Effectiveness of Aromatherapy Evaluated with Subjective and Objective Cognitive Indicators: A Clinical Trial on Young Adults Using Near-infrared Spectroscopy

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The purpose of this research was to noninvasively evaluate the influence of aromatherapy on work performance in 14 healthy young adults. Participants in a room filled with the fragrance of lavender completed a self-reported questionnaire and multi-dimensional fatigue inventory-20 (MFI-20). Further, as an objective measure, blood flow in the inferior frontal cortex was evaluated via near-infrared spectroscopy (NIRS) as a parameter of working memory capacity. Compared to the control stage (no aromatherapy), exposure to aromatherapy achieved a significant reduction in general and mental fatigue according to MFI-20. Self-reported questionnaires also indicated improvement, but the differences were not statistically significant. NIRS measurement during the task performance of an N-back program indicated that regional blood flow in the inferior frontal cortex was significantly increased through exposure to aromatherapy, compared to without. The prefrontal area in the brain is involved in working memory, attention concentration and judgment. These results suggest that lavender may improve both cognitive ability and mood. A larger study with more aroma oils seems warranted.

Key words —— aromatherapy, multi-dimensional fatigue inventory-20 (MFI-20), near-infrared light spectroscopy (NIRS), clinical trial

Introduction

Aromatherapy with aromatic oils has used traditionally for over a millennium and is widely used as a complementary medicine throughout the world. Functional magnetic resonance imaging (fMRI) study has shown that aroma information is passed to the thalamus, hypothalamus and cerebral limbic system¹¹, and may influence human emotion, behavior, learning and memory. The effectiveness of certain odor components for changing mood has been confirmed by the use of self-reported questionnaires, as well as measurements of blood pressure and pulse, and objective indicators of work load²⁻³.³

Near-infrared spectroscopy (NIRS) measures blood flow volume of interior frontal cortex to control cognitive function. NIRS is a relatively new imaging technique for investigating cortical hemodynamic responses by measuring changes in the attenuation of near-infrared light as it passes through tissue, and for example, has been used to visualize changes in regional cortical activity during finger movement⁶.

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The International Pharmaceutical Federation (FIP) has defined aromatherapy as a Complementary and Alternative Medication (CAM), with a similar position to that of prescription and non-prescription products as healthcare drugs. Little attention is currently given to aromatherapy in pharmaceutical education in Japan. Also, there have been few studies on aromatherapy efficacy using objective evaluation methods, such as NIRS. We previously reported a clinical trial to examine the effectiveness of energy drinks, and found significant effects on cognitive ability. So, here we focused on the feasibility of using NIRS as an objective measure. Firstly we examined the effectiveness of aroma oil by using both subjective and objective indicators, i.e., questionnaires and NIRS monitoring, respectively.

This study was approved by the Keio University Faculty of Pharmacy Medical Ethics Board. All subjects gave prior written informed consent.

Methods

1. Aroma oil

Lavender oil by Farfalla Lavendel Fein (Lot No. 031076) was used. Three drops of oil were added to 80 mL of water (2% solution), and the solution was placed in a diffuser (aroma de light, YCHO-JIN, effective space 13.2~24.8 m²). The diffuser was run in a 13.2 m² room during the trial.

2. Subjects

Adults from 22 to 28 years old working in the Faculty of Pharmacy in Keio University campus were recruited to participate. Participants who disliked lavender aroma were excluded. Ultimately fourteen participants were selected for the study.

3. Duration of study

This trial was undertaken in Keio University Faculty of Pharmacy (Tokyo, Japan) in January through February 2011.

4. Evaluation items

The following test items were evaluated under control and aromatherapy conditions.

1) Motivation, feeling of drowsiness and general fatigue were evaluated on a subjective scale in self-reported questionnaires.

2) Categories in multi-dimensional fatigue inventory-20 (MFI-20) were completed.

3) A NIRS apparatus (compact size, portable wearable near-infrared spectroscopy appliance, Hitachi Ltd.) was used to measure cerebral blood flow. The NIRS headset fits on the front of the head for multichannel monitoring, as illustrated in Fig. 1. We focused on channels 5, 6, 7, 8 and 9 as regions of interest, as discussed later.

5. Experimental schedule

In the control run (no aromatherapy), participants completed the questionnaire, MFI-20 and NIRS testing without aromatherapy. In the subsequent aromatherapy run, participants completed the questionnaire, MFI-20 and NIRS testing in the same room with the aroma diffuser in operation. In order to avoid the influence of environmental stress, the participants were seated in calm and comfortable individual cabins with air-conditioning. The interval between the control run and aromatherapy run was 40 minutes. It took 5 minutes to pervade the room with lavender aroma.

6. Method of evaluation

1) Self-reported questionnaire (Fig. 2)

Questions were asked about motivation, feel-
ing of drowsiness and general fatigue in a self-reported questionnaire, on ascending scales of 1 to 5. Participants selected and checked only 1 point, which they considered the most suitable.

2) MFI-20 (Table)

MFI-20 Japanese version has 20 questions in 5 categories, covering general fatigue, physical fatigue, reduced activity, reduced motivation, and mental fatigue. Participants decide among five options in each category.

3) Oxygenated hemoglobin (Oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) can be measured by NIRS based on their different absorption spectra. The concentration of oxy-Hb responds to regional cortical activation and blood flow is increased in the corresponding area. We focused on channels 5, 6, 7, 8 and 9 of the NIRS instrument, corresponding approximately to the frontal cortical area.

4) Working memory task

Task performance of an N-back program (load condition) was examined with and without aromatherapy. The N-back program requires a response to random numbers on a computer display. The high load condition asks for a response corresponding to the stimulus number two trials previously (2-back program), and the low load condition simply requires the given number (0-back program). The load is repeated between 2 back and 0 back (0-back → 2-back → 0-back → 2-back → 0-back). One program takes 52 seconds, and the test is complete within 5 minutes.

Participants were given a 1 minute resting period before and after the N-back program (rest time).

7. Statistics

Data were expressed as means ± standard error. The control state and aromatherapy state were compared using a two-tailed test implemented in the SAS 9.2 procedure (SAS Institute). The criterion of significance was $p < 0.05$ by the t-test procedure (PAIRED statement).

1) Self-reported questionnaires

Self-reported questionnaires completed by participants were evaluated in terms of numerical values on a 5-point scale. The effects of the aro-
matherapy were examined by comparing the control and aromatherapy stages.

2) MFI-20

Twenty items in five categories were evaluated on a 5-point scale. The effects of the aromatherapy were examined by comparing the control and aromatherapy stages.

3) NIRS

Average values of $\Delta$ oxy-Hb for the 2-back program – 0 back program were calculated, and the values in the control and aromatherapy stages were measured to compare the high load condition (2-back) with the low load condition (0-back).

In addition, average values of $\Delta$ oxy-Hb for the N-back program – rest time were calculated, and the values in the control and load condition of aromatherapy stages were compared to evaluate the influence of lavender aroma versus the resting state.

Results

1. Background of participants

Among the 14 participants, 5 were male and 9 female. Average age was 23.7 ± 0.3 years (average ± standard error).

2. Self-reported questionnaires

The results on motivation, feeling of drowsiness and general fatigue from the questionnaires are shown in Fig. 3. No significant difference was found.

3. MFI-20

As shown in Fig. 4, aromatherapy significantly decreased general fatigue (average ± standard error of the aromatherapy: 11.6 ± 0.7, $p = 0.039$, average ± standard error of the control: 13.3 ± 0.7), as well as mental fatigue (average ± standard error of the aromatherapy: 10.4 ± 0.8, $p = 0.012$, average ± standard error of the control: 11.9 ± 0.8).

Table Questions in 5 categories of MFI-20 Japanese version

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of respondents</th>
<th>Question items</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Fatigue</td>
<td>1</td>
<td>I feel fit</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>I feel tired</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>I am rested</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>I tire easily</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Physically I feel only able to do a little</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Physically, I can take on a lot</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Physically I feel I am in a bad condition</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Physically I feel I am in an excellent condition</td>
</tr>
<tr>
<td>Physical Fatigue</td>
<td>3</td>
<td>I feel very active</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>I think I do a lot in a day</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>I think I do very little in a day</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>I get little done</td>
</tr>
<tr>
<td>Reduced Activity</td>
<td>4</td>
<td>I feel like doing all sorts of nice things</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>I dread having to do things</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>I have a lot of plans</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>I don’t feel like doing anything</td>
</tr>
<tr>
<td>Reduced Motivation</td>
<td>7</td>
<td>When I am doing something, I can keep my thought on it</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>I can concentrate well</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>It take a lot of effort to concentrate on things</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>My thoughts easily wander</td>
</tr>
</tbody>
</table>

Table Questions in 5 categories of MFI-20 Japanese version
Fig. 3. Data from self-reported questionnaires
Scores for general fatigue, feeling of drowsiness and motivation about aromatherapy, compared with the controls. The error bars represent the standard errors of scores.
GF: general fatigue
FD: feeling of drowsiness
MV: Motivation

Fig. 4. Data from MFI-20
The error bars represent the standard errors of scores.
GF: general fatigue RF: physical fatigue
RA: reduced activity RM: reduced motivation
MF: mental fatigue
*: Aromatherapy significantly decreased general fatigue and mental fatigue, in comparison with the controls (*p<0.05).

4. NIRS

The average Δoxy-Hb for the N-back program – rest time in the control and aromatherapy stages are shown in Fig. 5a. On channel 7, Δoxy-Hb in the aromatherapy stage was significantly increased versus the control stage (average ± standard error of the aromatherapy: 0.077 ± 0.049, p = 0.0063, average ± standard error of the control: 0.027 ± 0.043). The results for the 2-back program – 0 back program are shown in Fig. 5b. On channel 7, Δoxy-Hb of the aromatherapy stage was slightly increased versus that of the control stage (average ± standard error of the aromatherapy: 0.062 ± 0.048, p = 0.063, average ± standard error of the control: 0.038 ± 0.030).

Discussion

The self-reported subjective questionnaire did not show a significant improvement of motivation, feeling of drowsiness or general fatigue in response to aromatherapy. On the other hand, general fatigue and mental fatigue in MFI-20
were significantly reduced by the aromatherapy. Thus, the fragrance may influence mood via the cerebral limbic system. This finding that lavender aroma affected mood is consistent with a previous report. Moreover, it is noteworthy that the multi-dimensional approach of MFI-20 indicated greater effectiveness than the single-dimensional method. In a previous clinical trial, we examined the effect of energy drinks containing vitamin compounds, taurine, caffeine and several botanical herbs extracts on work performance by using MFI-20. It was found that the energy drinks significantly decreased general and physical fatigue. It is interesting that aromatherapy was also beneficial for mental fatigue.

The 2-back task involves constant renewal of working memory, and an increase of prefrontal cortex activity was shown by means of NIRS study to be induced by a working memory task. Indeed, we found that aromatherapy caused a significant increase of Δoxy-Hb compared to the control in channel 7, corresponding to the dorsolateral prefrontal area of the frontal cortex (Fig. 1), which is associated with working memory, attention concentration and judgment. This is consistent with a report of increased activity of the inferior frontal gyrus area in the right hemisphere during a logical cogitation task. However, we found no objective change of blood flow volume in the prefrontal cortex in the high load condition compared with the low load condition. This result is not consistent with a previous report. Although the increase was not observed in all channels, the Blood flow was increased in right 46 field of Brodmann’s area (Brodmann’s brain map), and evaluated the influence of lavender aroma versus the resting state. In contrast, there is a report that fragrance administration altered the dominant side of stress-induced prefrontal cortex activity from the right to the left side. A larger study with more subjects, focusing on laterality of the prefrontal cortex activity, seems warranted.

It has been shown that Δoxy-Hb of the right interior frontal cortex is significantly decreased by alcohol, which is known to be a depressant. This supports the idea that the increase of Δoxy-Hb in the same area represents an activating effect. It should be noted that NIRS measurement may be influenced by body motion, breathing, headset position, etc. Also, NIRS only detects hemodynamic change near the surface of the brain. Therefore, fMRI might be a useful approach for further investigation. We found that females showed larger significant decrease of mental fatigue scale in MFI-20 in response to aromatherapy (p<0.008, data not shown), in agreement with a previous report. It will be important to take into account cognitive gender difference and episodic memory of fragrance in future studies.

Our results indicate that blood flow in the response area associated with right 46 field of Brodmann’s brain map was increased. It would also be interesting to do a larger study with more subjects to evaluate the effect of aromatherapy in more detail with different aromas.

Acknowledgments

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References

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