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# Literature review of the effect of sole-ground contact while eating on the feeding-swallowing function

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## Summary

Feeding-swallowing movements are coordinated movements of the whole body accompanied by muscle contractions, and are affected by the positions of the head, neck, trunk, and lower limbs. However, the effect of sole-ground contact while eating on feeding-swallowing function has not been well examined. This study aimed to review studies on the association of sole-ground contact while eating with feeding-swallowing function. A literature review was conducted using two databases, PubMed and Ichushi-Web. The following keywords were used: ground on foot bottom OR foot bottom ground OR foot flat OR sole-ground contact AND swallowing OR tongue pressure OR mastication OR occlusion. The inclusion criteria were as follows: (a) written in English or Japanese in a peer-reviewed journal, (b) describing the effect of sole-ground contact while eating on the feeding-swallowing function, and (c) published from 1980 - 2022 August. Twenty-six articles were identified, and only four met the inclusion criteria. The results showed that the presence or absence of sole-ground contact while eating affected the swallowing function, occlusal force, and mastication. All articles were experimental studies, and none addressed nursing support for patients' sitting posture while eating. Nurses should pay more attention to support in adjusting the sitting posture, including sole-ground contact while eating, to prevent aspiration pneumonia in elderly patients. Future studies investigating the actual situation of support by nurses for sitting posture while eating in elderly patients are needed to promote nursing support to prevent aspiration while eating in medical facilities and nursing homes.

**Keywords:** feeding-swallowing function, posture, sole-ground contact

## Introduction

As the elderly population grows worldwide, prolongation of healthy life expectancy is gaining attention (1).

Pneumonia is a major cause of morbidity and mortality in the elderly, and the leading cause of death (2). Epidemiologic studies have showed that the incidence of

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pneumonia increases with age, with risks being almost six times higher in people  $\geq 75$  years old compared to those  $< 60$  years of age (3). Moreover, mortality rates associated with pneumonia increase greatly with age (4). Aspiration is an important etiologic factor leading to pneumonia in the elderly, and the increased incidence of pneumonia may be a consequence of impairments in swallowing and cough reflexes that come with aging (2). In Japan, pneumonia is the fifth leading cause of death (12) and those aged 65 years and older account for 96% of deaths (13), and 66.8% are due to aspiration with dysphagia (7). Aspiration pneumonia can be a grave illness despite treatment, so prevention is important (8). Posture adjustment is an effective compensatory intervention for dysphagia and plays a role in preventing aspiration pneumonia (9,10,11). For example, adjustment of the neck angle and trunk inclination affects the sense of difficulty in swallowing has been reported (12). The study reported that the sense of difficulty in swallowing was low at a trunk inclination of  $60^\circ$  and neck extension of  $20^\circ$ , and the sense of difficulty in swallowing was negatively correlated with the muscle activity of the mylohyoid and sternohyoid muscles. A study that reported the relationship between improper sitting posture, while eating and tongue pressure measured, reported that the adjustments of posture in bed and wheelchairs significantly increased tongue pressure in healthy adults and elderly individuals (14). Moreover, this study suggests the importance of posture adjustment, including that of the lower limbs, on swallowing function because the efficiency of the muscles involved in swallowing changes depending on the positioning of the neck, trunk, and lower

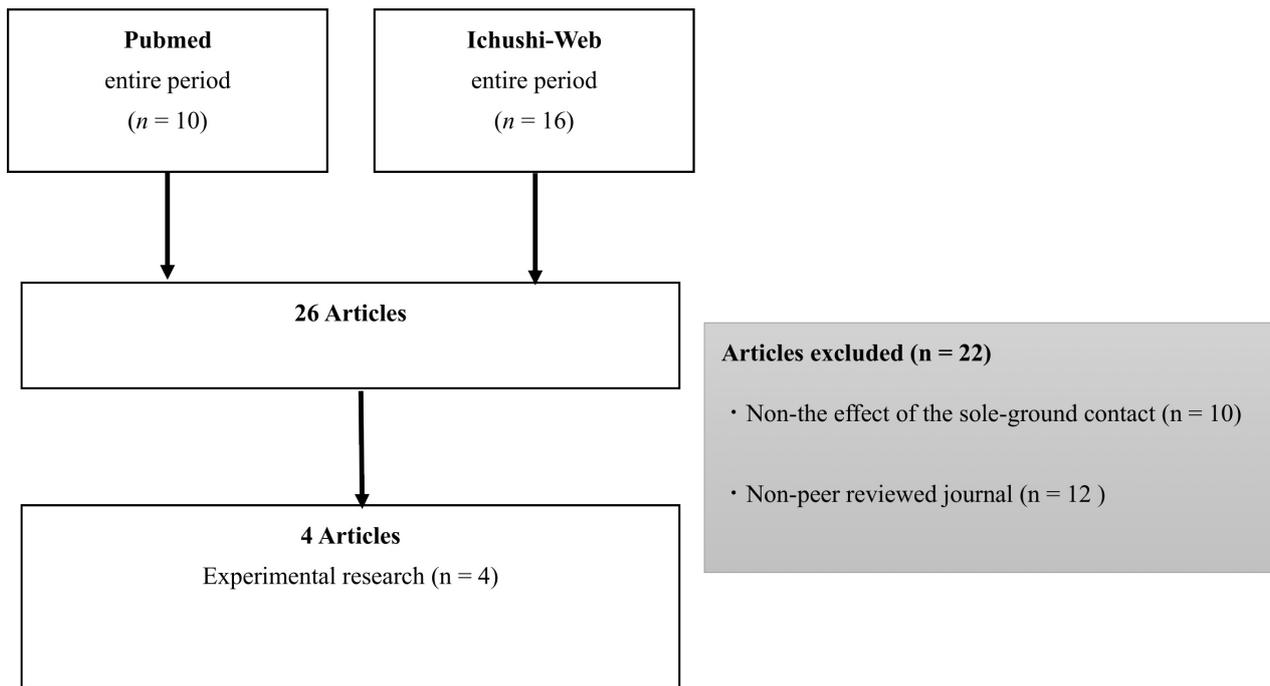
limbs. The importance of sole-ground contact has also recently attracted attention (15).

According to a search on Ichushi-web, studies using the term “sole-ground contact” began in the 1980s in Japan, and it has been shown to affect gait analysis, standing balance, stair climbing, and mental stress. Stimulation of the sole of the foot has been suggested to affect brain activity (16). Meanwhile, sole-ground contact may also be important in supporting dysphagia since the lower limbs are connected to the pelvic girdle, trunk, and neck through the musculoskeletal system.

In Japan, elderly patients hospitalized in medical facilities spend their daily lives sitting in wheelchairs when their activities of daily living are impaired due to the exacerbation of disease or muscle weakness, and these patients are forced to eat in a wheelchair. In these patients, the posture of the lower limbs is seldom adjusted, and the lower limbs remain on the footrest when eating while sitting in a wheelchair. Compared with patients who can sit in a regular chair and control their posture, those sitting in wheelchairs have difficulty maintaining the same posture while eating, and it becomes easy to maintain a poor posture in the wheelchair (14). Thus, it is necessary to provide nursing support so that these patients can maintain an appropriate posture while eating, including through sole-ground contact. This study aimed to review studies on the association of sole-ground contact while eating with the feeding-swallowing function and to obtain relevant findings.

### **Materials and methods**

A literature review was conducted using two databases, PubMed and



**Figure 1.** Search strategy

Ichushi-Web. The following keywords were used: ground on foot bottom, foot bottom ground, foot flat, sole-ground contact, swallowing, tongue pressure, mastication, and occlusion. The inclusion criteria were as follows: (a) written in English or Japanese in a peer-reviewed journal, (b) describing the effect of sole-ground contact while eating on the feeding-swallowing function, and (c) published from 1980 - 2022 August. Database searches were completed in August 2022.

The review was conducted from four perspectives in this study: "Participants," "Posture," "Methods and evaluation index," and "Evaluation." All analyses were performed using Microsoft Excel (Microsoft Japan, Tokyo, Japan).

## Results

The search strategy is illustrated in Fig. 1. Of the 26 articles initially identified, four met all the inclusion criteria. A summary of the literature regarding the effect of sole-ground contact while eating on the feeding-

swallowing function is presented in the Attachment section. All articles on the effect of sole-ground contact while eating on the feeding-swallowing function were experimental studies, and there was no nursing research. Although one study included elderly individuals (nursing home residents), participants in the other three studies were healthy adults. The evaluation indices were "The muscular activities of the suprahyoid muscle and the sternocleidomastoid muscle during swallowing," "masticatory efficiency and masticatory movement," "maximum occlusal force," and "measurement of occlusal contact area and masticatory ability."

Uesugi et al. (2019) used "the muscular activities of the suprahyoid (SH) and sternocleidomastoid (SCM) muscles" as an evaluation index (15). This study set three types of postures: sole off the floor, sole-ground contact with knees bent at either 90°, and sole-ground contact with knees bent at either 135°. They examined the effects of sole-ground contact on the activities of the

suprahyoid and sternocleidomastoid muscles during swallowing using four types of bolus materials: saliva, 5 ml water, 10 ml water, and 5 ml yogurt. As a result, the duration of SH during a 10 ml water swallow for soles off the floor was significantly longer than that for sole-ground contact with knees bent at 90°. The duration of SH during a 5 ml yogurt swallow for soles off the floor was significantly longer than that for sole-ground contact with knees bent at 90°.

Moreover, the integration of SH during a 10 ml water swallow for soles off the floor was significantly greater than that for sole-ground contact with knees bent at 135°. In addition, the integration of SH during a 5 ml yogurt swallow for soles off the floor was significantly greater than that for sole-ground contact with knees bent at 90°. This study showed that people who contact the sole on the ground could swallow more efficiently. As a future issue, it was considered that healthy participants had "autonomous adjustment mechanisms" to maintain a stable sitting posture while swallowing various bolus materials regardless of the sole-ground contact conditions. Thus, single sole-ground contact conditions might not have affected muscular activities. Future studies investigating the effect of different sole-ground contact positions on swallowing function in the elderly or subjects with dysphagia are needed to confirm the declining strength of the autonomic adjustment mechanism of deglutition.

Shinya et al. (2016) used "masticatory efficiency and movement" as an evaluation index (17). This study set two types of postures: soles off the floor and sitting in a vertical sitting position on a height-adjustable chair without a backrest so that approximately

one-half of the thigh is in contact and the same posture with sole-ground contact. In the two types of postures, the participants masticated gums as bolus materials for 60 s. As a result, the masticatory efficiency was higher with sole-ground contact than with the soles off the floor. However, no significant difference was observed between sole-ground contact and the soles off the floor. On the other hand, there was no significant difference in the duration of each phase of mastication between sole-ground contact and sole-off. In addition, there was no significant difference in the coefficient of variation of the mastication rhythm between the open-mouth, closed-mouth, and mastication cycles. During the stop phase, the masticatory movement was lower with sole-ground contact than with the soles off the floor. In other words, participants might be able to masticate rhythmically when it took time to crush the food because the posture was more stable in the sole-ground contact condition. Thus, the importance of sole-ground contact while eating was suggested. Meanwhile, the number of samples was small in this study; therefore, future studies with a larger sample size are needed.

Ishikawa et al. (2006) used "maximum occlusal force" as an evaluation index (18). This study set two types of postures, namely, trunk sitting position with the soles off the floor and sitting on the edge with sole-ground contact. The occlusal force was measured using a dental prescale. There was a significant difference between the edge sitting position and trunk sitting position for the maximum occlusal force in healthy adults and elderly individuals. These results suggest that sole-ground contact might be a desirable posture during eating. Future studies exploring

these factors are needed because the difference in maximum occlusal force between the interval sitting position and the edge sitting position in the elderly may be due to multiple factors.

Hamaguchi et al. (2016) used "measurement of occlusal contact area and masticatory ability" as an evaluation index (19). This study set four types of postures, namely, sole-ground contact while keeping the trunk vertical to the floor surface and a horizontal eye-ear plane, sole-ground contact while keeping the trunk tilted forward by about 45°, soles off the floor while keeping the trunk vertical to the floor surface, and soles off the floor while keeping the trunk tilted forward by about 45°. When measuring the occlusal contact area, the posture of the sole-ground contact while keeping the trunk vertical to the floor surface and a horizontal eye-ear plane was significantly larger than the other three postures. The time until swallowing and the number of times of mastication were significantly increased in sole-ground contact while keeping the trunk vertical to the floor surface and a horizontal eye-ear plane < sole-ground contact while keeping the trunk tilted forward about 45° < soles off the floor while keeping the trunk vertical to the floor surface < soles off the floor while keeping the trunk tilted forward about 45°. The results showed that poor posture might affect the occlusal contact area, the time until swallowing, and the number of mastication times. It is presumed that the occlusal contact area increases due to attrition caused by aging; however, since the study participants were younger adults, 20-32 years old. Therefore, future studies investigating elderly individuals are required.

## Discussion

In this study, we reviewed studies on the association of sole-ground contact while eating with feeding-swallowing function. Only four experimental and nursing studies were not found. Each of these studies used different evaluation indexes to evaluate the feeding-swallowing function, such as "The muscular activities of the suprahyoid muscle and the sternocleidomastoid muscle during swallowing," "masticatory efficiency and masticatory movement," "maximum occlusal force," and "measurement of occlusal contact area and masticatory ability." However, all the literature suggests the importance of sole-ground contact during eating.

Uesugi et al. (2019) examined the effects of sole-ground contact on the SH and SCM muscles' activities during swallowing using four bolus materials in three types of postures (15). The study reported that the sole-ground condition significantly impacted the duration and integration of SH activity and the peak and integration of SCM muscles. This result suggests that a stable sitting position with a firmly and evenly distributed sole-ground contact may promote effective swallowing while eating in patients with dysphagia. In other words, the effort required for swallowing could be reduced, and more effective swallowing could be achieved by firmly stabilizing the soles of the foot and grounding it on the ground.

Although mastication efficiency with sole-ground contact showed a larger value than with soles off the floor, there were no significant differences between sole-ground contact and soles off the floor (17). During the stop phase, the masticatory movement was lower with sole-ground contact than with the soles off the floor. It has been suggested that postural stability by sole-ground contact

affects the movement rhythm during mastication. The coefficient of variation of masticatory motion is significantly larger in patients with impaired masticatory function than in healthy subjects (20). Therefore, it is important to stabilize posture by sole-ground contact to stabilize the movement rhythm during mastication and support dysphagia.

Regarding maximum occlusal force, sitting on the edge with sole-ground contact was suggested as a desirable eating posture because there was a significant difference between the edge sitting position and trunk sitting position in healthy adults and elderly individuals (18). This study reported that when the sole is of the foot on the ground, the movement distance of the center of gravity is large, and the occlusal force is reduced. In people with unstable occlusion, the stability of the sitting position affects occlusal force and occlusal area (21). To counteract the forward tilt of the body axis, the temporalis and masseter muscles and the trapezius muscle in the posterior neck region changes the amount of muscle activity. Moreover, the head and neck muscles are used to maintain posture, and bite force is reduced (22). In other words, it is essential for people with unstable occlusions to maintain a stable sitting position. Therefore, trunk stability by sole-ground contact is important for maximizing masseter muscle activity.

In measuring the occlusal contact area, the posture of the sole-ground contact while keeping the trunk vertical to the floor surface and a horizontal eye-ear plane was reported to be significantly larger than the other three postures (19). In addition, the time until swallowing and the number of times of mastication

were significantly increased with changes in posture, and the number of times of mastication tended to be smaller in the sole-ground contact condition. Generally, swallowing occurs when the bolus hardness and crushing degree reach a certain standard, and there is a negative correlation between masticatory efficiency and the number of mastications until swallowing (23). This is because the time until swallowing and the number of times of mastication increased to compensate for the decrease in masticatory efficiency due to the change in posture. Thus, the sole-ground contact condition might affect the occlusal contact area, time until swallowing, and the number of mastication times.

Our results suggest that posture stability by sole-ground contact conditions while eating might affect the swallowing function, mastication, and occlusal force. Eating and swallowing are a series of processes that carry food from the oral cavity to the stomach by recognizing food, mastication, and swallowing. They have five stages: the preceding, preparatory, oral, pharyngeal, and esophageal stages (24). Many nerves and muscles and voluntary and reflex movements combine to produce a feeding-swallowing function. Since the muscles involved in swallowing are not limited to the head and neck, they are attached to the trunk, collarbone, sternum, and shoulder blade, such as the sternocleidomastoid muscle. Swallowing is susceptible to head and neck tension, posture, and gravity (25). In other words, to encourage smooth swallowing, it is essential to maintain a stable posture. Posture adjustment has been reported as a compensatory technique that improves dysphagia by changing the angle and position of the head and body, thereby

preventing aspiration pneumonia (14). The clinical benefits of adjusting postures are reported to be effective in 80-90% of patients with dysphagia (26). Moreover, stable sole-ground contact while eating is essential to promote antigravity activity and achieve safe swallowing (15). Before predation, there is a coordinated movement of the upper limbs and lips to catch food with the upper limbs and bring it close to the lips, and a movement to tilt the trunk forward also occurs. Swallowing is a series of movements that occurs after feeding. Because swallowing is performed smoothly, it is necessary to maintain a stable sitting position and have freedom in the head, neck, and upper limbs, as well as the coordinated movement of the whole body, including the trunk and lower limbs (25). Thus, if a person cannot maintain a sitting position on their own, they will try to maintain that position by compensating elsewhere in the body, often in the head and neck (27). Therefore, stabilizing posture by contacting the soles on the ground while eating is considered to help maintain the feeding-swallowing function and is important for supporting patients with dysphagia.

In Japan, elderly patients hospitalized in medical facilities are forced to eat in wheelchairs when their daily activities are impaired due to disease exacerbation or muscle weakness. However, it is difficult for these patients to maintain a stable posture because of declining physical strength. Postural stability affects swallowing function more in such patients than in patients who can use a normal chair. However, postural adjustment of the lower limbs is rarely performed because most nurses' awareness does not extend to the

postural adjustment of the lower limbs. Hence, the patients' lower limbs remain on the footrest when providing meal assistance. Both lower limbs are raised by the lower limbs on the footrest of the wheelchair. They do not contact the soles on the ground, causing the rectus abdominis, oblique abdominis, and transversus abdominis muscles to be activated, increasing intra-abdominal pressure (13). Increased intra-abdominal pressure increases gastric and esophageal pressures (28). During normal swallowing, esophageal pressure temporarily decreases during the glottal closure phase of pharyngeal swallowing (29). This decrease in esophageal pressure raises the pressure gradient between the increased pharyngeal pressure at the entrance of the esophagus and the driving force for transporting the bolus (30). Therefore, the increase in esophageal pressure is due to the pressure gradient, making it difficult to transport the bolus with normal swallowing pressure. More optional contractions of the swallowing muscles are required. In normal swallowing, smooth swallowing is possible with minimum necessary muscle contraction. However, adding excessive optional factors promotes fatigue and delays swallowing timing, thereby increasing the risk of aspiration. Therefore, it is necessary to select a stable sitting position that does not apply intra-abdominal pressure in consideration of the action of posture-maintaining muscles, such as anti-gravity muscles (13). Especially for patients in wheelchairs, it is necessary to adjust the posture so that the soles are firmly in contact with the ground and stabilized, instead of the condition that the soles on the footrest are not judged as sole-ground contact. This will lead to

support for safe food intake with a view to dysphagia and as a result, prevent aspiration pneumonia. Hence, nurses should adjust their posture so that the soles are firmly in contact with the ground and stabilized while eating for patients in wheelchairs, not on the footrest when assisting with meals in medical settings and nursing homes.

The studies reporting on association of sole-ground contact while eating with feeding-swallowing function extracted by this study were published after 2006. The long-term care insurance system in Japan was introduced in 2000, and the Japanese public long-term care prevention project was initiated in 2006 (31). There was a focus on frailty as a biological syndrome associated with a decline in physical status and activities, as well as increased vulnerability to adverse health outcomes (32). The need for strategies to prevent frailty forms the basis of a Japanese public long-term care prevention project. It has been suggested that the role of nutrition be considered in strategies for prevention of frailty (33). For this reason, the importance of "eating" support has attracted attention and the importance of building a support system for maintaining the feeding-swallowing functions of the elderly has been noted. Thus, efforts have been started to prevent functional deterioration of various muscles and organs associated with feeding-swallowing (34). This might have affected the publication dates of the extracted literature in this study, leading to them being published after 2006.

This study has some limitations. First, the review may have been limited by relying solely on published journal articles written in Japanese and English and the interpretations of the present study's authors. Second, only four papers

met all the inclusion criteria, and no study treated nursing support for patients' sitting posture while eating. Therefore, in considering nursing support for the adjustment of appropriate posture to prevent aspiration in medical facilities and nursing homes in Japan, it is necessary to collect and summarize the results of these studies. As the next step, future studies should investigate the actual situation of support by nurses for sitting posture while eating to elderly patients might be needed to promote nursing support for the prevention of aspiration while eating in medical facilities and nursing homes.

In conclusion, the present results may provide a basis for nurses to better understand nursing support for adjusting sitting posture, including sole-ground contact while eating; thus, effective strategic plans for promoting adjustment of the sitting posture, including sole-ground contact while eating, can be further considered.

### **Declarations**

The authors declare no potential conflicts of interest concerning the research, authorship, or publication of this article.

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## 食事中の足底接地が摂食嚥下機能に与える影響に関する文献検討

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### 要旨

誤嚥性肺炎の予防には、食事中の適切な姿勢保持が重要である。摂食嚥下運動は、筋収縮を伴う全身の協調運動であり、頭部・頸・体幹・下肢の位置により影響を受けるが、摂食嚥下機能に対する足底接地の影響は十分に検討されていない。本研究は、食事中の足底接地が摂食嚥下機能に与える影響についての研究を概観し、知見を得ることを目的とした。検索は、Pubmed、医中誌 Web の 2 つのデータベースを用いた。論文の選定基準としてタイトルと要約に、日本語では「足底接地」「嚥下」「舌圧」「咀嚼」「咬合」、英語では「sole-ground contact」「ground on foot bottom」「foot bottom ground」「foot flat」「swallowing」「tongue pressure」「mastication」「occlusion」の用語を含む、英語または日本語の査読付きのジャーナルへの掲載論文である、食事中の足底接地が摂食嚥下機能に与える影響に関する説明を含むこととし、検索期間を 1980 年から 2022 年 8 月とした。その結果、論文数は 26 件であり、そのうちすべての選定基準を満たした論文は 4 件であった。本結果より、食事中の足底接地の有無が、嚥下機能、咀嚼機能、咬合力に影響を与えることが示された。抽出した論文は、すべて実験研究であり、看護研究は見当たらなかった。以上より、高齢者の誤嚥予防には、食事中の足底接地を意識した姿勢調整が重要であることが示された。今後、誤嚥予防のための看護支援について検討するうえでは、高齢者への食事中の座位姿勢に対する看護師による支援の実態を調査することの必要性が示唆された。

キーワード：摂食嚥下機能、足底接地、姿勢