国際医療福祉大学審査学位論文（博士）

大学院医療福祉学研究科博士課程

題目：高齢者の３つの異なる排泄シミュレーション姿勢における呼吸機能と安楽性

（邦題：Respiratory function and comfort levels in three different defecatory simulation postures in the elderly）

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Compliance with Ethical Standards

This study was approved by the International University of Health and Welfare Ethics Review Board, and informed consent was obtained from all participants before the commencement of the study (approval number: 18-Ifh-025).

ABSTRACT

[Background]

Elderly people experience a heavy physical burden due to deteriorated respiratory function when they are kept sitting for a long time due to constipation. In recent years, to reduce the physical burden of defecation, arm-support handrails, which support the arms in a forward-leaning posture, have become more widely available; however, their impact on breathing comfort has not yet been verified. This study's purpose was to compare the respiratory function of elderly people in traditional defecation postures and the arm-supported, forward-leaning position using the handrail, and thus verify whether the supported position has a positive effect.

[Methods]

The trunk leaning angle, respiratory function, thoracic range of motion, and subjective comfort of 57 healthy elderly people were measured and compared in each of three sitting defecation postures: upright, forward-leaning, and arm-supported forward-leaning.

[Results]

The arm-supported, forward-leaning position involves a trunk leaning angle of 61.84° ± 7.47°, and vital capacity of the respiratory function, thoracic range of motion (axillary region), and subjective comfort in this position are all shown to be significantly higher than for the other postures.

[Conclusion]

The arm-supported, forward-leaning defecation posture provides a high degree of freedom in the abdomen due to proper forward-leaning, while the upper limb support improves the mobility of the upper thorax, thus ensuring high lung volume. In addition, the increased stability provides a comfortable feeling. Therefore, we conclude that the arm-supported, forward-leaning position is more effective for defecation than the general defecation position.

Keywords: Elderly, Defecation, Posture, Respiratory function, Arm-support, Forward-leaning

Study highlights

What is already known?

Previous studies have reoorted the arm-support forward-leaning position using a chair that had positive effects, such as improved respiratory function, reduced dyspnea, and decreased work required for breathing.

What is new in this study?

The new in this study is a comparison of the arm-support forward-leaning position using a toilet bowl and the conventional defecation posture from the viewpoint of respiratory function.

What are the future clinical and research implications of the study findings?

By adjusting the defecation posture based on the results, we can anticipate lower physical burden, leading to improved comfort for elderly people during activities of daily living.

INTRODUCTION

Elderly people are prone to constipation due to the decreased levels of physical activity and food intake associated with aging [1]. For this reason, many elderly people are forced to maintain a sitting position on the toilet for long periods of time. Many of the toilets produced in recent years have high seat surfaces, to improve stability when standing up, and do not incorporate a backrest. These design features make it difficult to sit on the toilet with a relaxed posture. Henry et al. [2] reported that "the oxygen consumption increased by several-fold in tense muscles than in relaxed muscles and [that] its amount in respiratory muscles increased to 30% of the oxygen uptake in all muscles at rest," indicating that maintaining a sitting position for a long time during defecation increases fatigue. Furthermore, the holes in toilet seats induce a posterior pelvic tilt, which may cause excessive kyphosis. Secker et al. [3] reported that kyphosis increases the respiratory workload and raised concerns that maintaining a prolonged sitting position may induce dyspnea and fatigue. Therefore, in addition to treatment for fundamental constipation, a comfortable defecation posture with low physical burden and improved respiration efficiency is required.

There are two types of sitting defecation postures typically adopted by humans: the upright position, with the hands placed on the thighs, and the forward-leaning position, with both the forearms and the elbows placed on the thighs [4]. It is known that the anorectal angle decreases and the level of excretion increases in the forward-leaning sitting position [5], and many elderly people adopt this posture. However, the forward-leaning position typically also entails anterior protrusion of the head, with the ribs pulled downward and the rib cage sunken, so it is not considered an ideal position [6].

In recent years, in an attempt to reduce the physical burden of defecation, both fully installed and portable varieties of arm-support handrails that enable the arm-supported, forward-leaning position have become more widely available. This position has positive effects, such as improved respiratory function [7], reduced dyspnea [8], and decreased work required for breathing [9]. However, previous studies have reported the effects of this position when sitting in a chair, rather than when using a toilet bowl.

This study's purpose was to compare the respiratory function of elderly people in traditional defecation

postures (upright and forward-leaning positions) and in the arm-supported, forward-leaning position using the arm-support handrail, and thus to verify whether the latter posture has a positive effect. The findings provide evidence that may be useful when adjusting the defecation environment, such as movement guidance and advice regarding the use of a front supporting handrail or a forward-tilt-posture-assisting handrail. The results indicate that we can anticipate lower physical burden, leading to improved comfort for elderly people during activities of daily living.

METHODS

The subjects were 57 community-living elderly individuals (13 males and 44 females; age range 74.30 ± 5.34 years; height range 154.58 ± 7.34 cm; weight range 55.01 ± 9.51 kg; thoracic kyphosis index [10, 11] 7.23 ± 2.48). Those needing care for their daily activities or with serious respiratory or motor disorders that affect defecation posture were excluded.

Measurements for each of the three sitting defecation postures (the upright, forward-leaning, and arm-supported forward-leaning positions) were compared and examined. The upright position involved placing the hands on the thighs; the forward-leaning position entailed a forward tilt, with both the forearms and the elbows resting on the thighs; and the arm-supported forward-leaning position consisted of a forward tilt, with the elbows resting on top of the posture-assisting handrail (Rakusukesan SRC, Idea Life Care, Nagano, Japan). In all postures, the participants' legs were positioned shoulder-width apart, with the soles of the feet flat on the floor. A portable toilet with a 40-cm seat height (Zaraku, SEKISUI, Tokyo, Japan) was used in the study. Both respiratory function and subjective comfort levels were determined.

The factors measured were the trunk leaning angle, respiratory function, thoracic range of motion, and comfort. For the trunk leaning angle, the angle formed between the trunk and the thigh was measured using a goniometer. Respiratory function measurements, consisting of vital capacity (VC), tidal volume, expiratory residual volume (ERV), inspiratory residual volume, inspiratory capacity, forced vital capacity (FVC), forced expiratory volume in 1s (FEV1), forced expiratory volume % in 1s (FEV1%), and peak expiratory flow, were taken using a

spirometer (Multi-functional Spirometer HI-801, Chest, Tokyo, Japan). A nose clip was used during the spirometry measurements. A front–back- and left–right-adjustable fixing device was used to take the spirometry measurements without the participant holding the spirometer (Fig.1). After sufficient practice, following the guidelines by the American Thoracic Society and the European Respiratory Society [12, 13], measurements were taken three times in each posture. The maximum value obtained was used for the analyses. Before each measurement, the instrument was calibrated, and its precision was verified. Consistent instruction timings and methods were used during the measurement process. Each participant was asked to remove or loosen their belts and undergarments to avoid abdominal area compression before measurement. The order of posture was block randomized. Participants were given at least a 3-min break before each measurement to minimize the effects on the measurements taken in the latter half of the posturing.

For the thoracic range of motion, the difference in the thoracic cavity circumference (axillary region, xiphoid region, and ten-rib region) between the maximum expiration and the maximum inspiration in each position was measured using a thoracic range of motion measurement device (Takei, Niigata, Japan) [14, 15]. Subjective comfort was determined by ranking and using a numerical rating scale (NRS), which quantified the level of breathing comfort on an 11-point scale (0–10) [16].

SPSS Statistics version 26.0 (International Business Machines Corp., Armonk, NY, USA) was used for statistical analyses. Trunk leaning angle measurements and NRS scores were compared using the Friedman test, and respiratory function and thoracic range of motion were compared using one-way repeated measures analysis of variance with sex, height, and weight as covariates. Multiple comparisons were performed, by the Bonferroni method, when there was a significant main effect. An $\chi 2$ test was used to compare subjective comfort rankings among the postures. A p value of <0.05 was considered statistically significant.

RESULTS

The trunk leaning angles in each posture were as follows, in ascending order: forward-leaning position, 54.74 ± 8.04°; arm-support forward-leaning position, 61.84 ± 7.47°; and upright position, 88.42 ± 3.01°. These results

indicate significant differences between the postures ($p < 0.01$). Table 1 shows the respiratory function in each posture. VC showed significantly higher values in the arm-supported, forward-leaning position than in the upright and forward-leaning positions ($p < 0.01$). ERV ($p < 0.05$) and FVC ($p < 0.01$) showed significantly higher values in the arm-supported, forward-leaning position than in the forward-leaning position. FEV1 showed significantly lower values in the forward-leaning position than in the upright position ($p < 0.05$) and arm-supported, forward-leaning position ($p < 0.01$). With regard to thoracic range of motion, the axillary region showed the highest value in the arm-supported, forward-leaning position, and the highest values for the xiphoid region and the ten-rib region were observed in the forward-leaning position (Table 2).

Based on the subjective comfort ranking, the arm-supported forward-leaning position was the most comfortable posture ($n = 32$), followed by the upright position ($n = 18$) and the forward-leaning position ($n = 7$). The residual analysis showed significant differences in the number of responses, with the highest number in the arm-supported, forward-leaning position, followed by the upright and then the forward-leaning position ($p < 0.01$). Moreover, the NRS score (Table 3) for the arm-supported forward-leaning position was significantly greater than that for the upright and forward-leaning positions ($p < 0.01$).

DISCUSSION

This study's purpose was to examine the usefulness of the arm-supported, forward-leaning position as a defecation posture. The findings indicate that the arm-supported, forward-leaning position resulted in significantly higher respiratory function and comfort than the other defecation postures. This result can be attributed to a number of factors.

The first factor is the trunk leaning angle. An appropriate trunk leaning angle can be expected to increase abdominal pressure and assist in expiration [17]. It also allows the anterior thorax to expand, due to gravitational effects [18], improving lung volume, and reducing inspiratory effort. On the other hand, an excessive trunk leaning angle increases abdominal pressure further, which can lead to restriction of diaphragm movement [19, 20]. This suggests that, in this study, the trunk forward-leaning angle was moderate in the arm-

supported forward-leaning position, while that in the forward-leaning position was excessive. It is further considered that, in the upright position, the movement of the abdomen became free, without restriction of respiration movement, because it was not accompanied by trunk forward inclination [21].

The second factor is the upper limb's bearing capacity. Upper limb support removes the weight of the upper limbs and shoulder girdle from the thorax [17] and improves thorax mobility. It is also expected to reduce the upper trunk muscles' contribution to postural maintenance, thus reducing the workload on those muscles [19, 20]. On the other hand, in the upper limb support posture, the shoulder girdle is fixed and inspiratory muscle function decreases [22]. In the current study, the upright position did not support the upper limbs. Therefore, the freedom of the accessory respiratory muscles may have been high due to the lack of fixation of the shoulder girdle, even though the weight of the upper limbs fell on the thorax. In contrast, the forward-leaning and arm-supported, forward-leaning positions both supported the upper limb. Of these, it is estimated that the weight of the upper limbs and shoulder girdle decreased significantly in the arm-supported, forward-leaning position due to a wider support-base surface and the support capacity improvement provided by the posture-assisting handrail.

The third factor involves the shape of the toilet bowl and the posture peculiar to the elderly. Toilets have a hole in the middle of the seat, unlike normal chairs, and the buttocks are in a sinking posture. As a result, the pelvis leans backward and the spine curves. Moreover, those who sit for long periods often assume a slumped posture, increasing thoracic kyphosis. Posterior kyphosis may limit the freedom of the spine, impair the thoracic extension, and affect the shape of the diaphragm in functional residual capacity, which may adversely affect respiratory function [3, 23]. In addition, in the forward-leaning position, kyphosis becomes more pronounced due to the hips leaning forward from the sunken position. In many individuals, kyphosis increases with aging. Therefore, in this study, the respiratory function may have declined as a result of sitting on the toilet, and the forward-leaning posture compounded this issue. On the other hand, in the arm-supported forward-leaning position, the use of the posture-assisting handrail increased the bearing capacity and decreased kyphosis.

Among the three factors above, the bearing capacity of the upper limb was most likely the cause of the arm-supported, forward-leaning position receiving a higher subjective comfort rating than the other postures. The increased bearing capacity may have reduced the workload of the respiratory and postural muscles around the scapular girdle, as well as improving physical stability and reducing psychological burden. However, this study has not provided a fully verified explanation regarding why the arm-supported, forward-leaning position was rated the most comfortable, so this is an issue for future research. In addition, in this study, the “comfort of maintaining the defecation posture” for all elderly people was verified, but the “ease of defecation” was not verified. Because factors such as anorectal angle and straining are involved in actual defecation, it is necessary to have elderly people with constipation actually defecate and verify the “ease of defecation” in the future.

In conclusion, our results indicate that adding support to the upper limb relieved some of the load on the body and increased stability. As a result, upper thorax mobility was enhanced, and the lung volume centered on exhalation was secured. The arm-supported, forward-leaning position can be said to be a more effective posture during defecation because it provides superior comfort, compared with general defecation postures, due to stability, and a higher degree of freedom of breathing.

There is scope for further development of this research since the height of the toilet bowl and seat were uniform throughout this study. In addition, future work should take into account that there are individual differences in physical burden and in the anterior tilt angle for each posture due to variation in body structure. In addition, we will further investigate the "ease of defecation" when elderly people with constipation actually defecate.

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TABLES

Table 1. Respiratory function in the three defecation postures. VC vital capacity, TV tidal volume, ERC expiratory residual volume, IRV inspiratory residual volume, IC inspiratory capacity, FVC forced vital capacity, FEV I forced expiratory volume in 1 s, FEV 1% forced expiratory volume % in 1 s, PEF (l/s)

	Upright position	Forward-leaning position	Arm-supported forward-leaning position
VC (L)	2.61 ± 0.59	2.56 ± 0.52	2.67 ± 0.58**††
TV (L)	0.62 ± 0.26	0.65 ± 0.32	0.65 ± 0.25
ERV (L)	0.84 ± 0.35	0.75 ± 0.38	0.86 ± 0.34†
IRV (L)	1.50 ± 0.48	1.45 ± 0.43	1.48 ± 0.45
IC (L)	2.01 ± 0.58	1.98 ± 0.48	2.03 ± 0.51
FVC (L)	2.20 ± 0.54	2.14 ± 0.47	2.25 ± 0.50††
FEV1 (L)	1.93 ± 0.45	1.87 ± 0.39*	1.95 ± 0.41††
FEV1% (%)	90.80 ± 6.34	90.48 ± 6.51	89.81 ± 7.48
PEF (L/s)	5.40 ± 1.77	5.21 ± 1.69	5.36 ± 1.80

Values are mean ± standard deviation. Multiple comparisons (Bonferroni)

Covariates: gender, height, body weight

* $p < 0.05$ vs. upright position

** $p < 0.01$ vs. upright position

† $p < 0.05$ vs. forward-leaning position

†† $p < 0.01$ vs. forward-leaning position.

Table 2. Thoracic range of motion in the three defecation postures

	Upright position	Forward-leaning position	Arm-supported forward-leaning position
Axillary region (cm)	1.14 ± 0.47	1.28 ± 0.65	1.64 ± 0.95**††
Xiphoid region (cm)	1.38 ± 0.83	1.84 ± 0.86**	1.72 ± 0.89**
10 rib region (cm)	1.57 ± 1.26	2.25 ± 1.35**	1.77 ± 1.43††

Values are mean ± standard deviation. Multiple comparisons (Bonferroni)

Covariates: gender, height, body weight

** $p < 0.01$ vs. upright position

†† $p < 0.01$ vs. forward-leaning position.

Table 3. Numerical rating scale for the three excretion postures. NRS numerical rating scale

	Upright position	Forward-leaning position	Arm-supported forward-leaning position
NRS‡	6.37 ± 2.28	5.47 ± 1.87	7.49 ± 1.84 *††

Values are mean ± standard deviation. Multiple comparisons (Bonferroni)

‡ 11 points (0–10). A higher score indicates a higher sense of comfort.

* $p < 0.05$ vs. upright position

†† $p < 0.01$ vs. forward-leaning position.

FIGURE CAPTION

Fig. 1 Three defecation postures. a Upright position. b Forward-leaning position. c Arm-supported forward-leaning position. The red lines in each image show the trunk leaning angles