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REVIEW ARTICLE

Massage Changes Babies' Body, Brain and Behavior

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Abstract: Tactile stimulation is an important factor in mother-infant interactions. Many studies on both human and animals have shown that tactile stimulation during the neonatal period has various beneficial effects in the subsequent growth of the body and brain. In particular, massage is often applied to preterm human babies as "touch care", because tactile stimulation together with kinesthetic stimulation increases body weight, which is accompanied by behavioral development and the changes of endocrine and neural conditions. Among them, the elevation of insulin-like growth factor-1, catecholamine, and vagus nerve activity may underlie the body weight gain. Apart from the body weight gain, tactile stimulation has various effects on the nervous system and endocrine system. For example, it has been reported that tactile stimulation on human and animal babies activates parasympathetic nervous systems, while suppresses the hypothalamic-pituitary-adrenalcortical (HPA) axis, which may be related to the reduction of emotionality, anxiety-like behavior, and pain sensitivity. In addition, animal experiments have shown that tactile stimulation improves learning and memory. Facilitation of the neuronal activity and the morphological changes including the hippocampal synapse may underlie the improvement of the learning and memory. In conclusion, it has been strongly suggested that tactile stimulation in early life has beneficial effects on body, brain structure and function, which are maintained throughout life.

Keywords: *Tactile Stimulation, Massage, Weight Gain, Brain, Behavior*

1. INTRODUCTION

Mammalian mothers lick their babies after the delivery. Through the licking, amniotic fluid is removed and the babies' various body systems such as cardiovascular, digestive, urinary, respiratory, nervous and immune systems get normalized. In human, massage is given if babies do not start to breath at the delivery. Massage is also applied to preterm babies and babies with low birth weight.

In 1950's, Harlow showed the importance of tactile stimulation in the mother-infant interactions [1]. He investigated the infant monkeys' preference of their mothers by a series of experiments. In his experiments, two artificial foster mothers were placed next to the infant monkeys' cage. One is a "cloth" mother that was made of wires covered with a soft cotton cloth, and the other is a "wire" mother without the cotton cloth (Fig.1). Infant monkeys assigned to the test in which the wire mother lactated and the cloth mother did not. Interestingly, they gradually spent more time with the cloth mother than the wire mother, despite the lactation. From this study, Harlow concluded that the infant monkeys prefer the mothers for comfortable tactile stimulation rather than a source of food.

In another experiment, the infants were raised either on a wire mother or on a cloth mother, both of which gave milk. There were no differences in the amount of milk they drank and the body weight gain between the two groups. However, the feces of the infants raised by the wire mother were softer than that of the infants raised by the cloth mother, suggesting the worse digestive function. Therefore, the wire mother may be adequate biologically to give milk, but not appropriate enough from physiopsychological points of view. These results confirmed the importance of the mother's tactile stimulation.

The last experiment showed that the infant monkeys sought the mothers as their source of security. In the presence of an artificial foster mother, the infants first always rushed to the mother in a strange environment and they gradually started to explore a new environment. On the other hand, in the absence of foster mother, they froze in a crouched position. Also, they increased vocalization, crouching, rocking, and sucking sharply, indicating that the emotionality increased. They used the mother as the base of security. From Harlow's experiments, contact comfort is really important in the mother and infant relationships.

In this review, we will explain the importance of the tactile stimulation during the neonatal period in the maturation of body, brain structure and behavior. We will focus on the body weight gain and a variety of physiological parameters and behavior, with special reference to stress response, learning and memory.

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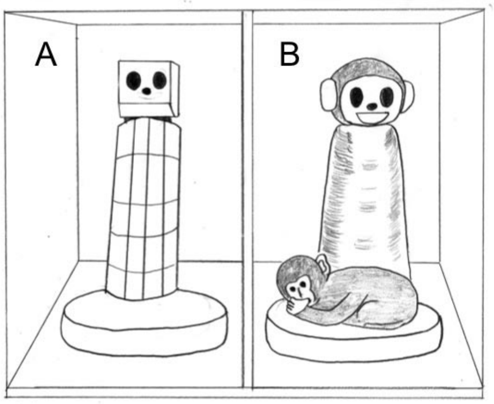

Figure 1: “Wire” mother (A) and “cloth” mother (B) in the Harlow’s experiment (modified from Harlow [1]).

Figure 2: Tactile stimulation of a pup of mouse on wooden chips using a paintbrush.

2. TACTILE STIMULATION AND KINESTHETIC STIMULATION

Massage is tactile stimulation by stroking other’s body using hands and thereby activates the neural pathway from the skin to the brain. It has been shown that tactile stimulation has a lot of positive physiological and behavioral effects on babies. From these reasons, massage is often recommended in human babies as “touch care” [2]. In the touch care, babies are placed prone and are given stroking with hands and/or fingers on their head, shoulder, arms, back and legs, in the direction from the head to the legs. The tactile stimulation is sometimes combined with kinesthetic stimulation, in which the babies are placed supine and are given flexion/extension movements of their arms and legs. To examine effects of the tactile stimulation and the mechanisms mediating the effects of the tactile stimulation, rats and mice have been often used as an animal model. In this case, the tactile stimulation seems to mimic the maternal behavior such as licking and grooming (LG). The experimenter uses a paintbrush either in wet or dry and strokes it on the pups’ back, from the head to the tail (Fig. 2).

3. TACTILE STIMULATION INCREASES BODY WEIGHT AND PROMOTES PHYSIOLOGICAL MATURATION

3.1 Human babies

Many studies have reported that tactile stimulation increases babies’ body weight, compared to non-stimulated ones [3-7]. For example, Field et al. reported the effects of tactile/kinesthetic stimulation on the body weight of preterm babies [4]. In their report, average body weight of preterm babies was 1,280 grams at birth and they were kept in neonatal intensive care unit. The stimulated babies received three 15 minutes tactile/kinesthetic stimulation everyday for 20 days. The stimulated babies gained averaged 25 grams, 1.5 times heavier as compared with the body weight gain of the non-stimulated babies (17 grams).

Weight gain is often correlated with physiological and behavioral development. Tactile stimulated babies have better physiological and behavioral development which includes more matured habituation, alertness to visual and auditory stimuli, and self-regulated physiological behavior such as regular breathing, state of alertness, balanced tonus, a range of posture, coordinated movements, hand-to-face movement control, suction, and grip support [4, 5, 7, 8]. In particular, body-massaged preterm babies showed early maturation of the electroencephalographic (EEG) activity and of visual function [9]. Massage also increased insulin-like growth factor-1 (IGF-1) and IGF binding protein 3 (IGFBP3) in the blood. IGF-1 has a structure similar to insulin and promotes growth of various cells, and IGFBP3 helps IGF-1 to bind to its receptor. Growth hormone from the pituitary induces IGF-1, and then IGF-1 and IGFBP3 are correlated with the maturation of visual system. In the animal experiment using rats, amount of IGF-1 was increased in the visual cortex and the auditory cortex of tactile stimulated pups when examined using histological method. In contrast, JB1 (IGF-1 antagonist which blocks the IGF-1 function) inhibited the maturation of visual acuity. Thus, massage modulates endogenous factors, such as IGF-1, and regulates the brain growth. These physiological and behavioral developments may accelerate the babies’ body weight gain.

Catecholamine may also be related to the weight gain and various aspects of physiological and behavioral development. Catecholamine includes adrenaline, noradrenaline, and dopamine, and the production and secretion of catecholamine are regulated by sympathetic nervous system and endocrine system. In the tactile stimulated babies, urinary concentration of catecholamine, both adrenaline and noradrenaline, is increased, which may be involved in the regulation of the blood glucose concentration, lung maturation, and maintenance of cardiovascular homeostasis [6]. Elevated urinary catecholamine levels may also cause enhanced activity that is observed in the tactile stimulated babies [6].

In addition, weight gain is related to the activity of the vagus nerve, a component of the autonomic nervous system, and the gastric motility. In Diego's study, some babies were given moderate tactile stimulation in which the skin color changed slightly from pink to white or slight indentations were seen in skins, while the others were given light pressure tactile stimulation [10]. Although the preterm babies who received moderate pressure-tactile/kinesthetic stimulation gained more weight than those who received light tactile/kinesthetic stimulation, they did not take more calories, compared to those received light pressure-tactile/kinesthetic stimulation. Moreover, the preterm babies who received tactile/kinesthetic stimulation showed weight gain but did not save their energy since they were more active than those who did not receive tactile/kinesthetic stimulation [11]. Therefore, weight gain is not simply correlated with the food intake and the energy consumption. One additional important mechanism may be that tactile/kinesthetic stimulation increases vagus nerve activity and gastric motility [10]. Skin pressure receptors that are involved in tactile stimulation activate the vagus nerve, and then it releases gastrointestinal hormones including gastrin and cholecystokinin that promote food absorption, and ornithine decarboxylase (ODC). ODC is the first enzyme in the synthesis of polyamines and acts in tissue growth and differentiation. Therefore, weight gain may be mediated at least by vagus nerve activity and gastric motility.

In contrast to these reports, several studies have shown no change in weight gain between the non-stimulated infants and stimulated ones [8]. It was suggested that the types and amount of stimulation are important, which will be described below [5, 7].

First, many studies that indicated increase in daily weight gain used the combination of tactile and kinesthetic stimulation [3-7], whereas the some studies that indicated no changes in weight gain used tactile stimulation only [8]. White-Traut et al. reported that tactile stimulation increases cortisol in saliva of infants, however multisensory stimulation (a combination of the two stimuli of the following; tactile, visual, auditory, and vestibular) decreases cortisol [12]. Cortisol is a stress hormone, which is secreted from the adrenal cortex in response to the stress. In addition, tactile/kinesthetic stimulation on very low birth weight infants improves the motor activity [13]. This leads to development in organized behavior, and in turn infants are skilled to reach and digest food better and they are easier to maintain early parent-infant interactions. Therefore, it will affect the subsequent development [4].

Second, total amount of stimulation was greater and repetitive stimulation was introduced in the study of no changes in weight gain [8]. Relevant length, frequency, and pressure of tactile stimulation may be essential. The moderate pressure-massaged babies showed decrease in heart rate and arousal, which indicates less stressed and more relaxed conditions, compared to the light pressure-massaged ones [14]. Therefore, moderate pressure-massage may be more optimal for growth. It is also true for mice, because two minutes of tactile stimulation during the first 10 days after the birth showed less emotional responsiveness, compared to five minutes of tactile stimulation [15]. Thus, too strong stimulation may induce stress, instead of all of those good outcomes. Also, repetitive stimulation leads to habituation and infants face difficulty to discriminate whether the stimulation is a special event.

3.2 Babies of experimental animals

Both growth hormone and ODC are decreased in maternally deprived rats, which have been separated from their mother daily for 1-2 hours during the neonatal days [5]. Growth hormone from the pituitary regulates ODC and also IGFs. ODC acts in tissue growth and differentiation as described above and IGFs are responsible for skeletal and possibly organ growth. Tactile stimulation reverses decrease in growth hormone and ODC by maternal deprivation rats [5]. Taken together, it is suggested that tactile stimulation regulates the organ growth through growth hormone, ODC, and IGFs.

4. STRESS RESPONSE

4.1 Human babies

In human, it is known that tactile stimulated infants can handle better in response to stress, compared to non-stimulated ones [16]. Feldman et al. did a still-face test on 6-month-old babies. In the test, mothers played freely with their babies for 3 minutes, then showed still-face for the next 2 minutes with or without tactile contact, and played again for additional 2 minutes. The stress hormone (cortisol) was measured in the babies' saliva. In the still-face period, babies' cortisol in the saliva was increased. However, with maternal touch, the increase of cortisol level during the still-face period was reduced, which suggests that maternal touch attenuates the stress response. In addition to the hormonal response, the cardiac vagal tone was calculated by recording the electrocardiogram, to examine the response by the autonomic nervous system. Vagal tone is controlled by the parasympathetic nervous system. When vagal tone is increased, heart rate slows down, which suggests the relaxed conditions. The maternal touch during the still-face period increased the cardiac vagal tone, suggesting the attenuation of the stress response [16]. In conclusion, maternal touch reduces the physiological responsiveness to stress through both endocrine system and autonomic nervous system. It was also shown that massage in preterm babies decreased blood (plasma) cortisol concentrations, but not blood catecholamine concentrations such as adrenaline and noradrenaline [17]. Catecholamine is also secreted in response to stress, but physiological actions are different between cortisol and catecholamine. Cortisol increases blood glucose to make it available for the body during stress, whereas catecholamine increases heart rate, blood pressure, and blood glucose levels.

4.2 Babies of experimental animals

Hypothalamic-pituitary-adrenocortical (HPA) axis plays an important role in response to stress (Fig.3). Stress activates hypothalamus to release corticotropin-releasing hormone (CRH), then CRH activates pituitary gland to release adenocorticotropic hormone (ACTH), which activates adrenal cortex to release cortisol in human and corticosterone in rats and mice. Cortisol and corticosterone bind to either glucocorticoid receptor (GR) or mineralocorticoid receptor (MR) to induce various stress responses and anti-inflammation effects. Cortisol and corticosterone act back on the hypothalamus, pituitary gland, and hippocampus in a negative feedback to reduce the release of CRH and ACTH. In rats, stress activates HPA axis, while tactile stimulation suppresses it [18, 19]. Tactile stimulation reverses the increase of ACTH and corticosterone in blood, and CRH messenger RNA (mRNA) expression in hypothalamus, and reduction in mRNA expression of GR and MR in hippocampus and prefrontal cortex, all of which were induced by maternal deprivation. Thus, it is suggestive that tactile stimulation can modulate the stress response by the nervous system and endocrine system.

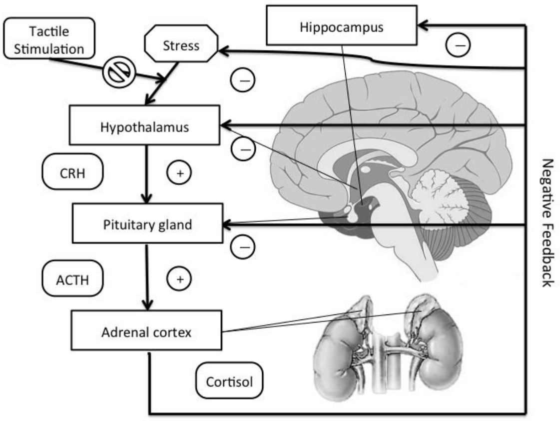

Figure 3: Effects of stress and tactile stimulation on the neuroendocrine systems.
(+: stimulation, −: inhibition)

Behavioral tests have also shown the beneficial effects of tactile stimulation on stress. In rats, maternal deprivation showed elevation in emotionality, anxiety-like behavior and pain sensitivity by a variety of experiments, but tactile stimulation reversed these changes [20, 21]. In mice, 2 minutes of tactile stimulation over the first 10 days after the birth decreased in emotional activity [16].

5. LEARNING AND MEMORY

Animal experiments have shown that the tactile stimulation improves learning and memory, although there are no reports in human. In the passive avoidance test, rats are placed in a cage that has the light and dark compartments. Rats usually prefer the dark compartment to the light one, but an aversive stimulus such as an electric foot shock is given when rats enter the dark compartment in this test. Rats, which received the tactile stimulation during the first postnatal week, learn faster to avoid the dark compartment, showing that the tactile stimulation improves the learning ability [22, 23].

The mild tactile stimulation also enhances the spatial working memory [24, 25]. This effect depends on the number of brush strokes given as tactile stimulation and whether the test environment is novel or not. The brain mechanisms mediating the tactile stimulation on the spatial memory are partly understood. The neuronal pathway from the ventral part of the hippocampus (vHIP) to the medial part of the prefrontal cortex (mPFC) is involved in the information-encoding processes, learning in avoidance of aversive stimulus, and spatial working memory function. The dopamine receptor (D1 receptor) in neurons of the mPFC modulates both the neuronal activity in the vHIP-mPFC pathway and the spatial working memory. Considering that tactile stimulation increases the neuronal activity in the vHIP-mPFC and activates D1 dopamine receptor [24], the possibility is suggested that tactile stimulation regulates the neuronal activity in the vHIP-mPFC through activation of the D1 dopamine receptor in mPFC, which underlies the enhancement of the spatial working memory.

Tactile stimulation also changes the morphology of neurons in the hippocampus, which may provide the structural bases for the improvement of the learning and memory. The offspring of high licking and grooming (LG) mother, which seems to receive more tactile stimulation, showed longer length of dendrites of pyramidal cells, more complex dendritic arbors, increase in the numbers of synapses and dendritic spines which are postsynaptic structures of the excitatory synapse [26, 27]. During early postnatal period, there is a burst increase in synapses and dendritic spines in hippocampus. This event occurs during the intense periods of mother-infant interactions, and the somatosensory system, which perceives tactile stimulation in the skin and transmits it to the cerebral cortex, develops during the first postnatal week [28]. Thus, tactile stimulation may modulate the morphology of neural circuit. In addition, tactile stimulation prevented hippocampal damage, which was caused by hypoxia-ischemia [29].

6. CONCLUSION

Many studies have shown that massage or tactile stimulation have positive effects of body weight and various physiological conditions and behavior, including stress response and learning and memory, in both human and animals. Neuroendocrine and nervous systems may underlie these effects, although further studies are needed to elucidate the mechanisms underlying the effects of tactile stimulation.

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