Abstract  We examined the effect of post-prandial body posture on orocecal transit time and absorption of milk lactose using the breath hydrogen test. In this experiment, subjects ingested a cup of commercially available milk to which we had added a small amount of lactosucrose (an indigestible trisaccharide), and then they lay on their backs or sat on a chair for the first 4 hr (from 08:00 to 12:00). After four hours lying or sitting, they remained sedentary on a sofa for the second six hr (from 12:00 to 18:00). Participants’ end alveolar breath samples were collected every 15 min from 08:00 to 12:30, then every 30 min from 13:00 to 18:00. The experiment was conducted on two consecutive days using a randomized, crossover study design. Examination showed that the orocecal transit time of the oligosaccharides (lactosucrose and milk lactose) under the post-prandial supine condition was significantly longer than that under the sitting condition. In addition, the amount of breath hydrogen excretion under the supine condition was significantly lower than under the sitting condition, indicating that the unabsorbed milk lactose moved into cecum under the supine condition is smaller than that under the sitting condition. These findings provide evidence that postprandial supine posture works more beneficially to digest and absorb milk lactose when compared to the sitting posture.

Effect of Post-prandial Posture on Orocecal Transit Time and Digestion of Milk Lactose in Humans

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Introduction

In Japan, the consumption of milk was increased steadily from 48.8 g in 1965 (The Public Health Bureau, the Ministry oh Health and Welfare, Japan) to 126.0 g in 1995 (The Health Service Bureau, the Ministry oh Health and Welfare, Japan), per capita, per day. This steady increase in milk consumption might be partially due to a recent, thirty-year recommendation that milk contains adequate nutrients to meet most nutritional requirements for our health. In addition, the idea that appropriate calcium intake throughout one’s lifetime prevents osteoporosis at a later stage in life (Teegarden et al., 1999), may have contributed to increase in milk consumption of Japanese older adults. Although milk is widely recommended as a nutritious food, especially rich in protein and calcium, it is well known that lactose intolerance is common in Southern Asian, including in Japan (Zlotkin, 1991). Lactose intolerance due to a decrease in the intestinal brush border lactase causes discomfort, bloating, flatulence, and diarrhea in severe cases. Therefore, severe lactose mal-absorption accompanied with milk consumption is an important health and nutritional problem for the Japanese, and in particular, for bed-bound elderly person whose digestive activity has been in decline (Lee et al., 1998).

In order to pursue the beneficial posture for bed-bound elderly people at mealtime, we have examined the effect of the post-prandial posture on the digestion of usual solid meals by a breath hydrogen test (Hirota et al., 2002). In that examination, we found that less breath hydrogen was excreted in the supine position than in the sitting position, which suggests that the postprandial supine posture helps digestion and absorption of dietary carbohydrates more efficiently when compared to the sitting posture.

Lactose intolerance is common for the Japanese. The previous empirical result led us to postulate that the post-prandial supine posture could have the advantage of digestion and absorption of milk lactose through the gastrointestinal tract. In this study, to test this hypothesis, we measured the orocecal transit time and the degree of milk lactose absorption by the same experimental procedure as that for the previous
experiment, except that subjects ingested a cup of commercially available milk instead of a usual solid meal.

Materials and methods

Subjects
Subjects for this experiment were eleven healthy female students (aged 18 to 20 years, body weight 48.4±4.6 kg, height 156.5±3.1 cm, mean±SD), who suffered neither constipation nor received antibiotic therapy for at least 2 months prior to the experiment (Gilat et al., 1978). This experiment was conducted for two consecutive days during the follicular or luteal phase of the participants’ menstrual cycles, excluding menses. All participants were non-smokers.

Before this experiment, each participant was informed of the purpose of the study and experimental procedure. Each participant gave her written, informed consent for this experiment.

Experimental procedure
Figure 1 shows the experimental procedure. The experiment was conducted for three days, where the first day was the adjustment phase for the measurement where the subjects stayed in the experimental room to adjust themselves to the experimental environment on the first day, and the second and third days were the measurement phases of “lying” or “sitting”. These two measurement phases were conducted on continuous days with a randomized order of the sitting and lying conditions.

The subjects were advised to avoid hard physical work and to have the same evening meal prepared for them by the examiner as on the first control day. To avoid the influence of caffeine on the gastrointestinal function by drinking caffeine-rich beverages such as coffee and tea, participants were allowed to drink only water during the experiment. The participants entered the experimental room (illuminated by 2000 lx, roughly controlled at 25°C, relative humidity, 65%) at 7:30 of the second day, and changed their own clothing to loose-fitting experimental garments that are free from skin pressure (Sone et al., 2000).

Participants took a test milk solution at 08:00 sitting on a chair, and their breath samples were collected every 15 minutes from 08:00, including just before taking the test milk solution, until 13:00, followed by a sampling every 30 min until 18:00. The test milk solution was prepared by mixing 5 g of lactosucrose into a cup of commercially available milk (200 ml). This test milk was served as a cool solution at about 7~10°C. In order to determine the small bowel transit time of the dietary oligosaccharide, even if the subject is lactose tolerant, an indigestible lactosucrose (Ensuko Sugar Refining Co., Ltd., Tokyo, Japan), was added to the milk. Lunch, a snack, and dinner were considered ordinary meals and served at 13:00, 16:00, and 19:00, respectively. These meals were not standardized for the body weight of the subject, namely, each

Fig. 1 Experimental schedule.
subject was served the same meals. The composition of the meals served in this experiment is summarized in Table 1. For each subject, the same time schedule was repeated on the third day under a different post-prandial posture.

In the “supine (lying on their back)” experiment, a participant lied on a bed for four hours just after taking the test milk solution (from ca. 08:10 to 12:00) and then maintained a sedentary posture for six hours. In the “sitting” experiment, a participant sat on a chair for four hours (from 08:00 to 12:00) and then took a sedentary posture on a sofa for six more hours. The participants were allowed to listen to music and/or read magazines, but they were prohibited from taking a nap. This experiment was performed in June 2001, and in February 2002.

**Breath hydrogen analysis**

We collected samples of participants’ end alveolar breath for ten hours (every 15 min from 08:00 to 12:30, and then every 30 min until 18:00) using a special breath-collection bag purchased from TERAMECS (Kyoto, Japan). The breath hydrogen concentration in the collection bag was measured by gas chromatography (MicroLyzer model 12i, Quinton Instruments, Milwaukee, WI, USA), and expressed as parts per million (ppm).

The breath hydrogen test has been widely used as a noninvasive and simple method of detecting orocecal transit time of food and for assessing malabsorption of dietary carbohydrates in humans (Levitt et al., 1970). In this experiment, we defined the orocecal transit time (OCTT) as the time between milk ingestion and an increase of five or more ppm over baseline levels, which were sustained for at least two consecutive intervals (Hitakawa et al., 1988).

Because it showed that there is a rough linear correlation between the rate of breath hydrogen excretion and the quantity of carbohydrate malabsorption (Fritz et al., 1985), the area under hydrogen concentration vs. time curve (AUC) can be used as an approximated hydrogen excretion due to the fermentation of malabsorbed carbohydrate by microflora in the cecum. In this experiment, AUC was calculated from the initial sustained rise for hydrogen to the end of the experiment (18:00). This area, thus, has the units of ppm · hr.

**Statistical data analysis**

All the results are expressed as the mean values±SEM, or where indicated, as the mean values±SD. The statistical tests between supine posture and sitting posture on the breath hydrogen levels at all the sampling points, OCTT and AUC were carried out by the Wilcoxon signed-ranks test. A p-value <0.05 was considered to be significant.

**Result**

Figure 2 shows the serial average of hydrogen concentration in breath (mean±SEM) of 11 subjects in supine posture (closed circle) and in sitting posture (open circle). This figure shows that the time at which the breath hydrogen level started to rise is slower in the supine posture than in the sitting posture (ca. 11:30 and 10:30, respectively), and that the breath hydrogen levels under the supine position are lower than those in the sitting position at all the sampling points from 10:15 to the end of the experiment. These significant differences of breath hydrogen excretion are statistically proved by the individual comparison of OCTT and AUC. First, Figure 3 shows the individual values and compares the subjects’ OCTT in the post-prandial supine posture to the sitting posture. In 10 out of 11 subjects, OCTT in the supine posture is longer than in the sitting posture, with the statistical test showing a significant difference between them (p<0.05). Second, Figure 4 compares the subjects’ AUC individually between the two positions, indicating that, in all subjects, the AUC in supine posture is lower than in the sitting posture. Furthermore, a significant difference exists between the postures (p<0.005). Therefore, these statistical differences in OCTT and AUC clearly give the following evidence; namely, that milk lactose (including indigestible lactosucrose) is passed through the small intestine more slowly in the supine posture than in the sitting posture, and a smaller amount of undigested and unabsorbed milk lactose moved into the colon in the supine posture than in the sitting posture.

**Discussion**

Concerning the effect of the post-prandial body posture on the function of the gastrointestinal tract, several studies deal with postural effects on gastric function, but there are few studies dealing with a discussion of the postural effects on the digestion and absorption of dietary nutrients. This might be due to the underdevelopment of simple and noninvasive methods applicable to the examination of digestion and

### Table 1  Composition of meals served in this experiment

<table>
<thead>
<tr>
<th></th>
<th>Test meal</th>
<th>Lunch</th>
<th>Snack</th>
<th>Dinner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight (g)</td>
<td>205</td>
<td>650</td>
<td>200</td>
<td>830</td>
</tr>
<tr>
<td>Total energy (kcal)</td>
<td>134</td>
<td>671</td>
<td>280</td>
<td>400</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>7.0</td>
<td>26.3</td>
<td>2.8</td>
<td>20.5</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>3.0</td>
<td>18.1</td>
<td>11.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>15.3</td>
<td>97.9</td>
<td>39.4</td>
<td>56.0</td>
</tr>
</tbody>
</table>
absorption of nutrients using human subjects. From this point of view, our present empirical result obtained by means of the breath hydrogen test on human subjects is very interesting because it provides evidence that the post-prandial posture affects digestive activity in the human gastrointestinal tract.

In this study, we obtained the result that the OCTT of the carbohydrates (in this experiment, lactosucrose and milk lactose) in the supine position was longer than in the sitting position. This longer transit time of the disaccharides in milk could be due to slower gastric emptying in the supine position as reported by Moore et al. (1988) and Asada et al. (1989). In these studies, the authors revealed by using radio-labeled or sulfamethizole capsule food meal, the lying position is significantly slower for gastric emptying when compared to any other position. However, it should be kept in mind that the OCTT determined by the breath hydrogen test is the sum of the transit time of the food through the stomach and the small intestine. Thus, we cannot exclude the longer transit time of

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**Fig. 2** Average breath hydrogen concentration of 11 subjects before and after the intake of the test milk solution in sitting (open circle) and supine position (closed circle). Bars represent SEM.

**Fig. 3** Comparison of each subject's orocecal transit time (OCTT) between the postprandial supine position and the sitting position.
the disaccharide through the small intestine from the possible cause of the longer OCTT in the supine position. In this experiment, although we cannot detect the main cause of the longer OCTT of the disaccharides, it is clear that the post-prandial posture has a profound effect on the rate at which the disaccharides pass through the stomach and the small intestinal tract, resulting in a longer transit time of the disaccharides in the supine position.

In this experiment, we demonstrated that the subjects excreted less breath hydrogen in the supine position compared to the sitting position after they ingested commercially available milk including lactose, and the additive lactosucrose. Concerning the digestion of milk lactose, Zuccato et al. (1983) have proved the positive and linear relationship between AUC and the amounts of lactose ingested in Italian lactose intolerant subjects. In addition, they have revealed that the rate of breath hydrogen excretion depends on the amount of milk lactose digested and absorbed in the small intestine; in other words, the more milk lactose is absorbed, the less breath hydrogen is excreted. Our present results, thus, indicate that milk lactose was digested and absorbed in the supine position more effectively than in the sitting position, and from the opposite point of view regarding absorption, the sitting position caused a mal-absorption of milk lactose. One of the possible causes of this milk lactose mal-absorption is a drop in lactase activity in the small intestine in the sitting position. It is well known that most Japanese are lactase-deficient to some extent, but they don’t always have significant symptoms after milk ingestion (Suzuki et al., 1980). If most breath hydrogen excretion in the supine position is due to the fermentation of lactosucrose by the microorganisms in the cecum, it is possible that the subjects are lactose-intolerants whose lactase levels meet the digestion of lactose in the test milk solution in the supine position, but the post-prandial sitting position reduces the duration of exposure to lactase to a level not sufficient for the complete digestion of the milk lactose. Of course, the proof of this hypothesis needs further study.

Concerning the effect of orocecal transit time on the carbohydrate absorption of the liquid form of food, Moukarzel et al. (2000) have recently demonstrated an interesting empirical result; shorter gastric emptying time of fruit juice is associated with greater production of breath hydrogen, indicating that the mal-absorption of the juice carbohydrates is partially related to the effect of juice on the gastric physiology. The results of Moukarzel et al. appear to be very similar to our present result. Thus, the experiment to discover the effect of post-prandial posture on gastric physiology should be carried out in order to reveal the contribution of gastric emptying to the mal-absorption of milk lactose.

The present result described above is coincident with the previous one obtained in the experiment with a solid meal (Hirota et al., 2002), in which a greater amount of dietary carbohydrate was absorbed in the post-prandial supine position than in the sitting one. These differences in the absorption of dietary carbohydrate between the supine and sitting condition can be explained by the contribution of the autonomic nervous system on the control of the gastrointestinal function including gastric activity, as well as by digestive juice secretion. In general, the noradrenergic impulses to the effecter organs, such as the stomach and the intestine, are suppressive (Ganong et al., 1999). Miki et al. found that a relaxed posture is associated with a decrease in sympathetic nerve activity during normal daily activity in Wister rats (Miki, K., Nara Women’s University, personal correspondence). Recently, Tsunoda et al.
Post-prandial posture and digestion of milk lactose

(2001) showed in human subjects that the plasma noradrenaline level was lower in the supine position than in the sitting position on the sofa. In addition, they revealed that the parasympathetic nervous indicator (the high frequency power component) obtained by heart rate variability analysis was higher in the former position than in the latter one. These studies clearly indicate that the parasympathetic nerve function works more predominantly in the supine position than in the sitting position on the chair. In the present experiment, therefore, it is likely that the relaxed post-prandial supine position results in lowering of sympathetic nerve activity; moreover, the concomitant prevalence of parasympathetic nerve function produces an enhancement of the digestive activity of the gastrointestinal tract. However, we need to prove this hypothesis by further studies.

In summary, the post-prandial supine posture works more beneficially to digest and absorb milk lactose than the sitting posture does.

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Received: December 29, 2003
Accepted: April 1, 2004
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