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Original Article

Effects of Postprandial Body Position on Gastrointestinal Motility, the Autonomic Nervous System and Subjective Comfort

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We examined postprandial body positions' effects on gastrointestinal motility, the autonomic nervous system and subjective comfort, *i.e.*, whether lowering the head after a meal is beneficial for gastrointestinal motility and the prevention of pressure ulcer. We examined 10 healthy subjects and compared 3 body positions: (1) Seated upright. (2) Lying on a bed with the head at 60° and knees up by 20° (60° position). (3) Identical to (2) until post-meal; the head was then lowered to 30° (60°-30° position). Gastrointestinal motility was assessed as gastrointestinal sounds measured by sound-editing software. Digital plethysmography assessed autonomic nerve function as heart rate variability. The pressure ulcer risk was estimated as subjective comfort/discomfort using a visual analog scale. Gastrointestinal sounds increased post-meal. The 60°-30° position showed the highest number of sounds and longest cumulative sound duration. Post-meal, sympathetic activation was suggested in the 60° position, whereas vagal activity was relatively preserved in the 60°-30° position. The 60°-30° position was the most comfortable, and the 60° position was least comfortable. Lowering the head after a meal is beneficial to augment gastrointestinal motility and decrease the pressure ulcer risk. The 60° head-up position increases the pressure ulcer risk.

Key words: gastrointestinal sound, body position, autonomic nerve, pressure ulcer, patient care

Good nutrition is essential for patients' recovery. Patients who cannot sit upright in a chair while eating may be required to stay in bed with a head-up position. A survey in Japan showed that the 60° head-up position was most frequently used for such patients [1]. The survey also revealed that this position was usually maintained even after the meal, in order to avoid aspiration. However, it is not clear whether the 60° head-up position is optimal for digestion. The digestive system is partially under the control of the autonomic nervous system, and sympathetic activation is usually inhibitory to gastrointestinal (GI) function [2]. A relative predominance of parasympathetic activity may thus be preferred for better digestion. Nevertheless, several studies showed sympathetic activation after meals [3-5]. Postural changes affect autonomic function and, notably, lowering the head from a 70° head-up tilt to the supine position attenuates sympathetic activity [6]. It is therefore of interest to determine whether lowering the head after a meal facilitates GI function through the attenuation of sympathetic activity.

Keeping the 60° head-up position may present another problem, *i.e.*, an increased risk of the development of a pressure ulcer, or decubitus, at the sacrococ-

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cygeal region. The peak pressure at the sacral area increased with the increase in the bed's elevation of the head [7]. Thus, lowering the head has been recommended to reduce the risk of pressure ulcer [8].

We conducted the present study to determine whether lowering the head after consuming a meal has any effects on GI motility, the autonomic nervous system, and subjective comfort. The results are important for all medical personnel, toward the improvement of healthcare for patients with eating difficulties.

Subjects and Methods

Materials. A pulse analyzer (TAS9 VIEW, YKC Co., Tokyo, Japan) was used for the heart rate variability (HRV) analysis. An automated blood pressure monitor (HEM7130, Omron, Kyoto, Japan) was used. Gastrointestinal sounds were recorded using a stethoscope (Littmann® Classic II, 3M), a condenser microphone (ECM-CS3, Sony, Tokyo, Japan) and a digital recorder (PCM-M10, Sony). The bed equipped with head-up and knee-up functions was from Paramount (KQ-603, Tokyo, Japan).

Subjects. Ten healthy subjects (5 males and 5 females, ages 21-56) without major abdominal surgery were recruited in this experiment. They were requested not to take any food or caffeine-containing beverages for 3 h prior to the experiment.

Experimental protocol. Three different body positions were compared for each subject on three different days in a randomized order. The first position is an upright sitting position on a chair with a backrest (the sitting position) for the duration of the subject's consumption of a meal and afterward. The second position is a lying on a hospital bed with 60° head-up and 20° knee-up (the 60° position) while the subject consumed a meal and thereafter. The third position was identical to the second position (*i.e.*, 60° head-up and 20° knee-up) until the end of the meal, at which time the subject's head was lowered immediately by the bed to 30° up with keeping the 20° knee-up (the 60°-30° position). The room temperature (24 ± 2°C) and moisture (50 ± 10%) were controlled by an air conditioner.

First, after taking one of the 3 positions, the subject was allowed to rest for 10 min, and his or her baseline GI sound and HRV were measured for 5 min, and then the blood pressure was measured and a visual analog scale (VAS) was completed by the subject as a measure of comfort/discomfort (maximal comfort = 0 and maximal discomfort = 100). Blood pressure was measured on the right arm. These measurements were defined as pre-values.

The subject then ate a meal consisting of a cooked chicken + eggs bowl (360 g/349 kcal) and green tea (130 ml/0 kcal). The actual meal time was 10.9 ± 2.9 min. The surface temperature of the meal at serving was 65 ± 4°C for the chicken + eggs bowl and 25 ± 2°C for the tea, which was measured by an infrared thermometer (IT-545N, Horiba, Kyoto, Japan). For the 60°-30° position, the head was lowered to 30° immediately after the subject completed eating the meal. The GI sound, HRV, blood pressure and VAS were then measured again, and were defined as time = 0 min values. These measurements were repeated at 20, 40 and 60 min after the meal. The subjects were requested to keep their body position between each measurement.

Heart rate variability and standardization of the data. For the HRV analysis, the heart beat interval was measured for 5 min and analyzed by digital plethysmography using the TAS9 VIEW. The pulse detector was equipped on the subject's left index finger. The ratio of low frequency (0.04-0.15 Hz)/high frequency (0.15-0.4 Hz) (LF/HF) was calculated. Vagal activity is reported to be the major contributor to the HF component [9]. The LF/HF ratio is considered to reflect the sympathetic/vagal balance, and the LF/HF ratio increases when sympathetic activity predominates [10]. The root mean square of the successive differences (RMSSD) is the square root of the mean squared differences of successive heart beat intervals, and it estimates high-frequency variations in heart rate [9], and thus reflects vagal activity.

Regarding the RMSSD and LF/HF in the present study, the inter-subject variation in these values was large, and this variation obscured the relatively small changes induced by postural difference and food intake. In order to minimize the inter-subject variation, we standardized the 15 data (*i.e.*, 3 body positions × 5 time points) obtained from each subject as follows, in which "SD" refers to standard deviation:

Standardized data = (Original data — Mean of the 15 data)/SD of the 15 data

Sound acquisition and analysis. The microphone was directly connected to the chest piece of the stethoscope using a silicone tube, and the chest piece was taped on the right upper quadrant of the subject's abdomen. In order to avoid noise, care was taken that no part of the subject's clothing or blanket directly touched the chest piece or microphone. Typically the sound was recorded for slightly over 300 sec, and a digital audio editor (Audacity; <http://www. audacityteam. org/>) was used to process and analyze the GI sound. Background noise was reduced from the original sound data using the audio editor's Noise Reduction function, and then the GI sounds were detected using the audio editor's Sound Finder function (Fig. 1).

When the interval between sounds was less than 0.2 sec, these sounds were considered to be one GI sound (Fig. 1, arrow). The detected sounds were confirmed to be of GI origin by listening. For each recording, 300 sec of the sound was analyzed and the number of the detected sounds was counted. The duration of each sound was added together, and the ratio of this cumulative sound duration/total recording time was calculated.

Ethical issues. The experimental procedure was approved by the ethical committee of Okayama Prefectural University (approval #16-03). All procedures were carried out with the adequate understanding and written informed consent of all subjects.

Statistics. Data were tabulated and expressed as mean ± SD. A two-way analysis of variance (ANOVA) with Tukey's test was used for multiple comparisons, with Statcel QC software (OMS Publishing, Saitama, Japan). For the data of heart rate, standardized RMSSD, standardized LF/HF and blood pressure, the three body positions were analyzed individually by a repeated-measures ANOVA with Bonferroni's test, with IBM SPSS Statistics software (IBM, Armonk, NY, USA). *P*-values < 0.05 were considered significant.

Results

GI sounds increased post-meal, especially in the 60°–30° position. The number of GI sounds increased after the meals. The 2-way ANOVA showed that the data at 0 and 40 min were significantly higher than that of the pre-value (Fig. 2). Interestingly, the 60°-30° position showed the highest number of GI sounds, and it was significantly higher than that of the 60° position. The differences in the GI sounds between each position became more evident when the ratio of cumulative sound duration/total recording time was calculated (Fig. 3). The ratio was highest in the 60°-30° position, and it was significantly higher than those in the other 2 positions. As for the time course, the data

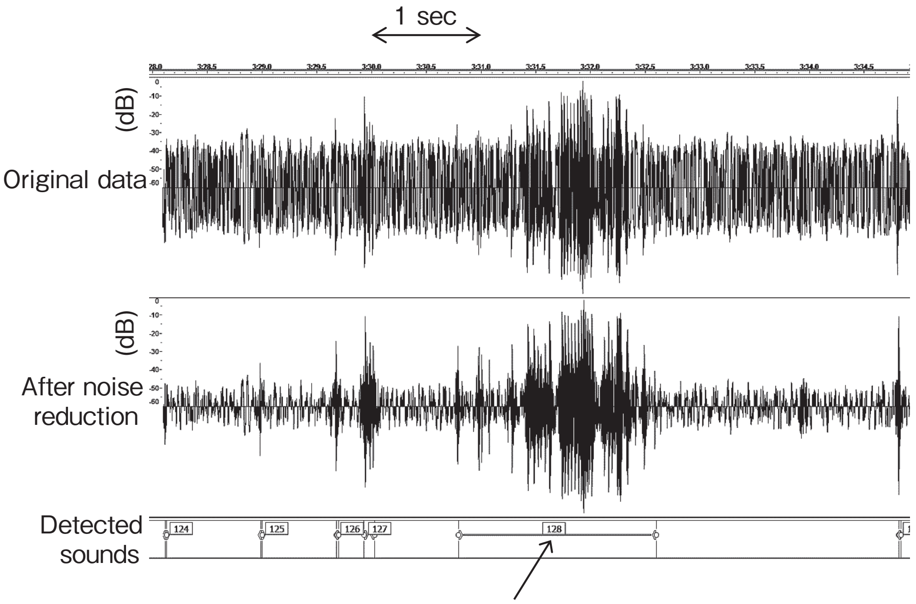

Fig. 1 Digitally recorded GI sound was processed and analyzed by the digital audio editor Audacity. The background noise was reduced using the editor's Noise Reduction function, and then the GI sound were detected using the Sound Finder function (detected sounds). The arrow indicates a series of sounds the intervals between sounds of which were < 0.2 sec; these sounds were considered to be one GI sound. The detected sounds were confirmed to be of GI origin by listening.

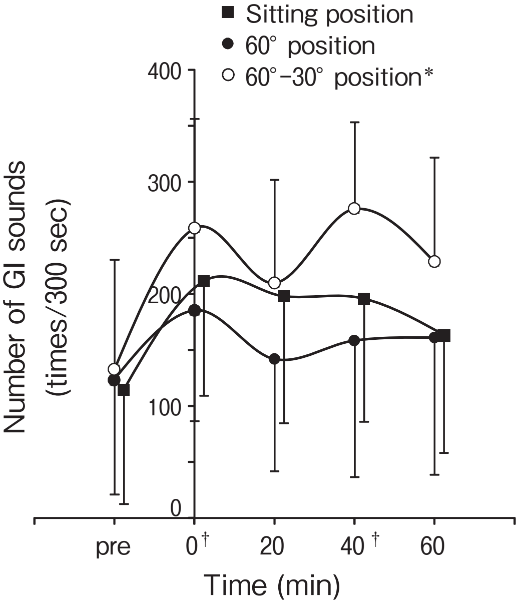

Fig. 2 Beginning from the indicated time points, 300 sec of the sound was analyzed and the number of the detected sounds was counted. †Significantly higher than the pre-value. *Significantly higher than the 60° position. No significant interaction was observed between time course and body position (two-way ANOVA, $p > 0.05$).

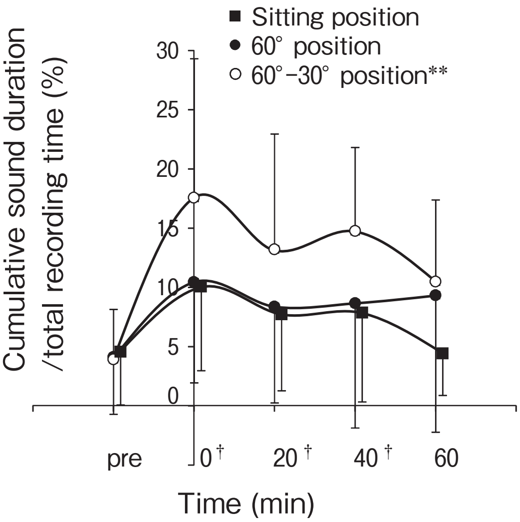

Fig. 3 The duration of each detected GI sound was added together, and the ratio of this cumulative sound duration/total recording time was calculated. †Significantly higher than the pre-value. **Significantly higher than the other 2 positions. No significant interaction was observed between time course and body position (two-way ANOVA, $p > 0.05$).

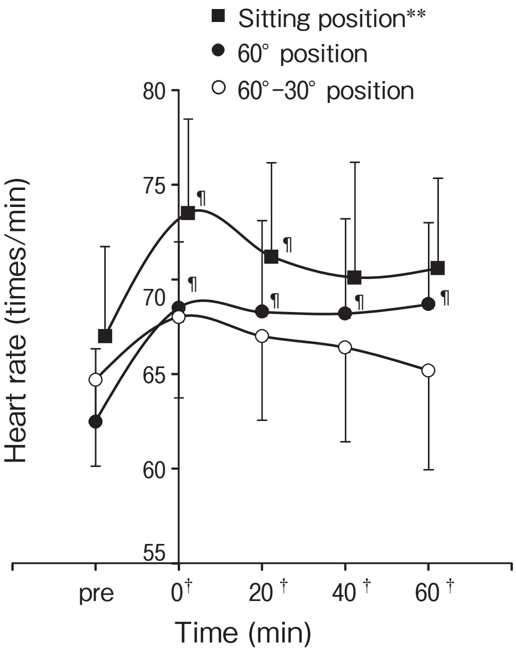

Fig. 4 Each subject's heart rate was calculated from the 300-sec recording of the digital plethysmography, which was also used to analyze HRV. †Significantly higher than the pre-value. **Significantly higher than the other two positions. No significant interaction was observed between time course and body position (two-way ANOVA, $p > 0.05$). In addition, each body position was individually analyzed by a repeated-measures ANOVA. ¶Significantly higher than the corresponding pre-value ($p < 0.05$).

at 0, 20 and 40 min were significantly higher than that of the pre-value.

The heart rate increased after the meal, especially in the sitting position and 60° position. The 10 subjects' heart rate increased significantly after the meal. When compared with the pre-value, the heart rates at 0, 20, 40 and 60 min were all significantly higher (Fig. 4). Notably, the heart rate in the sitting position was significantly higher than those in the other two positions. When each body position was analyzed individually by a repeated-measures ANOVA, the sitting position and 60° position both showed a significant increase in the heart rate after the meal (Fig. 4), whereas the 60°-30° position showed no significant change.

The standardized RMSSD decreased after the meal, especially in 60° position. Compared to the pre-value, the standardized RMSSD at 0 min was significantly decreased (Fig. 5), which suggested vagal suppression. In addition, the standardized RMSSD in the sitting position was significantly lower than those in the other

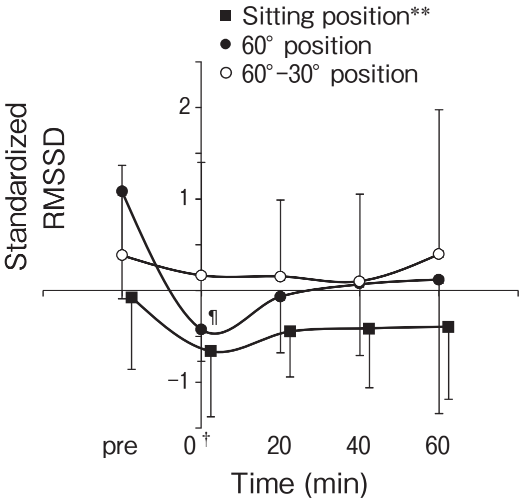

Fig. 5 Heart rate variability (HRV) was analyzed from the 300-sec recording of the digital plethysmography. For the time-domain analysis of the HRV, we calculated the RMSSD, which reflects parasympathetic nerve activity. As the RMSSD showed large inter-subject variation, the 15 data (*i.e.*, 3 body positions × 5 time points) obtained from each subject were standardized before analysis. †Significantly lower than the pre-value. **Significantly lower than the other two positions. No significant interaction was observed between time course and body position (two-way ANOVA, $p > 0.05$). In addition, each body position was individually analyzed by a repeated-measures ANOVA. ¶ Significantly lower than the pre-value of the 60° position ($p < 0.05$).

positions. When each body position was analyzed individually by a repeated-measures ANOVA, the 60° position showed a significant decrease in the standardized RMSSD after the meal (Fig. 5), whereas the 60°-30° position and the sitting position showed no significant change. On the other hand, no significant difference was observed in the standardized LF/HF, although the sitting position showed a trend of high standardized LF/HF (Fig. 6).

As for systolic and diastolic blood pressure, the two-way ANOVA showed no significant difference in relation to time course or body position (Fig. 7). However, when each body position was individually analyzed by a repeated-measures ANOVA, diastolic blood pressure in the 60°-30° position showed a significant decrease after the meal (Fig. 7).

The 60°–30° position was the most comfortable. The subjective comfort/discomfort VAS scores showed a marked difference between the body positions. Keeping the 60° head-up after the meal was the most uncomfortable (Fig. 8). The VAS value of the 60° posi-

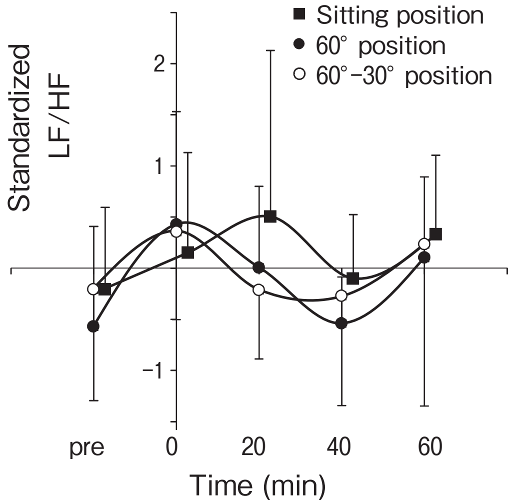

Fig. 6 For the frequency-domain analysis, the ratio of low frequency (0.04–0.15 Hz)/high frequency (0.15–0.4 Hz) (LF/HF) was calculated using a fast Fourier transformation. As the LF/HF ratio showed large inter-subject variation, the 15 data (*i.e.*, 3 body positions × 5 time points) obtained from each subject were standardized before the analysis. Although no significant difference or interaction was observed, the sitting position showed a trend of high LF/HF (two-way ANOVA, $p = 0.45$). The repeated-measures ANOVA showed no significant difference ($p > 0.05$).

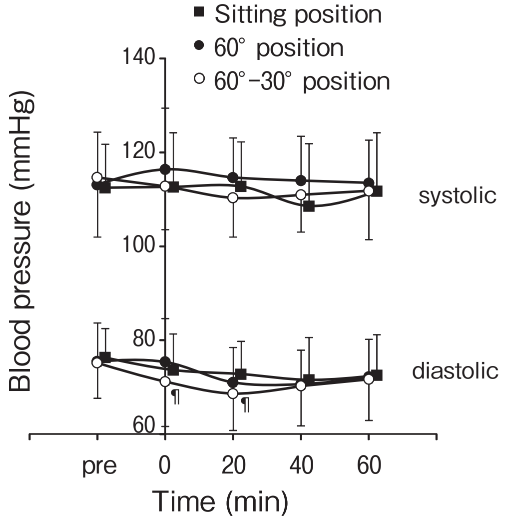

Fig. 7 Blood pressure was measured on the subject's right arm by an automated blood pressure monitor. Care was taken that the height of the manchette was at the level of the heart. Although no significant difference or interaction was observed by two-way ANOVA ($p > 0.05$), diastolic blood pressure in the 60°–30° position showed a significant decrease after the meal, when each body position was individually analyzed by a repeated-measures ANOVA. ¶ Significantly lower than the diastolic blood pressure pre-value of the 60°–30° position ($p < 0.05$).

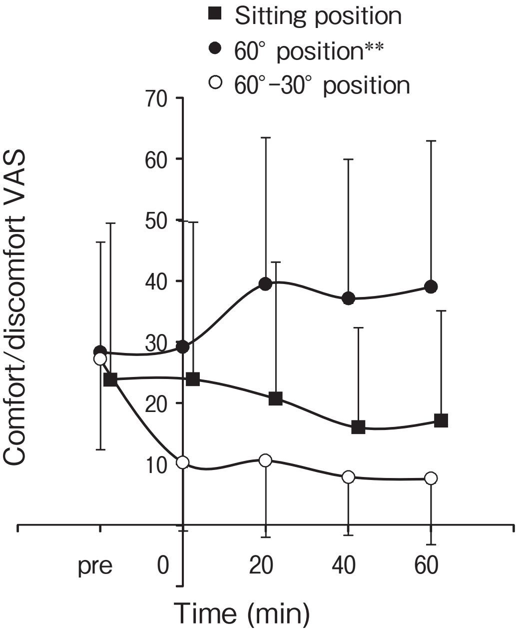

Fig. 8 Subjective comfort/discomfort was measured by a VAS, where maximal comfort = 0 and maximal discomfort = 100. **Significantly higher than the other two positions. No significant interaction was observed between time course and body position (two-way ANOVA, $p > 0.05$).

tion was significantly higher than those of the other two positions. The 60°-30° position was the most comfortable. No significant interaction between time course and body position was observed by the two-way ANOVA.

Discussion

Our results suggest that GI motility, as judged by GI sounds, increased when the head was lowered to 30° after the meal. This was accompanied by a relative preservation of vagal activity. Although the GI tract moves spontaneously, it is also under the control of the autonomic nervous system. An increase in vagal activity enhances GI tract movement and the secretion of digestive enzymes [2]. However, it is reported that sympathetic activity commonly predominates after the consumption of a meal [4]. One reason for this apparent discrepancy is that the blood supply to the brain must be maintained. After a meal, the blood flow of the superior mesenteric artery increases [11]. If there is no sympathetic nerve activation, the blood pressure may decrease and the brain cannot receive a sufficient blood supply. This is called postprandial hypotension, which is sometimes observed in patients with dysfunction of the autonomic nervous system as well as those with Parkinson disease [12]. However, this compensatory activation of sympathetic nerves may inhibit GI tract function.

Postural changes also modulate the activity of autonomic nerves, and raising the head is associated with sympathetic activation. When healthy adults were subjected to a 70° head-up tilt from the supine position, the RMSSD decreased and LF/HF increased, and both of these parameters returned to the original range after the subjects went back to the supine position again [6]. Consistently, the sitting position in our experiment resulted in a significantly lower standardized RMSSD and higher heart rate, which suggest a relative sympathetic predominance. When the effects of the meal were compared between the 60° position and the 60°-30° position, the 60° position showed an increase in heart rate, a decrease in the standardized RMSSD, and no significant change in diastolic blood pressure, which indicated sympathetic activation. These parameters were quite the opposite in the 60°-30° position, in which the diastolic blood pressure was decreased and no significant change was found in the heart rate or standardized RMSSD, which indicated a relative preservation of vagal activity. It is likely that lowering the head after the meal resulted in a relative preservation of vagal activity, which augmented GI motility.

It is also important to note that the 60°-30° position was most comfortable, which suggests that the risk of pressure ulcer might be decreased. Pressure and shear stress in combination suppress the blood flow of the skin [13], which increases the risk of a pressure ulcer. A previous investigation showed that a 60° head-up position was accompanied by a higher peak sacral pressure compared to a lower head-up position [7]. It is interesting that the 60° head-up was even less comfortable than the sitting position in the present study. Thus, keeping the 60° head-up position may not be good regarding the risk of a pressure ulcer as well as for digestion.

As lowering the head after the meal offered better GI motility and comfort, one might consider that the supine position would offer even better results. It should be mentioned that a higher head-up position may be preferable under certain circumstances. Some [14] but not all reports [15] suggest that the risk of aspiration pneumonia increases in the supine position. A recent systematic review showed that a semi-recumbent position (30° to 60°) significantly reduced the risk of clinically suspected ventilator-associated pneumonia [16]. In addition, gastroesophageal reflux tended to increase in the supine position compared to a semi-recumbent position, although this result was statistically nonsignificant [17]. It is still not clear whether the 60° position and 30° position differ regarding the risk of gastroesophageal reflux disease. Thus, the best position should be determined in consideration of all of these factors.

The limitations of this study are (1) the relatively small number of subjects, and (2) the lack of a comparison between age groups or gender. As autonomic functions may change with age [5], future experiments need to focus on age and gender differences.

In conclusion, lowering the head to 30° after a meal stimulated GI motility, as judged from the increase in GI sounds. This stimulation was probably from the relative preservation of vagal activity. Lowering the head also significantly improved subjective comfort. These results suggest that lowering the head to 30° after a meal is beneficial for patients' better digestion and lower risk of pressure ulcers.

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