked the smell.
   - The evaluations by the subjects resembled the results for each evaluation item, but for the relaxation, their evaluations were different.

4. Discussion and conclusion

In this study, we examined the effects of foot care with aroma oils and obtained the following results:

(1) Trend graph of hemoglobin concentration changes:
   - The differences of the hemoglobin concentration changes of the foot and aroma oil massages were observed by a trend graph. The oxy-Hb concentration increased in the frontal association area in both the foot and aromatherapy massages. The oxy-Hb concentration decreased in the somatosensory area of the massages.
   - We calculated the moving average to smooth the data. The change of the oxy-Hb concentration of the massages increased in the second half of each task and showed a trend to increase as a whole. The change of the oxy-Hb concentration with the aroma oil massages significantly increased in the first half and decreased in the second half.
   - These results suggest that a massage continues to activate the entire frontal association area, and the aroma oil massages first activate the entire frontal cortex, but the activation is reduced by the gradually relaxing effect of the aroma oils.

(3) Differences between:
   - We examined the differences of the oxy-Hb changes by concentrating on both feet. We found no differences between them. There was also not a big difference between the somatosensory and frontal association areas, but the former had more significantly different channels. These results suggest that the effect of foot care activates the somatosensory area.

(4) Differences between foot and aroma oil massages:
   - We also examined the differences of the changes in the oxygenation of the hemoglobin aroma massages and the foot massages. The change of the oxy-Hb concentration of the aroma oil massages remarkably changed in the frontal association area, and the change of the oxy-Hb concentration of the massages remarkably changed in the somatosensory area, suggesting that the effect of the aroma oil massages activates the frontal association area.
   - We captured the blood flow dynamics in the human brain associated with foot care with aroma oils using fNIRS. That is, we captured the relative variation of the oxy-Hb concentration, the deoxy-Hb concentration, and the total Hb concentration. In this paper, we visualized the effect of foot care with aroma oils by determining the concentration of the hemoglobin changes in the blood flow in the human brain by fNIRS. Since this experiment only had four female subjects, we failed to derive any deterministic knowledge from our obtained data. In future work, we plan to increase the number of subjects and develop a method and a tool to scrutinize the experimental data.

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