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# Using a Healing Robot for the Scientific Study of Shirodhara

*Altered States of Consciousness and Decreased Anxiety Through Indian Dripping Oil Treatments*

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**S**hirodhara is one of the oil treatments originating from Keraliya Panchakarma [1]. It has long been conducted to combat insomnia, headache, anxiety neurosis, depression, schizophrenia, motor-neuron disease, hypertension, and several kinds of psychosis.

In Sanskrit, *shiro* means head and *dhara* means dripping; shirodhara is the process of dripping some medium on the forehead for tens of minutes as shown in Figure 1. There are several kinds of dhara techniques, depending on the medium for dripping. For example, takra dhara uses takra that is prepared with the curd of cow's milk. Kshira dhara uses cow's milk mixed with some medicinal herbs such as *Sida cordifolia* or *Asparagus ramosus*. Taila dhara uses medicated oil mixed with cow's milk, water, herbs, and sesame oil [1]–[3].

Shirodhara is one of the characteristic healing techniques of Ayurveda, however, few reports on the physio-psychological changes during shirodhara have been reported [1], [4], [5]. Also, the psychological effects of shirodhara have not yet been referred to as altered states of consciousness. One of the critical problems in the study of physiotherapy of Oriental medicine is not being able to use the same reproducible stimulation, especially in Ayurvedic oil treatments. To address this problem, we developed a healing robot which conducts shirodhara in a computerized reproducible manner (Figure 2).

We studied the physio-psychological changes during taila dhara conducted by the healing robot and estimated the psychological experiences during taila dhara by psychometric studies of anxiety and altered states of consciousness (ASC). In order to simplify the study, at first we used plain sesame oil as the dripping medium. Usually in Oriental medicine, the effects on practitioners as well as patients are included as important factors for the treatments. Therefore, we have also checked the physiological changes of the practitioners themselves in this study.

## Study Assessments

We undertook a number of different studies to assess the impact of shirodhara on the patient's state of well being and to assess factors in the therapy that altered the patient's state.

## Experiment 1: Physiological Changes of Both Subjects and Technicians During Manual Shirodhara

Sixteen healthy adult females (ages 21–56,  $33 \pm 9$  years) signed informed consent and participated in this study. They had no mental disease nor any neuropsychological disorders. The pretreatment control period and the post-treatment period were set for 15 min; the shirodhara treatment session was 20 min long (Figure 3). The same subjects participated twice in the control and active studies at four-day intervals in a random order.

During shirodhara the monitoring items for the subjects were: blood pressure (continuous blood pressure monitoring, ANS508 by Nippon Colin Co., Ltd.) and intermittent blood pressure (automatic sphygmomanometer, Paramatek GP303S), electrocardiogram (ECG) R-R intervals, expired gas analysis (MetaMax from Marcotek Co., Ltd.), impedance cardiography (Nicoview from NEC), and EEG (F3, F4, P3, P4, or 16 points electrodes; Neurofax by Nihon Kohden Co., Ltd.). The single EEG (C3 lead) of the technician was recorded at the same time (Figure 2), and respiratory movement of the chests of both subject and technician were also recorded. In the active studies, shirodhara was performed by a machine with a pumping and heating system. During the control period, the technician manipulated the oil tube tip in as close to the same manner as possible. The oil used was plain cold-pressed preheated sesame oil (Kadoya Oil Co., Ltd.). The flow rate (2.1–2.6 L/min) and temperature ( $39 \pm 1$  °C) of the sesame oil were kept as steady as possible.

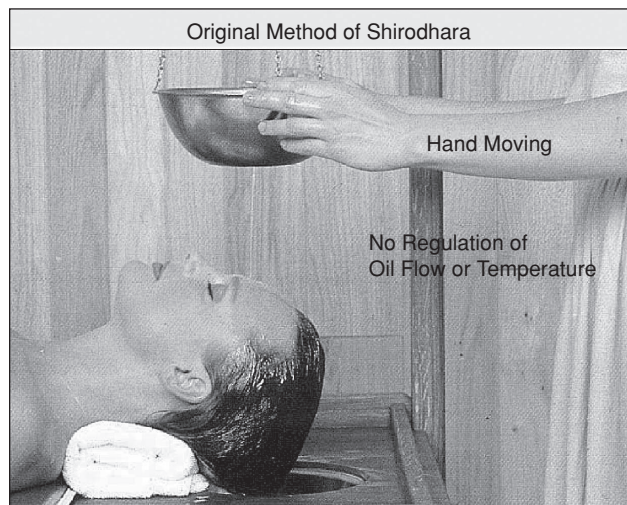
A power frequency analysis of R-R variability was performed to assess the balance of the autonomic nervous system. LF (low frequency) was considered to include the power spectral density (PSD) of 0.04–0.15 Hz, and HF (high frequency) was the PSD of 0.15–0.40 Hz [6], [7]. Coherence or spectral distribution of EEG and respiratory movements were calculated by computer using the program BIMUTUS II (Kissei Comteck).

## Experiment 2: Standardization of Oil Weight Between the Manual and Robotic Shirodhara

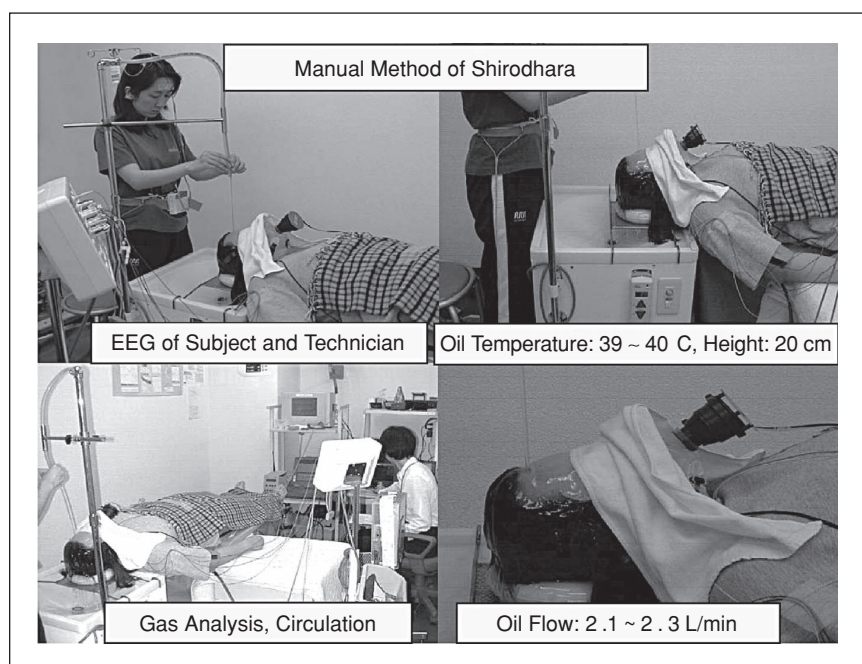
The weight of the dripped oil was measured at the forehead by a scale (Tanita Co., Ltd.) using various heights of the dripping nozzle and various flow rates.

### Experiment 3: Physio-Psychological Changes During Shirodhara by the Healing Robot in Relation to Anxiety and Altered States of Consciousness (ASC)

Fifty-seven healthy volunteers (ages 22–46,  $33 \pm 8$  years) participated in this study with the healing robot after signing informed consent. In this experiment, the treatment was regulated automatically by the computerized system using the healing robot (Figure 4). The temperature ( $39.0 \pm 0.5$  °C) and flow rate ( $2.3 \pm 0.2$  L/min) of the oil were kept constant in both the manual and robotic systems. However, minute regulation was possible in the healing robot; the robotic system can keep the same reproducible dripping speed and pattern.



**Fig. 1.** The original method of shirodhara. Various kinds of vessels are used for reservoirs of dripping oil or other mediums. The dripping technique cannot be regulated in a reproducible manner.



**Fig. 2.** The set up of the manual shirodhara. The technician stood at the head of the subjects. The subjects had various instruments attached to their bodies and their eyes were closed by towels.

The oil used was the same plain cold-pressed preheated sesame oil (Kadoya Oil Co., Ltd.). The pretreatment control period was set at 10 min and the shirodhara treatment session was fixed for 25 min. The mode of dripping sesame oil was as follows:

- oil temperature:  $39.0 \pm 0.2$  °C
- oil flow:  $2.3 \pm 0.2$  L/min
- dripping pattern: 5 min each for eight knot, horizontal, and vertical, then another 4 min for each.

The nozzle of oil moved at the slowest speed (1.5 cm/s). These conditions were decided based on results from Experiment 1.

The subjects' skin temperature of the right neck, right hand, and right foot was monitored throughout shirodhara. The psychological changes were assessed by psychometric studies using the State-Trait-Anxiety Inventory (STAI) before and after shirodhara and ASC questionnaires just after shirodhara. The validity of the ASC questionnaire was ascertained by Saito [8]. The questionnaire asked about ASC experiences in ten domains (Table 1). The average scores of these ten domains were calculated from 60 questions. Time recognition was measured by counting 15 or 30 s by a stop watch, without showing the time in the stop watch's display.

### Experiment 4: Anxiolytic Effect of the Robotic Therapy

In this experiment, ten of the 57 subjects with abnormally high STAI scores from Experiment 3 participated. An STAI score of more than 40 was considered the criteria for abnormal score groups. These 10 females (ages 23–35,  $30 \pm 6$  years) received shirodhara for 25 min once each week, four times a month. The conditions to regulate the healing robot were the same as those in Experiment 3.

POMS (Profile of Mood States) scores were also assessed before and after shirodhara. POMS was developed by McNair et al. and its validity was previously ascertained [10], [11]. POMS

has five assessment domains: tension and anxiety, depression, anger and hostility, vitality, exhaustion, and confusion.

### Experiment 5: Impact of Different Dripping Media on the Experiences of Shirodhara

Various mediums for dripping were prepared, such as warm water, warm cow's milk, bath salt, and a special bath salt with the same viscosity as sesame oil. The last, special bath salt was prepared from hyaluronic acid and collagen. The viscosity was measured by a viscometer (Bruckfield Co., Ltd.). Three healthy female subjects (34-, 28-, and 30-years-old) took part in this experiment. They had the same method of shirodhara by the healing robot system: five different media at the same time of day in a random sequence every four days. These media were ranked based on the subjects' answers to a like/dislike visual analog scale (VAS) and the ASC as well as their anxiety and changes in foot temperature.



### Statistical Analysis

Regarding physiological examinations, a paired t-test and one- or two-way ANOVA was adopted, while psychological questionnaires such as STAI or POMS were analyzed by Wilcoxon's signed rank test. The correlation between nonparametric parameters were calculated using Spearman's method. However, the average scores of psychological outcomes were analyzed as consecutive numbers, and Pearson's correlation coefficients were calculated. In all studies, a p value of less than 0.05 was considered statistically significant.

### Results

#### Standardization of Shirodhara

In the manual shirodhara, the oil weight was 16 g at the forehead from the nozzle at 20 cm high. In the shirodhara by the healing robot, the same weight of oil was obtained at 20 cm high in the flow of 2.3 L/min. The diameter of the nozzle was  $8 \times 8$  mm. This program of controlling the healing robot was adopted as the standardized method for oil application.

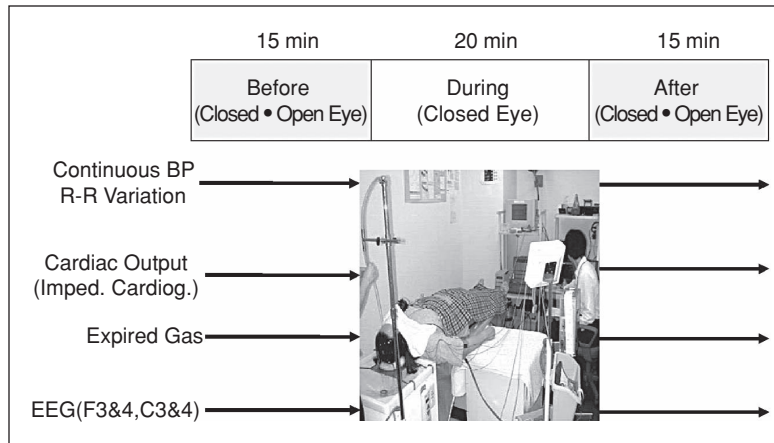
#### Physiological Examinations

In Experiment 1, comparing automatic with manual shirodhara, the heart rate and consumption of CO<sub>2</sub> were compared with the control studies of the same subjects. As shown in Figure 5, the heart rate decreased significantly just 5 min after starting shirodhara, while there were no significant changes in the control study. Similar to the heart rate, CO<sub>2</sub> excretion and tidal volume also decreased during shirodhara; again, there were no significant changes in the control study.

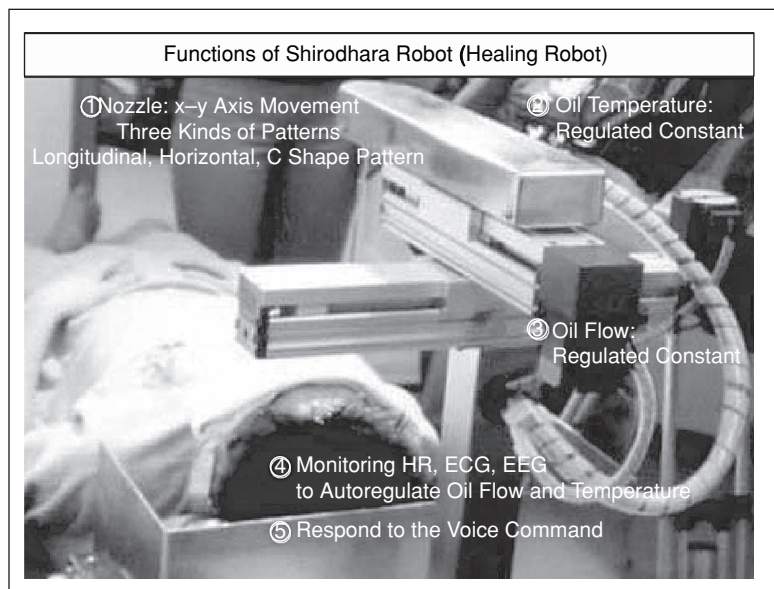
Four of the 16 subjects experienced troubles, such as headache, during shirodahra due to the prolonged bed rest or from maintaining the same position. Their data were excluded from the analysis. Data from 12 of the subjects (ages 22–46,  $33 \pm 8$  years) were analyzed.

The autonomic nervous balance of the subjects were also measured by means of ECG R-R variability (LF/HF and HF power of the R-R variability). Six subjects who had respiration rates under 0.1 Hz were excluded from the analysis because the LF and HF components overlapped when respiration rates were under 0.1 Hz. The results from the remaining subjects showed the LF/HF ratio, an alternative index of cardiac sympathetic activity, was suppressed during and after shirodhara (Figure 6). However, HF power, an index of the parasympathetic nervous tone, changed in a similar trend in both the active and control studies (Figure 7). The supine position of the experiment itself might activate parasympathetic activity.

Regarding a change of the EEG mapping due to shirodhara,  $\alpha$ -wave power dominance shifted from the occipital region to the frontal region



**Fig. 3.** The time table of the experiments. The 20 min of shirodhara was sandwiched between two 10 min pre- and postperiods.



**Fig. 4.** Functions of the healing robot. The movement of the oil nozzle is regulated. Oil flow and oil temperature are also kept constant. In the future, monitoring sensors of HR, ECG, and EEG can be equipped, the robot may respond to voice commands.

**Table 1. Ten domains of ASC in the psychometrics.**

- ① Loss of space perception: feeling like floating
- ② Loss of time perception: no notice of time passing
- ③ Loss of speech sense: no mood for saying words
- ④ Trance: enraptured
- ⑤ Concentration: no notice of any change in surroundings
- ⑥ Cosmic consciousness: experience such as to have seen truth
- ⑦ Passiveness: feeling like being under someone's control
- ⑧ Momentariness: feeling like only a short period of experience
- ⑨ Loss of difference between subjectivity and objectivity: no separation between oneself and others
- ⑩ Loss of bodily sense: feeling like only mind existing without body

*Toshimasa SAITO, Researches on ASC, Shoukei sha, Kyoto, 1981.*

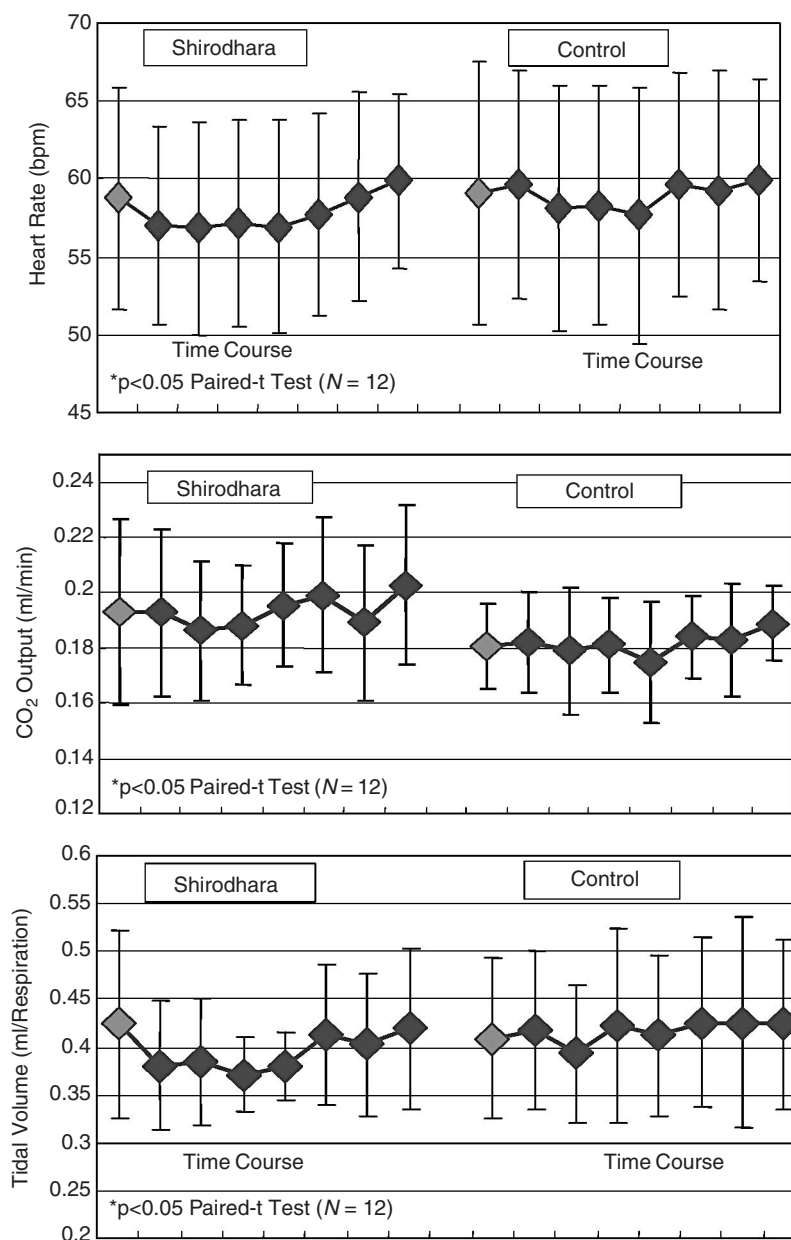
during the treatment. After shirodhara,  $\alpha$  wave activity was again dominant in the occipital region (Figure 8). Simultaneously,  $\alpha$ -wave coherence was also increased during shirodhara (data not shown). These differences in heart rate,  $\text{CO}_2$  excretion, sympathetic tone, and EEG were quite similar to the findings reported in the study of meditation [12].

We simultaneously measured the EEG findings of two handlers of the manual shirodhara method (Figure 9). C3 lead EEG measurements from them showed a relative increase of  $\beta$ -wave power and a relative decrease of  $\alpha$ -wave power during the active experiments, while there were no significant changes in the control studies. These results indicated the stressful conditions for the handlers.

## Psychological Examinations

### Anxiolytic Effects of the Shirodhara

At first, STAI scores of 12 healthy female subjects by shirodhara were compared with those of 12 other subjects who had algae packs applied facially for relaxation. The subject's state of anxiety, assessed just before and after shirodhara, decreased abruptly ( $p < 0.005$ , Wilcoxon signed rank test), while the decrease in anxiety in subjects receiving the algae pack was not as large as shirodhara ( $p < 0.05$ ); see Figure 10. The two groups had significantly different decreases in anxiety state as determined by two-way ANOVA.



**Fig. 5.** Changes in heart rate,  $\text{CO}_2$  output, and tidal volume during robotic shirodhara. The results show the averages for all subject who participated in both active and control studies. Compared to the baseline, statistically significant decreases in all three variables occurred more frequently during the robotic shirodhara treatment.

## The healing robot can keep the same reproducible dripping speed and pattern.

### ASC Experiences During Shirodhara

ASC is usually mistaken to be a peculiar experience induced by psychotropic drugs. Traditional healing techniques such as meditation and oil massage often induce ASC [8]. Saito classified the ASC into ten kinds of experiences (ten domains) as shown in Table 1, and he made up the ASC questionnaire after ascertaining its reliability and specificity [8]. We used the questionnaire developed by Saito and assessed each subject just after shirodhara. The level of the experiences was categorized into five different domains with more than four indicating an ASC experience. Forty-six of the 57 subjects (81%) who were treated with shirodhara experienced some kind of ASC. Average scores for each domain are shown in Figure 11. The highest ASC scores were obtained in the domains of trance, passiveness, timeless sensation, wordless sensation, and concentration.

### Change of Time

#### Recognition by Shirodhara

In order to ascertain the experience of loss-of-time perception, the time recognition was measured by a stop watch. Just before and after shirodhara, 15 or 30 s was measured. Of 57 subjects who had shirodhara treatment, 15 showed a significant increase in time recognition of 30 s (30–36 seconds on average), while ten control subjects who had no treatment showed no change during 1 h of routine work. This result indicated that shirodhara induced loss-of-time perception and altered time recognition of the brain.

### Correlation Between ASC

#### or Anxiolysis and Skin

#### Temperature of Foot and Hand

The correlation between the mean ASC score and anxiolytic effects was not very high, but a significant correlation was obtained (Figure 12;  $r = -0.34$ ,  $p < 0.01$ , Spearman's correlation coefficient).

A similar degree of correlation was obtained between the mean ASC score and the mean skin temperature of the foot during the latter half of the shirodhara (Figure 13;  $r = -0.35$ ,

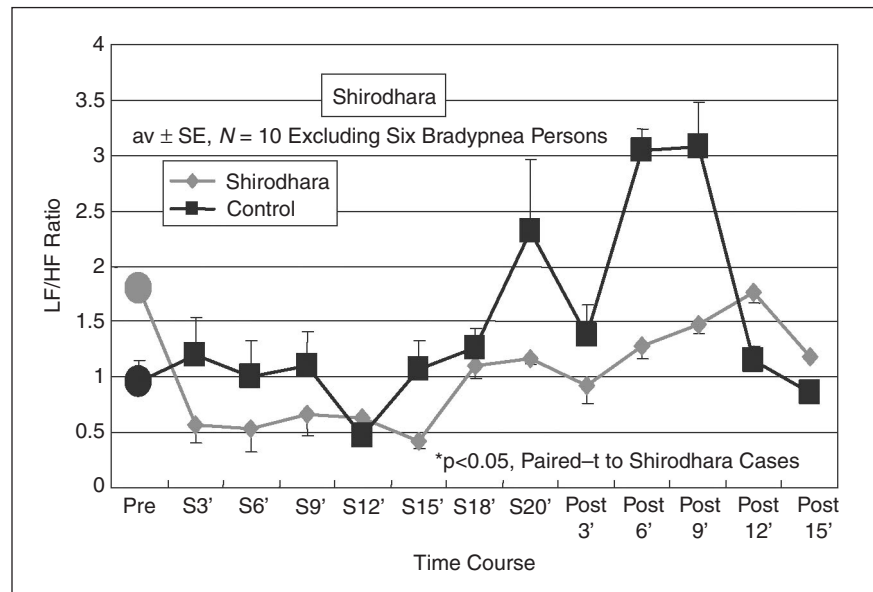


Fig. 6. Change of LF/HF ratio during shirodhara. LF/HF is suppressed after starting shirodhara.

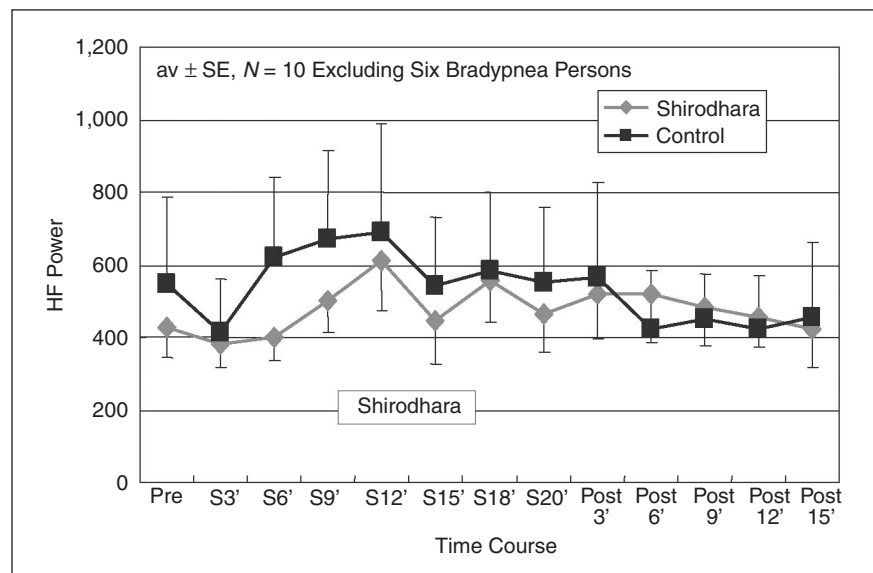
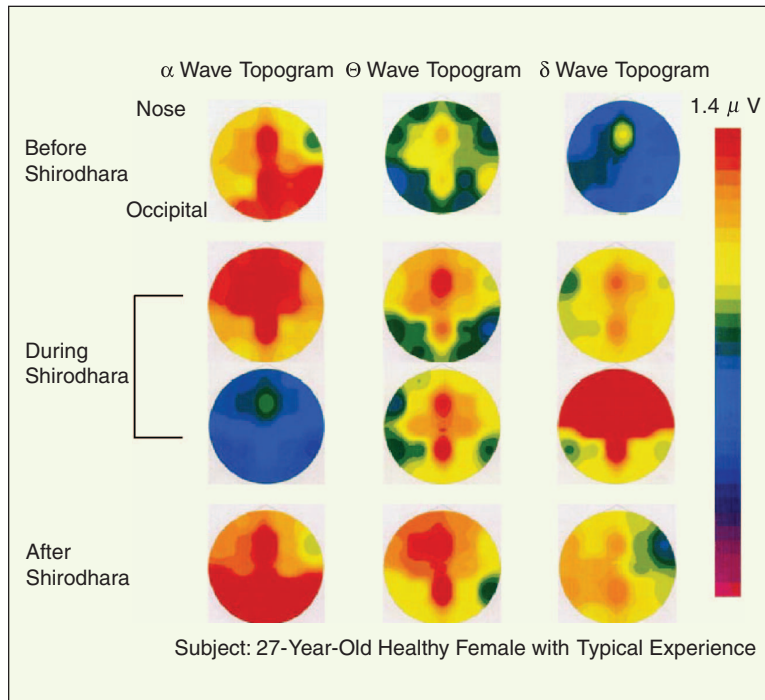


Fig. 7. The change of HF power during robotic shirodhara. There was no significant difference in HF from the active and control studies.

## The subjects' feelings during shirodhara showed deep restfulness with less anxiety



**Fig. 8.** The EEG mapping for one subject during robotic shirodhara. During shirodhara,  $\alpha$ -wave power in the frontal region was dominant, while after shirodhara, occipital  $\alpha$ -wave was dominant.

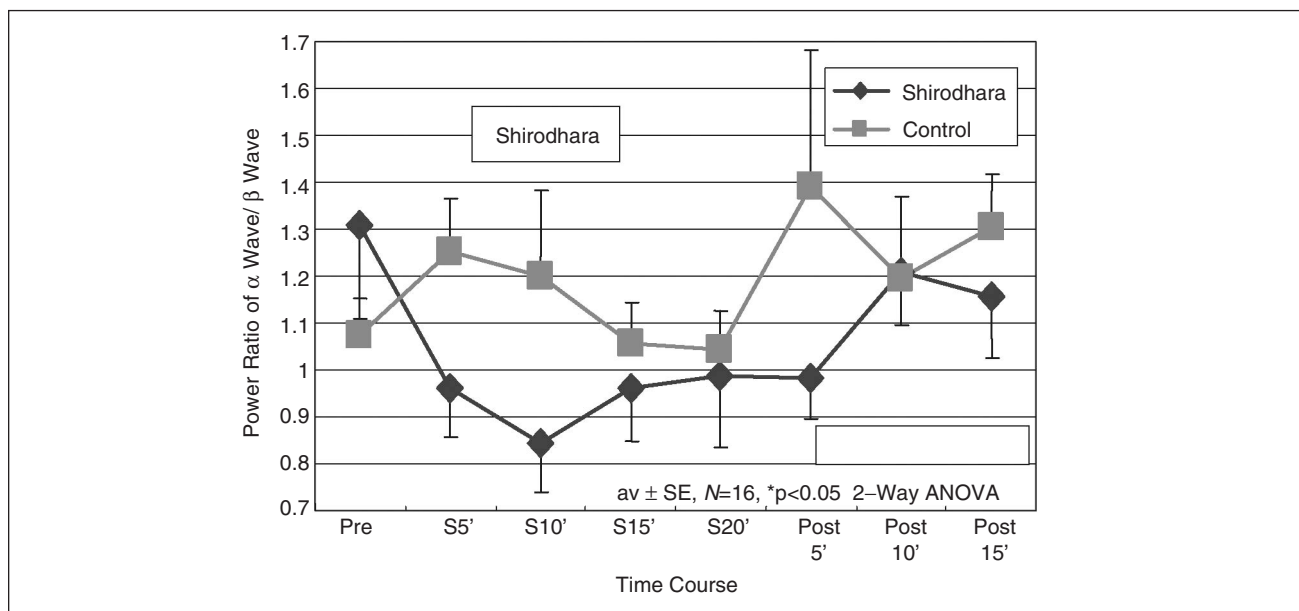
$p < 0.01$ , Spearman's correlation coefficient). The mean skin temperature of the foot in the latter half of shirodhara is also correlated with a decrease in the state of anxiety (Figure 14;  $r = -0.37$ ,  $p < 0.01$ , Pearson's correlation coefficient). The skin temperature of the right hand or right neck had nothing to do with ASC or anxiety.

### Anxiolytic Effects of Shirodhara in the Subjects with High Anxiety

Of the 57 subjects, ten with a high state of anxiety ( $>40$ ) had successive shirodhara treatments four times every week. The changes in the POMS score were assessed after the final shirodhara. The result indicated a significant decrease of tension and anxiety (Wilcoxon signed rank test,  $p < 0.05$ ) and a tendency towards a decrease in exhaustion (Figure 15). Concerning the other domains, the trend for the average level with shirodhara showed improvement, but none of these differences were statistically significant.

### Change of Lifestyle by Successive Shirodhara

One subject who was a heavy smoker cut his tobacco from 60 cigarettes per day to 15 per day. He also had an arrhythmia that improved after



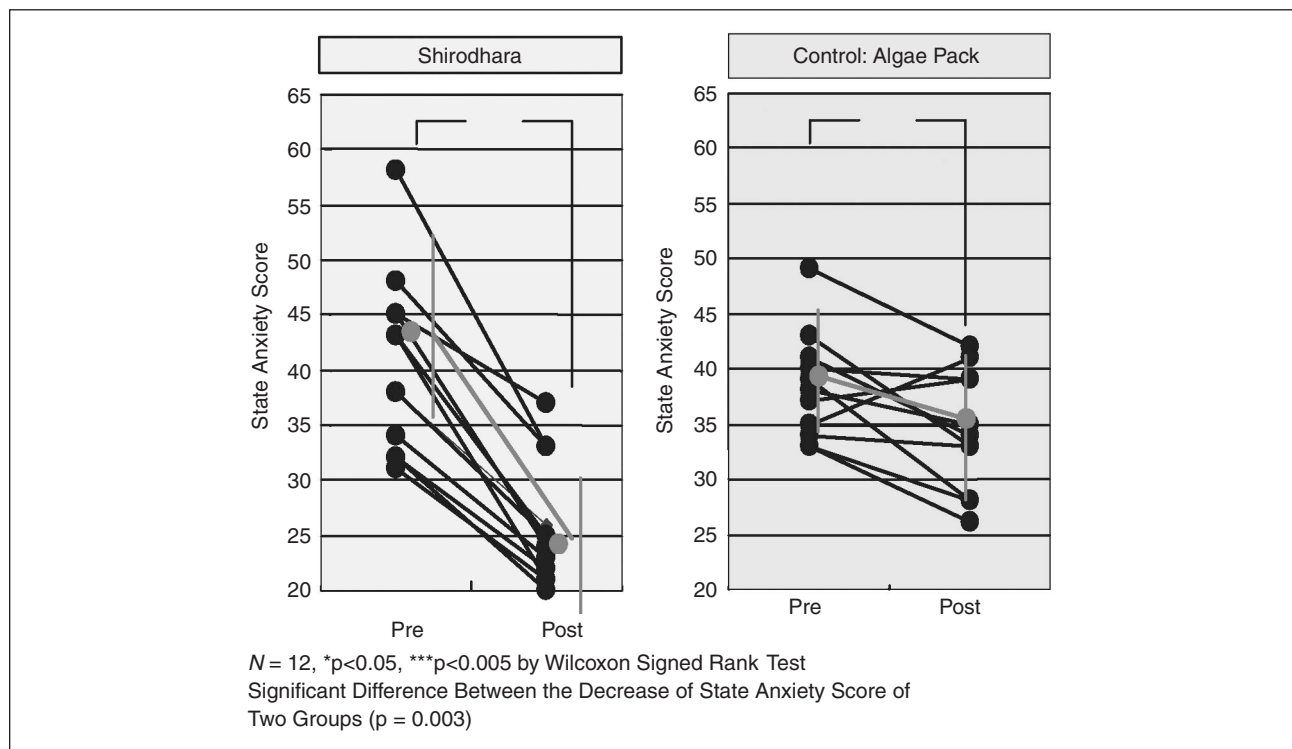
**Fig. 9.** Changes in EEG of the technicians during manual shirodhara. The decrease of  $\alpha/\beta$  ratio is indicative of more stressful conditions for these handlers.

four treatments of shirodhara. His favorite television programs also changed from variety shows to music programs. In addition, his speed of eating slowed more than before shirodhara treatments. Another obese female could control her eating habits after eight shirodhara treatments—even after her husband said something harsh to her.

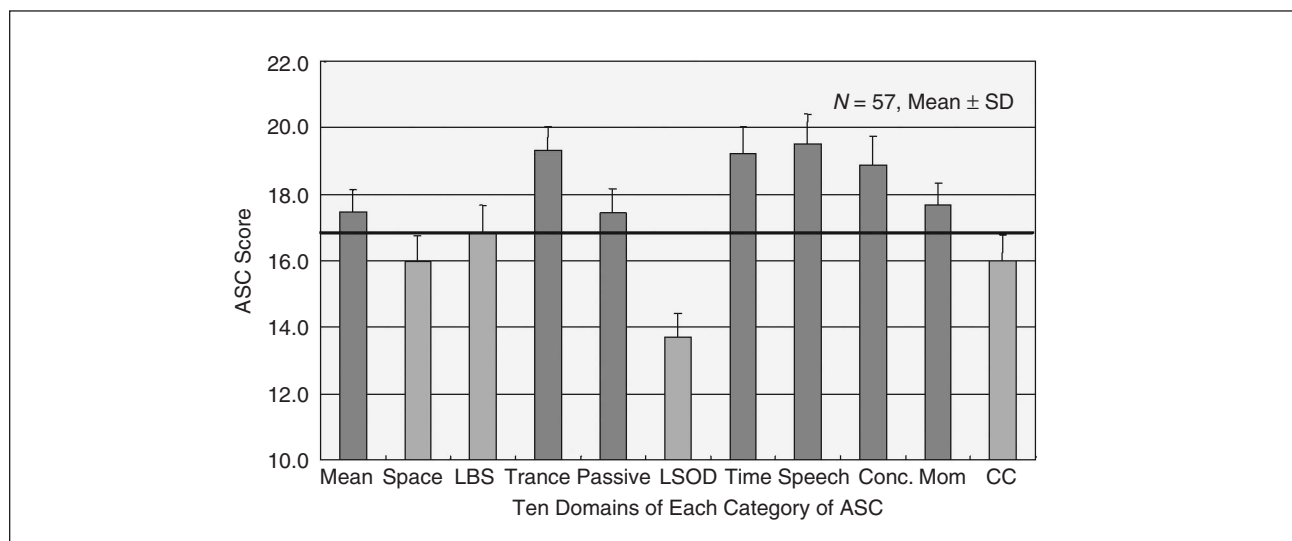
In a comparison of the various mediums of shirodhara, based on the order of the subjects' good experiences, sesame oil was the best medium (Figures 16 and 17). The sensation of being embraced might be the characteristic experience of the plain sesame oil shirodhara.

## Summary of Results

- Shirodhara induced bradycardia and lowered tidal volume and CO<sub>2</sub> output.
- During shirodhara, sympathetic nervous tone was suppressed while parasympathetic nervous tone was the same as that of the control's supine position.
- EEG during shirodhara showed an increase of slow  $\alpha$  and  $\theta$  or Fm $\theta$  waves. Shirodhara induced an increase of right-left EEG coherence. These results indicated restful alertness in which the frontal lobe, limbic system, and medulla oblongata were activated [12].

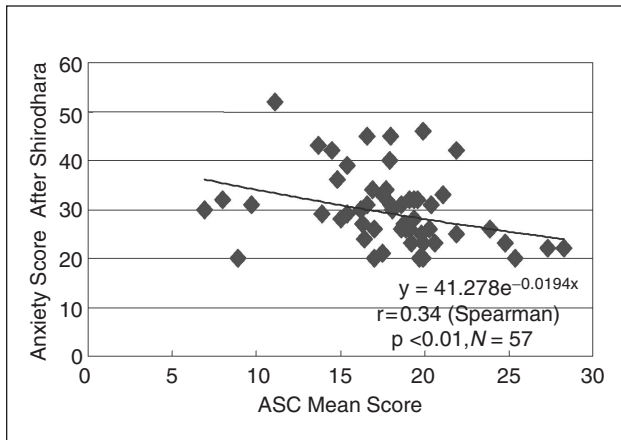


**Fig. 10.** The anxiolytic effects of robotic shirodhara,  $N = 12$ , (\* $p < 0.05$ , \*\*\* $p < 0.005$  by Wilcoxon signed rank test). Shirodhara showed greater anxiolytic effect than the control treatment with algae packs placed on the subject's face.

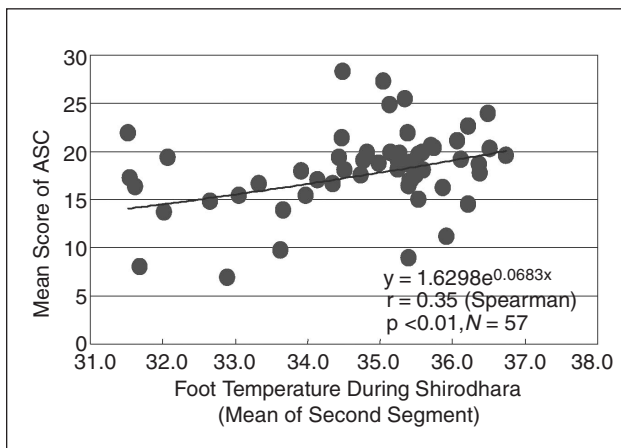


**Fig. 11.** ASC scores for each domains after shirodhara by the healing robot. Approximately 80% of the subjects had some ASC experiences.

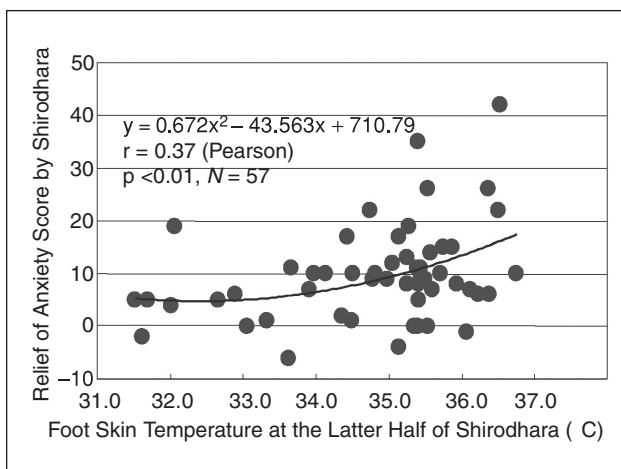




**Fig. 12.** The correlation between ASC and anxiety after shirodhara. This trend line shows that anxiety decreases with increasing ASC score.



**Fig. 13.** The correlation between the mean ASC score and foot temperature during shirodhara. This trend line indicates that as foot temperature increases, so does ASC.



**Fig. 14.** The correlation between foot skin temperature and anxiety score. The trend line shows that foot skin temperature increases with decreasing levels of anxiety.

- There were no cases of headache or skin eruption which was directly related to shirodhara. However, some subjects complained of a compression discomfort of the occipital region or a numbness of the extremities or lower back, which were not directly attributed to shirodhara.
- The technicians of shirodhara showed signs of a stressful condition based on their EEG findings. There was no coherent respiratory movement of the subjects and technicians.
- Shirodhara induced an altered state of consciousness in some subjects, and it reduced anxiety as well. The subjective anxiolytic effects and depth of ASC were correlated with the objective increase of the skin temperature of the foot.
- Successive shirodhara treatments reduced tension and anxiety of anxious subjects in one month.
- Successive shirodhara in a 43-year-old male heavy smoker changed his lifestyle dramatically. A 61-year-old obese female changed her character, overcame troubles with her husband, and realized an improvement in her bulimia after several shirodhara sessions. These typical cases supported the changes of lifestyle reports that have occurred after shirodhara, probably due to a decreased stress level.
- Plain sesame oil had a better effect than other mediums such as water, cow's milk, and bath salt. The effectiveness of shirodhara seemed to not be related to the viscosity of the medium.

## Discussion and Conclusion

The subjects' feelings during shirodhara showed deep restfulness with less anxiety—as if the subject were between the sleep and awake states. Shirodhara induced bradycardia and the relative suppression of LF/HF power spectrum density, which indicated lowered sympathetic tone. Expired gas analysis showed a decreased tidal volume and CO<sub>2</sub> excretion. The EEG showed the slowing of the  $\alpha$  wave, an increase in  $\alpha$  and  $\theta$  activity, and an increase in right-left coherence. These metabolic, ECG, and EEG findings support the reported experiences of relaxed and low metabolic states during shirodhara. Physiological changes during shirodhara were similar to those of meditation [12], including  $\alpha$ -wave dominance in the frontal area and a decrease in heart rate and CO<sub>2</sub> excretion. These findings indicated a change in the function of the frontal lobe, limbic system, brain stem, and autonomic nervous system. On the other hand, the EEGs of the technicians of manual shirodhara showed an increase in their stressful condition, which may also justify the utility of the healing robot as an assistant for the technicians.

Regarding mechanism of actions of shirodhara, three hypotheses may be speculated.

## Neurophysiological Mechanism

The neurophysiological mechanism of the effects of shirodhara on the psycho-physiological changes may be related to the tactile stimulation of the skin or hair follicles innervated by the first branch of the trigeminal nerves (ophthalmic nerve) [13]. The impulses would be transmitted to the thalamus through the principal nucleus and forward to the cerebral cortex (somato-sensory field) or limbic system. These routes would provide the subjects ASC experience and a relief from anxiety. Other routes from the principal nucleus to the reticular formation and posterior region of the thalamus, which is



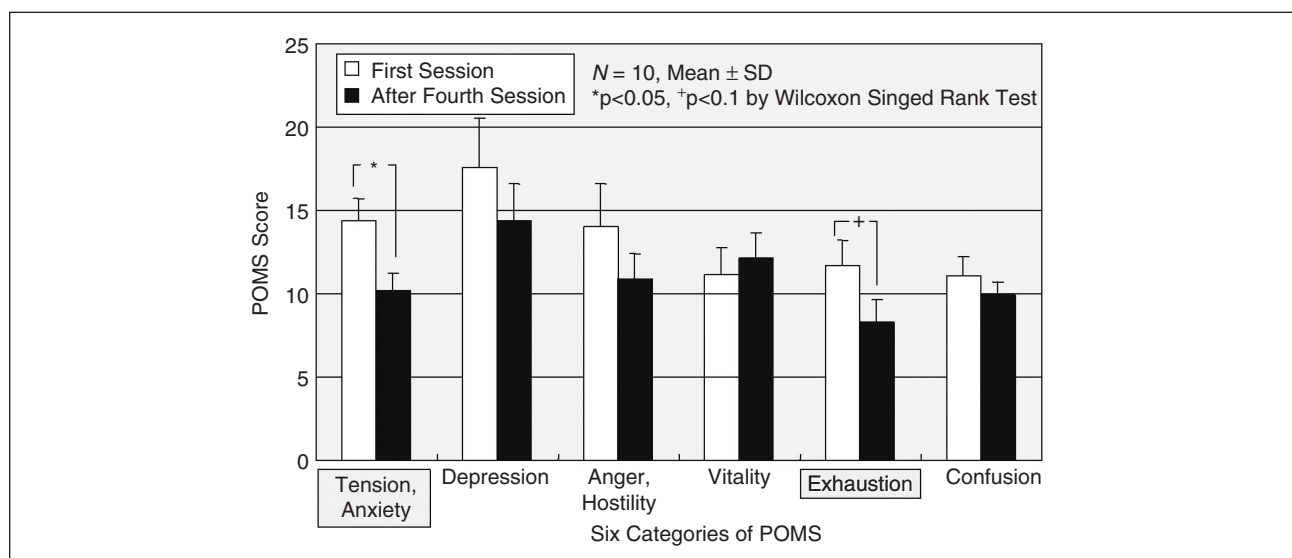
the center of autonomic nervous system, would be possible. These latter routes would provide a rationale for changes in sleep and changes of autonomic nervous balance, as reflected by R-R variability and the skin temperature of the foot. This hypothesis is outlined in Figure 18.

### Psychological Mechanism of Shirodhara

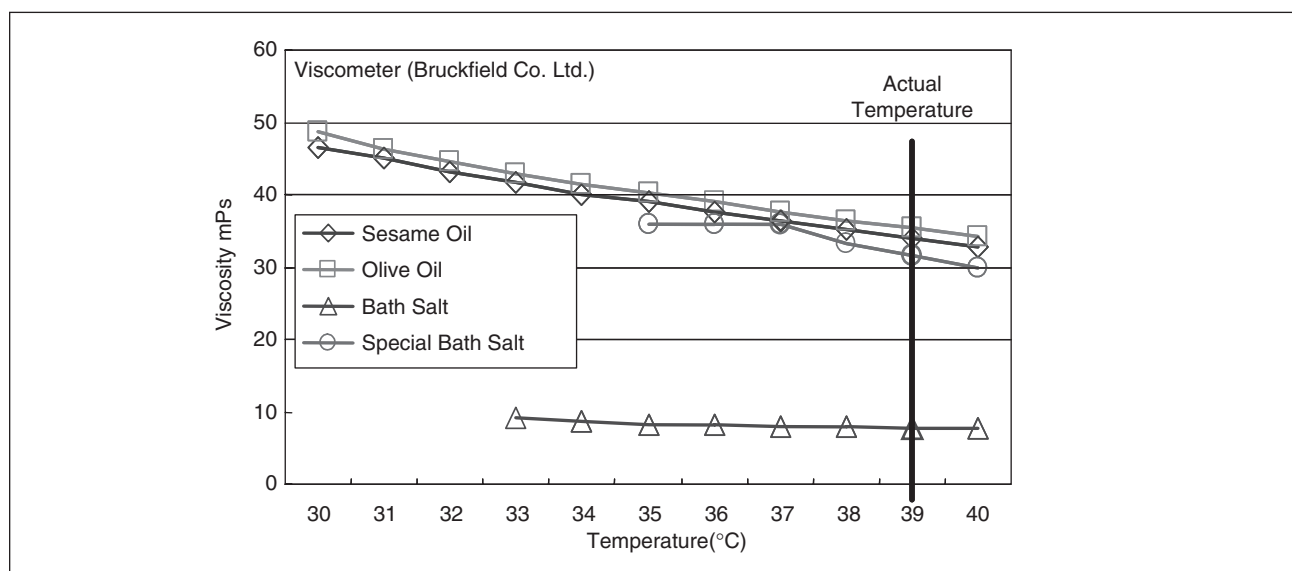
According to the traditional Ayurvedic concept of life, human beings arise from the consciousness [14]–[16]. Humans arise from consciousness (information field) to the body (matter field) through the mind (energy field). Troubles at the consciousness level may cause troubles of the body or behavior. This mechanism of manifestation of consciousness is analogous to the genome theory of modern medicine (biotechnology), where the genome (information) is manifested as the body (matter) through the proteome (energy) [17], [18]. As information stored in the conscious-

ness level manifests itself in the body or behavior through the mind, an ASC may be manifested due to changes in the peripheral circulation or as R-R variability changes with a decrease in anxiety.

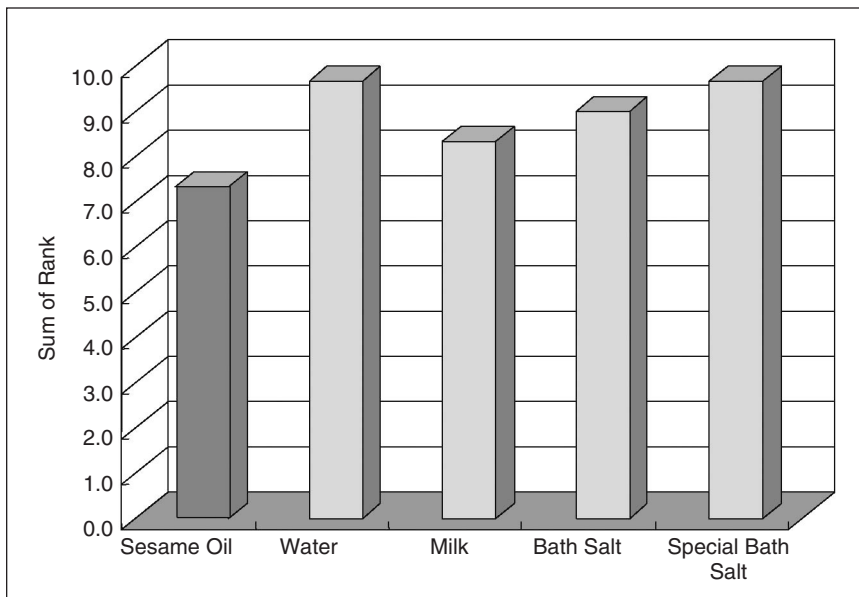
Because these mechanisms of manifestation of matter depending on biotechnology are so similar to the Ayurvedic mechanism of manifestation, we refer to it as “spiritual biotechnology” [19], [20]. Shirodhara may be the oldest but the most skillful healing technique that manipulates cerebral circulation, cerebral function, and the state of consciousness. It may provide a new tool and new knowledge for modern brain research into consciousness. Furthermore, it may open new paradigms for exploring what we refer to as spiritual biotechnology. The healing robot we have evaluated would offer an inexpensive, reproducible method for academic researchers to explore the mechanisms of Ayurvedic healing.



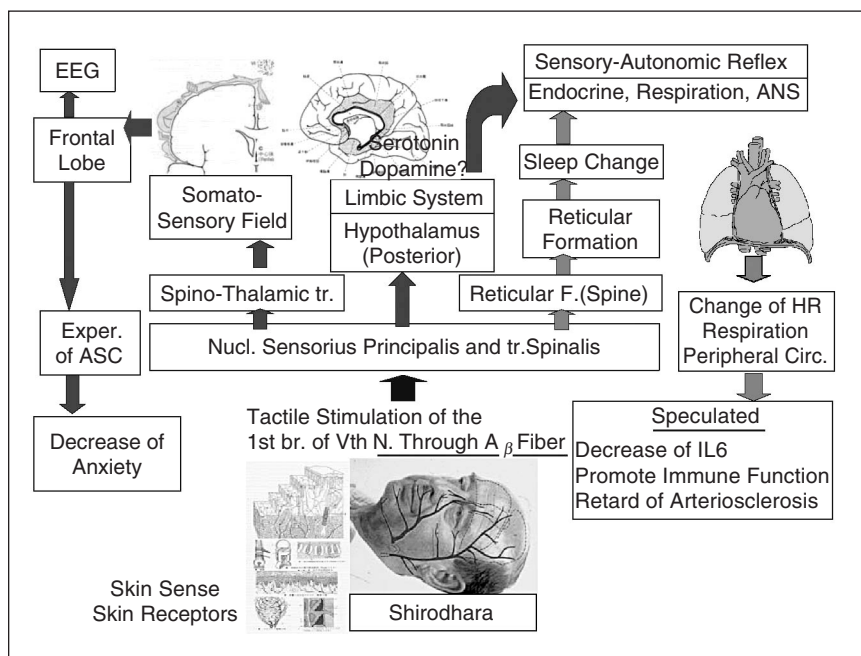
**Fig. 15.** The psychological effects of successive shirodhara. The subjects had abnormally high anxiety levels according to STAI. Their tension and anxiety decreased significantly after four sessions of shirodhara over a period of one month.



**Fig. 16.** The relationship between the temperature and viscosity of various media. In the study, the special bath salt had the same viscosity as the plain sesame oil at 39 °C.



**Fig. 17.** A comparison of the various media by the summation of the rank of each assessment item. Of the five mediums evaluated, sesame oil had the lowest rank score.



**Fig. 18.** A schematic presentation of the hypothesized neurophysiological mechanism of Shiroadhara.



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