

# Increase in Salivary Oxytocin Levels in Mothers After Tactile Contact Between Adiaper-like Nonwoven Sheet With Large Projectionsand the Palm: A Pilot Study

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## Research note

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# **Abstract**

## **Objective**

The aim of this pilot study was to investigate whether or not tactile contact between a diaper-like nonwoven sheet with specific physical characteristics and the palm of the hand would increase the maternal level of oxytocin which is one of the neuropeptides promoting formation of the mother-infant bond.

## **Results**

Ten healthy non-breastfeeding Japanese mothers were enrolled in this pilot study. We prepared diaper-like nonwoven sheets with large or small projections. Physical indices related to softness and fluffiness were higher in the sheet with large projections than in the sheet with small projections. Salivary oxytocin levels in the mothers were increased after tactile contact with the sheet with large projections, but not after contact with the sheet with small projections. This pilot study suggests that maternal oxytocin levels are increased by tactile contact between a soft and fluffy diaper sheet and the palm.

# **Introduction**

Mother-infant interaction behavior evokes physiological and cognitive responses in mothers and infants, and is associated with formation of a mutual bond [1–5]. Mothers interact with their infants in a variety of daily activities, including diapering, feeding, bathing, and playing. Diapering behavior in particular is a daily routine that involves intuitive parenting behavior. This activity is one of the most important interactions needed to establish a reciprocal relationship between a mother and infant [6–8].

Enhancement of the mother-infant relationship is related to the level of oxytocin, which is one of the functional neuropeptides synthesized in the brain [9–14]. It has been reported that the central oxytocin level shows a significant positive correlation with the peripheral oxytocin level [15–17]. Furthermore, salivary OT (sOT) levels in mothers are related to physical proximity to their infants and to the duration of mother-to-infant gaze [12, 18]. These suggest that an increase in the peripheral maternal oxytocin level is associated with improvement in the quality of the mother-infant relationship. Oxytocin is released in response to a variety of sensory inputs [19], in particular, tactile sensation [11, 19]. Touch is mainly perceived by the C-low-threshold mechanoreceptive (CT) fibers which project to the hairy skin, and the non-C type fibers which innervate not only the hairy skin but also the glabrous skin, indicating that touch in the glabrous skin of the palm is perceived by the non-C type fibers [20–33]. Mother-infant skin-to-skin contact, which could activate the CT fibers, increases peripheral levels of oxytocin [34, 35]. Moreover, foot massage which could activate both types of fibers promotes a pleasurable sensation, and increases peripheral oxytocin levels [29]. Therefore, it is plausible that activation of the non-C type fibers also upregulates oxytocin levels. However, this hypothesis has not been well investigated.

We hypothesized that activation of the non-C type fibers by tactile contact between the glabrous skin of the palm and a diaper with specific physical characteristics could increase maternal peripheral oxytocin levels with accompanying cognitive and psychological changes. To examine this possibility, we prepared a diaper-like nonwoven sheet with large projections (LP sheet) and a sheet with small projections (SP sheet). We expected that the physical characteristic values would be different between the two types of sheet. Additionally, we investigated the changes in sOT levels after mothers touched the sheets with both palms, and the differences in perceived pleasantness value between the different types of sheets.

## **Material And Methods**

### **Sp And Lp Sheets**

Top views of the SP and LP sheet are shown in Additional file 1. A nonwoven sheet was processed into small or large projections and laminated with a flat air-through nonwoven sheet. To construct the diaper-like shape, the nonwoven sheets with large or small projections were glued with substructural components composed of absorbent waterproof film and an outer nonwoven sheet.

#### **Measurement of physical characteristic values of the SP and LP sheets**

The convex parts of the cut sections of the SP and LP sheets were determined by observation under a microscope (VHX-1000, KEYENCE, Osaka, Japan) at a magnification of 10–100 $\times$ . Under microscopic observation, the length was measured along the upper and bottom surfaces as shown in Additional file 2, and the ratio of the upper length to the bottom length was calculated. The workload compression (WC), which indicates the compression energy per 1 cm<sup>2</sup>, was measured in each sheet at a velocity of 0.02 cm/sec and a maximum pressure of 50 g/cm<sup>2</sup> over an area of 2.0 cm<sup>2</sup> using the KESFB4-AUTO-A surface tester (Kato Tech, Kyoto, Japan).

## **Study Participants**

The study participants were 10 healthy non-breastfeeding Japanese mothers aged 30–49 years who were employees at Kao Corporation. The participants were instructed not to eat or drink (except for water), brush their teeth, smoke, or use hand care products for at least 60 min prior to the measurements.

## **Study Design**

Three conditions were randomly tested between 9:00 am and noon for each participant: (1) resting; (2) touching the SP sheet; and (3) touching the LP sheet. The minimum interval between the trials was 1 day. The participants were asked to wash their hands using hand soap. After resting for 5 min, the participants were asked to rinse the mouth with bottled water and spit whole saliva into a sterile plastic tube for 10 min. The participants were then asked to stroke their both palms over the SP or LP sheet for 30 sec

five times at intervals of 30 sec, or to rest for 5 min. Whole saliva was collected just after and 30 min after touching or resting for 10 min. The whole saliva was stored at -80 °C until further analysis. Perceived pleasantness was rated using a 10-cm visual analog scale just after touching or resting. On another day after the three trials, the participants were asked to touch the SP and LP sheets, and rate the softness and fluffiness scores.

## Measurement Of Salivary Oxytocin And Cortisol Levels

The sOT and salivary cortisol (sCORT) concentrations were quantified using a commercial kit (sOT: ADI-900-153, Enzo Life Sciences, Plymouth Meeting PA, USA; sCORT: 1-1102, Salimetrics Inc., Carlsbad, CA, USA). Saliva samples were extracted for measurement of sOT concentration following the manufacturer's protocol [36, 37]. The sOT and sCORT concentrations were assessed in duplicate and calculated using the Epoch2 microplate reader (BioTek Instruments, Inc., Winooski, VT, USA) according to the relevant standard curves. The intra-assay coefficients of variation for sOT and sCORT measurements were 13.8% and 3.1%, respectively. The salivary total protein concentration was determined using a standard bovine serum albumin curve (5000002JA, Bio-Rad Laboratories, Inc., Hercules, CA, USA).

## Statistical analysis

The statistical analyses were performed using GraphPad Prism version 6.0 (Graphpad Software Inc., La Jolla, CA, USA). One-way analysis of variance with Dunnett's and Tukey's *post hoc* tests were performed to compare the multiple groups.

## Results

### Physical Characteristic Values Of Sheets

First, we measured two physical characteristic values related to softness and fluffiness, i.e., the upper/bottom length ratio of the convex parts and the WC value in each sheet [38, 39]. Both indices were higher in the LP sheet than in the SP sheet (Table 1). Furthermore, the softness and fluffiness evaluation scores for the LP sheet were slightly but not significantly higher than those for the SP sheet (Supplementary File 3).

**Table 1** Physical characteristic values of the SP and LP sheets

Sheet	Upper/bottom length ratio	WC (gf•cm/cm <sup>2</sup> )
SP	1.1	0.20
LP	1.5	0.42

LP sheet: diaper-like nonwoven sheet with large projections; SP: diaper-like nonwoven sheet with small projections; WC: workload compression.

### Change in salivary oxytocin levels after resting and touching sheets

We calculated the amount of sOT (pg/mg protein) by dividing the sOT concentration by the total protein concentration in each saliva sample, given that psychological stress influences the salivary flow rate and total protein concentration [40, 41]. The amounts of sOT at 30–40 min ( $sOT_{30-40}$ ) after touching the LP sheet were significantly increased ( $p < 0.05$ ), and those at 0–10 min ( $sOT_{0-10}$ ) approached statistical significance ( $p = 0.0609$ ) compared with before touching (Fig. 1). However, there were no significant differences in the conditions of resting and touching the SP sheet (Fig. 1). Even without normalization using the total salivary protein concentration, the concentration of  $sOT_{30-40}$  after touching the LP sheet was significantly increased ( $p < 0.05$ ) compared with before touching (Additional file 4). There was no significant difference in the sCORT concentration under any condition (Additional file 5).

### Perceived Pleasantness Values After Resting And Touching The Sheets

The perceived pleasantness values just after touching the SP and LP sheets were significantly higher than those after resting ( $p < 0.05$ , Fig. 2). However, there was no significant difference between the SP and LP sheet ( $p = 0.9233$ , Fig. 2).

## Discussion

We have investigated the changes in maternal sOT levels after tactile contact between a nonwoven sheet and the palm which is innervated by the non-C type fibers. We prepared the two types of diaper-like nonwoven sheets (LP and SP sheet). The physical indices related to softness and fluffiness were higher in the LP sheet. Furthermore, we found that sOT levels were significantly increased after touching the LP sheet with the palms, but not after touching the SP sheet or resting. It has been suggested that activation of the CT fibers increases maternal oxytocin levels [34, 35]. To the best of our knowledge, this pilot study is the first report suggesting an increase in peripheral oxytocin levels after tactile contact between a soft and fluffy diaper sheet and the palm innervated by the non-C type fibers.

Maternal sOT levels were significantly increased after touching the LP sheet with the palm, but not after touching the SP sheet. The physical indices related to softness and fluffiness for the LP sheet were greater than those for the SP sheet. Furthermore, the perceived pleasantness values after touching both sheets were significantly higher than those after resting, but were not different between the two types of sheets. It has been suggested that greater activation of the CT fibers arouses a more pronounced feeling of pleasure, and a greater increase in oxytocin levels [34, 42, 43]. Therefore, this pilot study implies that perception of softness and fluffiness could have an important role in inducing an increase in oxytocin levels via the non-C type fibers.

In this study, the  $sOT_{30-40}$  levels after touching the LP sheet were significantly increased compared with before touching, but there were no significant differences in the  $sOT_{0-10}$  levels. Previous research

suggests that tactile stimulation arousing feelings of softness and fluffiness activates the mechanoreceptors innervated by the non-C type fibers in the glabrous skin of the palm, and induces an increase in the central oxytocin level by activation of oxytocin neurons in the brain followed by secretion in the periphery [26, 44, 45]. It has been reported that intranasal administration of oxytocin, which increases the central oxytocin level, increases peripheral oxytocin levels at 30 min after administration in humans [46, 47]. These observations imply that the increase of the amount of sOT<sub>30–40</sub> after touching the LP sheet might be attributed to increased central oxytocin level after activation of the non-C type fibers in the palm.

In summary, we have demonstrated that maternal sOT levels were increased after tactile contact between diaper-like nonwoven sheet with large projections and the palm innervated by the non-C type fibers. This pilot study could provide a new approach to increase maternal oxytocin levels by tactile stimulation during diapering behavior. This strategy might have the potential to improve the quality of the mother-infant relationship.

## Limitations

This pilot study has some limitations. First, the sample size was small, and all study participants were recruited from the author's institution. Although our participants did not have expertise in the field of neuroscience, it would be necessary to recruit a large number of unrelated participants for further study. Second, texture evaluation of the sheets and saliva collection for measurement of oxytocin level were performed on different days, which might account for the lack of a significant difference in the texture evaluation scores between the two types of sheets. Further studies would be required to clarify the effect of texture impression on changes in maternal oxytocin levels. Third, the influence of the menstrual cycle on the fluctuations in sOT levels may have been overlooked in this pilot study. However, fluctuations in the peripheral oxytocin levels over the course of the menstrual cycle are controversial [48–50]. In our study, the amounts of sOT before resting, touching the SP sheet, and touching the LP sheet were not significantly different ( $F[2, 23] = 1.490, p = 0.2463$ , one-way analysis of variance with Tukey's *post hoc* test). Therefore, although we did not confirm the phases of menstrual cycle of the participants, the influence of fluctuations in sOT levels before resting and touching the sheets might be ignored in this study.

## List Of Abbreviation

CT fibers, C-low-threshold mechanoreceptive fibers

LP sheet, diaper-like nonwoven sheet with large projections

SP sheet, diaper-like nonwoven sheet with small projections

sCORT, salivary cortisol

sOT, salivary oxytocin

sOT<sub>0-10</sub>, salivary oxytocin at 0–10 min after touching the sheet or resting

sOT<sub>30-40</sub>, salivary oxytocin at 30–40 min after touching the sheet or resting

WC, workload compression

## Declarations

### Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee at Kao Corporation (#T093-180123). Written informed consent was obtained from all study participants at the time of enrolment in the study.

### Consent for publication

All participants provided written informed consent for publication of this report.

### Availability of data and materials

All data generated or analyzed during this study are included in this published article and its supplementary information files.

### Competing interests

All authors are employees of Kao Corporation.

### Funding

Kao Corporation funded this research.

### Author contributions

TS, SI, and MT designed the experiments, performed the majority of the experiments, analyzed the data, and participated in writing and editing the manuscript. YF, YO, and NS designed the experiments, analyzed the data, and participated in editing the manuscript. JN designed the experiments, analyzed the data, participated in editing the manuscript, and oversaw all aspects of the study.

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Not applicable.

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## Figures

Fig 1

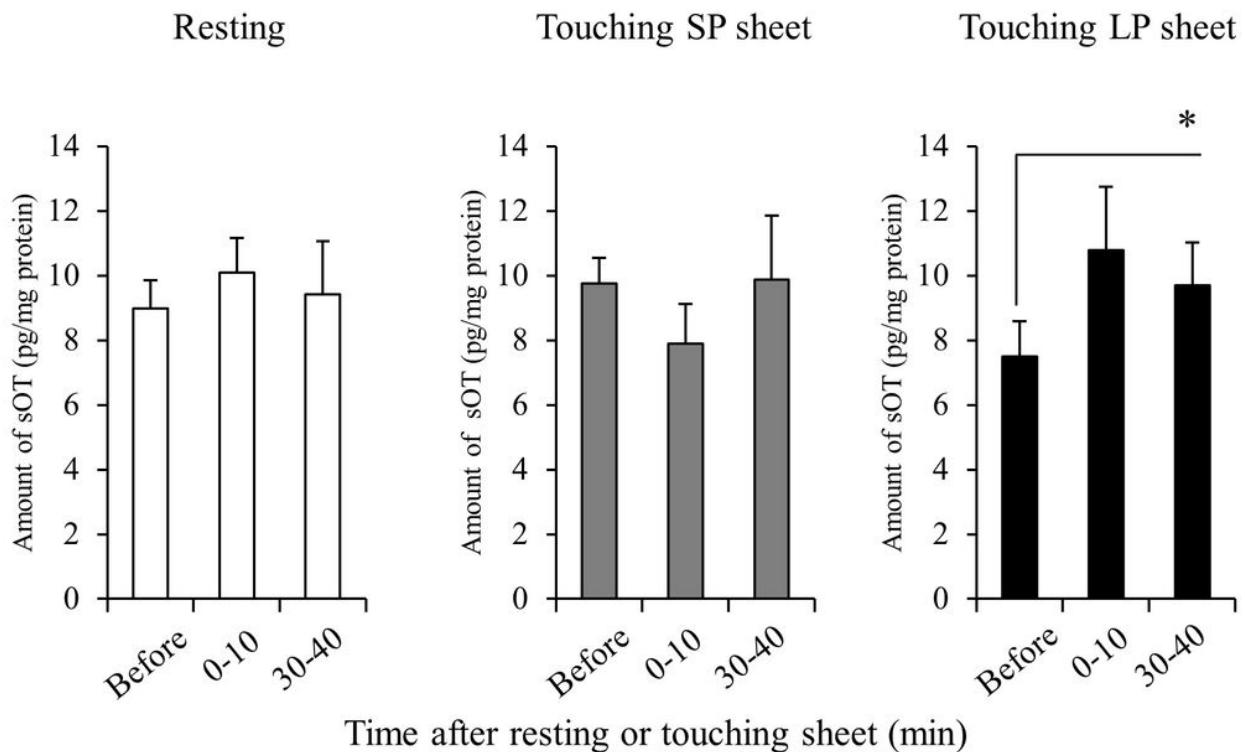


Figure 1

Salivary oxytocin levels before and after resting and touching the sheets. All data are presented as the mean  $\pm$  standard error of the mean ( $n = 8-9$ ). The data were analyzed using one-way analysis of variance with Dunnett's posthoc test(rest [ $F(1.815, 14.52) = 0.3478, p = 0.6919$ ; before:  $8.98 \pm 0.86$  pg/mg protein; 0–10 min:  $10.09 \pm 1.06$  pg/mg protein; 30–40 min:  $9.42 \pm 1.64$  pg/mg protein,  $n = 9$ ], SP sheet [ $F(1.973, 13.81) = 0.6746, p = 0.5235$ ; before:  $9.74 \pm 0.81$  pg/mg protein; 0–10 min:  $7.90 \pm 1.22$  pg/mg protein; 30–40 min:  $9.87 \pm 1.98$  pg/mg protein,  $n = 8$ ], LP sheet [ $F(1.233, 9.861) = 5.963, p < 0.05$ ; before:  $7.49 \pm 1.08$  pg/mg protein; 0–10 min:  $10.79 \pm 1.96$  pg/mg protein; 30–40 min:  $9.69 \pm 1.32$  pg/mg protein,  $n = 9$ ]). \* $p < 0.05$  vs. before resting or touching. LP sheet:diaper-like nonwoven sheet with large projections; sOT: salivary oxytocin; SP sheet:diaper-like nonwoven sheet with small projections.

Fig 2

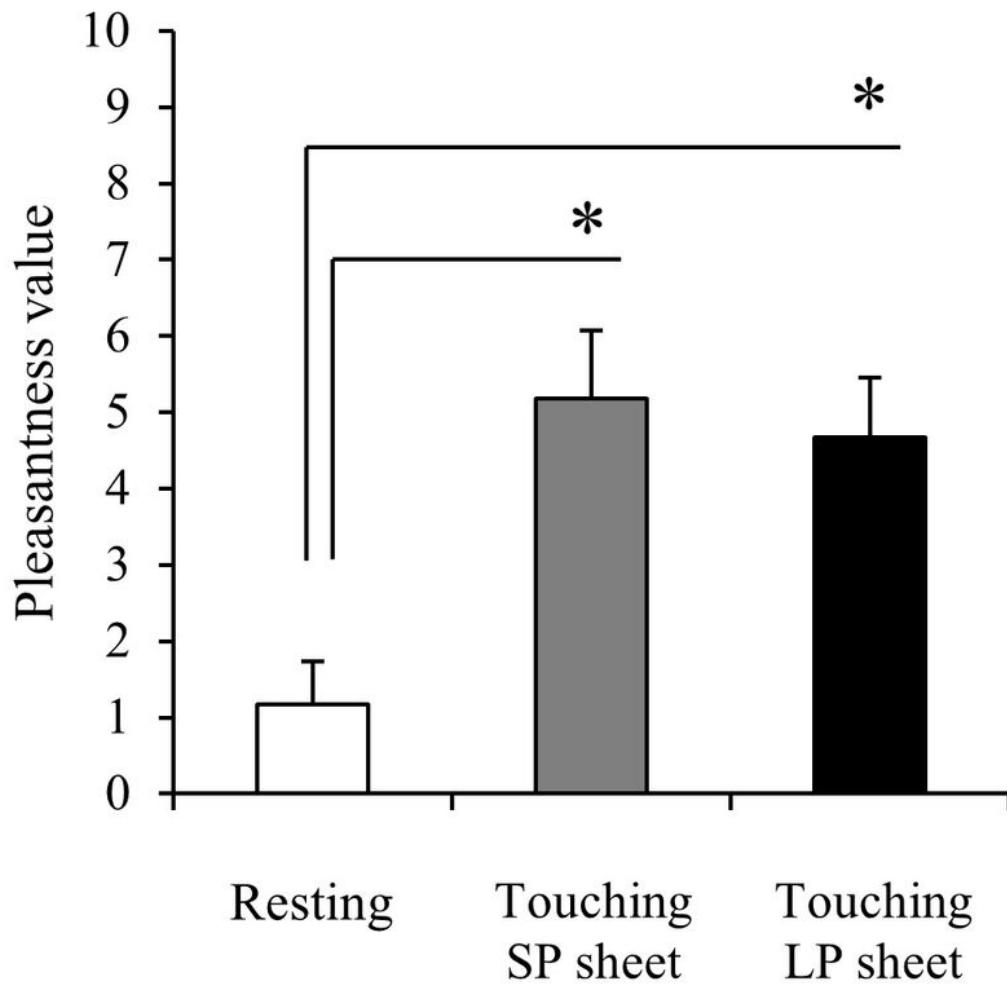


Figure 2

Perceived pleasantness values after resting and touching the sheets. All data are presented as the mean  $\pm$  standard error of the mean ( $n = 10$ ). Perceived pleasantness was rated using a 10-cm visual analog scale with the left end (0 cm) indicating "unpleasant" and the right end (10 cm) indicating "extremely pleasant". The data were analyzed using one-way analysis of variance with Tukey's posthoc test ( $F(1.863, 16.77) = 9.609, p < 0.01$ , rest:  $1.17 \pm 0.56$ ; SP sheet:  $5.18 \pm 0.90$ ; LP sheet:  $4.67 \pm 0.78, n = 10$ ). \* $p < 0.05$  vs.

resting state.LP sheet: diaper-like nonwoven sheet with large projections; SP sheet: diaper-like nonwoven sheet with small projections.

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