



Original Article

## Comparison of two instructions for deep breathing exercise: non-specific and diaphragmatic breathing

MASAMI YOKOGAWA, RPT<sup>1</sup>\*, TOMOYO KUREBAYASHI, RPT<sup>2</sup>, TOSHIKAZU ICHIMURA, RPT<sup>3</sup>,  
MANABU NISHINO, RPT<sup>4</sup>, HIROICHI MIAKI, RPT<sup>1</sup>, TAKAO NAKAGAWA, MD<sup>1</sup>

<sup>1</sup>) Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University: 11-80, Kodatsuno 5, Kanazawa, Ishikawa, 920-0942, Japan

<sup>2</sup>) Department of Rehabilitation, Saiseikai Kyoto Hospital, Japan

<sup>3</sup>) Department of Rehabilitation, Niigata Prefectural Myoko Hospital, Japan

<sup>4</sup>) Department of Rehabilitation, Ishikawa Prefectural Central Hospital, Japan

**Abstract.** [Purpose] Breathing exercises are frequently prescribed to reduce pulmonary complications after abdominal and thoracic surgery. Appropriate instructions ensuring the integrity of the self-exercise are important. This study compared the effects of two instructions, focusing on non-specific breathing (NB) and diaphragmatic breathing (DB) patterns, respectively, on the ventilatory efficiency and work of breathing. [Subjects and Methods] The participants were healthy men (n=15) and women (n=15). Ventilatory parameters, heart rate, and autonomic nervous system activity were measured during natural and deep breathing phases performed under the two instructions (NB and DB), with the deep breathing phase following the natural breathing phase. [Results] For both men and women, ventilatory efficiency was increased during deep breathing relative to natural breathing, regardless of the instructions. In women, the increment in ventilatory efficiency during deep breathing was greater under NB compared to that under DB. The work of breathing decreased during deep breathing in women under both instructions, but did not change in men under DB. [Conclusion] Under NB instruction, deep breathing elicits similar or greater effects on ventilatory efficiency compared to that under DB instruction.

**Key words:** Breathing exercise, Instruction method, Ventilatory efficiency

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### INTRODUCTION

Preoperative respiratory physical therapy, which consists of teaching patients breathing, coughing, and airway clearance exercises, is routinely prescribed to prevent pulmonary complications after abdominal and thoracic surgery<sup>1, 2</sup>. Moreover, Algar et al.<sup>3</sup> reported that the non-provision of preoperative respiratory physical therapy is an independent risk factor for postoperative pulmonary complications.

Breathing exercises in respiratory physical therapy are effective in postoperatively improving lung expansion, and include breathing control<sup>4</sup>, deep breathing<sup>5</sup>, and diaphragmatic breathing<sup>6</sup>. Among the deep breathing techniques, diaphragmatic breathing has been shown to reduce the work of breathing and improve ventilation efficiency<sup>7</sup>. The abdomen in diaphragmatic breathing rises during inspiration and returns during expiration<sup>6, 8</sup>, while the upper chest remains relatively motion-free<sup>6</sup>. During diaphragmatic breathing exercises, the clients are usually instructed to put their own hands on the abdomen and upper chest to confirm visually and/or tactilely that their movement is appropriate. Thus, during breathing exercises, the client's position and tactile, auditory, and visual cues are considered important strategies in obtaining diaphragmatic breathing<sup>7</sup>.

Generally, preoperative breathing exercises are performed as self-exercise, after receiving instructions. Appropriate

\*Corresponding author. Masami Yokogawa (E-mail: yokogawa@mhs.mp.kanazawa-u.ac.jp)

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instructions ensuring the integrity of the self-exercise are important to prevent pulmonary complications after abdominal and thoracic surgery. However, no fixed or unified instructions exist. The effectiveness of different instructional methods to facilitate diaphragmatic breathing has been evaluated<sup>9)</sup>, including the use of inhibitory techniques to promote relaxation of the accessory muscles and reduce the work of breathing in patients with primary pulmonary diseases. The use of the accessory muscles may assist in increasing ventilatory capacity in specific clinical situations, such as spinal cord injuries or other neuromuscular disorders<sup>9)</sup>. Moreover, Brannon recommended that when diaphragmatic breathing instruction is unsuccessful, the use of a patient's natural breathing pattern may be a more efficient method<sup>8)</sup>. In our experience, an upper costal breathing pattern dominates among patients (especially elderly women) who have difficulty performing diaphragmatic breathing. We may propose that for these patients, integrating deep breathing within their non-specific breathing pattern would better enable postoperative deep breathing exercises. As preliminary to studies involving patients, the purpose of this study was to compare two instructions for deep breathing exercise, focusing on non-specific and diaphragmatic breathing patterns, respectively, in healthy young adults.

## SUBJECTS AND METHODS

Fifteen men (age,  $22.0 \pm 0.6$  years; body mass,  $64.0 \pm 6.2$  kg; height,  $170.1 \pm 3.5$  cm; body mass index,  $21.9 \pm 2.2$  kg/m<sup>2</sup>) and 15 women (age,  $21.6 \pm 0.5$  years; body mass,  $51.9 \pm 3.4$  kg; height,  $159.3 \pm 5.1$  cm; body mass index,  $20.5 \pm 1.3$  kg/m<sup>2</sup>) participated. Participants were asked to refrain from food intake for two hours prior to measurements. The study procedure was explained to all participants and informed consent was obtained. The present study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Participants performed a deep breathing exercise under two instructions: one using a non-specific breathing (NB) pattern and one involving diaphragmatic breathing (DB). For NB, participants were instructed to take "slow and deep breaths, inhaling through the nose and exhaling through the mouth". For DB, participants were asked to "place their hand on their abdomen and expand their abdomen to lift their hand during inhalation". Prior to obtaining measurements, participants were asked to change into a tight-fitting shirt. The participants were then seated comfortably on a chair with back support; they received an explanation of the measurement procedures, and the correct performance of the deep breathing methods was confirmed. Electrocardiogram (ECG) leads were placed using standard procedures, and a sampling mask for the measurement of expired gases was fitted over the nose and mouth.

All measurements started with a natural breathing phase (5 min), followed by the deep breathing phase (5 min; NB or DB) and another 5-min period of natural breathing. All participants performed NB first, followed by a 10-min rest period prior to the start of DB; this design was used to avoid possible learning effects from DB on the NB deep breathing pattern. Following the completion of the deep breathing maneuvers, participants were asked to identify (orally) which of the two deep breathing techniques they found to be more comfortable.

Thoracoabdominal movement was recorded in the sagittal plane using a video camera (DCR-SR100, Sony Co., Ltd., Tokyo, Japan), and was used to classify breathing patterns as upper costal, diaphragmatic, or mixed. The breath-by-breath expired gas was sampled using a respiratory metabolism-measuring device (AE-300S, Minato Medical Science Co., Ltd., Osaka, Japan). The following ventilatory parameters were measured: oxygen uptake ( $V_{O_2}$ ), carbon dioxide output ( $V_{CO_2}$ ), expired minute ventilation ( $V_E$ ), respiratory rate ( $f$ ), tidal volume ( $V_T$ ), expiratory time ( $T_e$ ), and inspiratory time ( $T_i$ ). Heart rate was measured using a medical telemetry sensor (BSM-2401, Nihon Kohden Co., Ltd., Tokyo, Japan). ECG spectral power within high-frequency (HF: 0.15–0.4 Hz) and low-frequency bands (LF: 0.04–0.15 Hz) was calculated using heart rate variability analysis software (MemCalc, Suwa Trust Co., Ltd., Tokyo, Japan) and previously reported techniques<sup>10, 11)</sup>. The HF band reflects the effects of the respiratory cycle and depth of respiration on heart rate, while the LF band reflects vagal and sympathomimetic adjustments<sup>12, 13)</sup>. The LF/HF ratio is generally considered to represent the sympathetic-vagal balance, reflecting the relative sympathetic contribution to heart rate control<sup>12, 14)</sup>. Thus, the LF/HF ratio was used as an index of sympathetic nervous system activity. During deep breathing maneuvers, the respiratory rate sometimes decreased to  $\leq 9$  times per min. In these cases, we added the power level at this breathing frequency to the HF component of the parasympathetic respiratory sinus arrhythmia frequency (RSAF) and then calculated the LF/HF ratio.

Primary outcomes were ventilatory efficiency, work of breathing, heart rate and autonomic nervous system activity. Under both instructions, ventilatory parameters, heart rate, and LF/HF values were averaged within the natural breathing and deep breathing periods. Values are presented as mean  $\pm$  standard deviation. Instruction-related differences were evaluated using two-way repeated-measures analyses of variance (ANOVAs) within each gender. Significant interactions were further analyzed using the Bonferroni method. Statistical analyses were performed using SPSS version 23.0 (IBM SPSS Inc., Cary, NC, USA). A  $p$ -value  $< 0.05$  was regarded as significant.

## RESULTS

The participants' deep breathing patterns during the two instructions are reported in [Table 1](#). During NB, both men and women used an upper costal or mixed breathing pattern. During DB, with the exception of one man and one woman, participants used either a mixed or diaphragmatic breathing pattern. Ten men and thirteen women stated that NB was more

comfortable to execute than DB (Table 1).

The ventilatory parameters, heart rate, and LF/HF for both the natural and deep breathing phases within each instruction condition are shown in Tables 2 and 3. In both genders, significant main effects of phase (natural versus deep breathing) were observed for all parameters except VE and heart rate (Tables 2 and 3). In contrast, the parameters demonstrating a significant interaction differed between men and women. For men, only  $Vo_2$  demonstrated a significant instruction  $\times$  phase interaction ( $p < 0.01$ ), with a significant effect of phase ( $p < 0.05$ , Table 2). In men, the  $Vo_2$  was significantly higher during NB compared to that during DB in the natural breathing phase, but not during the deep breathing phase (Table 2). For women, f,  $V_T$ , and

**Table 1.** Deep breathing pattern classification and participants' assessment of the effectiveness of two kinds of breathing instructions

Instruction	Men				Women			
	Upper costal	Mixed	Diaphragmatic	Easier breathing	Upper costal	Mixed	Diaphragmatic	Easier breathing
Non-specific	8	7	0	10	7	6	2	13
Diaphragmatic	1	7	7	5	1	8	6	2

Participants' breathing patterns during deep breathing were classified as upper costal, diaphragmatic, or mixed. Following the completion of the deep breathing maneuvers, participants identified which of the two deep breathing techniques they found to be more comfortable.

**Table 2.** Comparison of the two instructions for deep breathing in men

	NB		DB		2-way ANOVAs
	Natural	Deep breathing	Natural	Deep breathing	Significant effects
$Vo_2$ (ml/min)	297 $\pm$ 30	269 $\pm$ 23*	272 $\pm$ 35 <sup>‡</sup>	278 $\pm$ 35	Phase <sup>‡</sup> ; Interaction <sup>††</sup>
$Vco_2$ (ml/min)	250 $\pm$ 44	298 $\pm$ 62	211 $\pm$ 44	313 $\pm$ 68	Phase <sup>††</sup>
VE (l/min)	9.3 $\pm$ 1.5	9.5 $\pm$ 3.2	8.2 $\pm$ 1.6	10.3 $\pm$ 3.4	
VE/ $Vco_2$	37.9 $\pm$ 4.2	32.4 $\pm$ 4.6	39.9 $\pm$ 5.6	33.2 $\pm$ 5.2	Phase <sup>††</sup>
f (/min)	15.2 $\pm$ 2.6	6.7 $\pm$ 1.9	14.9 $\pm$ 3.4	7.1 $\pm$ 1.7	Phase <sup>††</sup>
$V_T$ (/ml)	633 $\pm$ 116	1545 $\pm$ 421	576 $\pm$ 117	1607 $\pm$ 461	Phase <sup>††</sup>
Te (s)	2.44 $\pm$ 0.50	5.57 $\pm$ 1.94	2.53 $\pm$ 0.71	5.09 $\pm$ 1.63	Phase <sup>††</sup>
Ti (s)	1.75 $\pm$ 0.42	4.69 $\pm$ 1.25	1.88 $\pm$ 0.71	4.89 $\pm$ 1.66	Phase <sup>††</sup>
HR (bpm)	69.1 $\pm$ 8.6	70.1 $\pm$ 7.8	69.2 $\pm$ 8.5	70.6 $\pm$ 8.7	
LF/HF	1.20 $\pm$ 0.77	0.26 $\pm$ 0.16	1.75 $\pm$ 1.32	0.29 $\pm$ 0.14	Phase <sup>††</sup>

NB: Non-specific breathing pattern; DB: Diaphragmatic breathing pattern;  $Vo_2$ : oxygen uptake;  $Vco_2$ : carbon dioxide output; VE: minute ventilation; f: respiratory rate;  $V_T$ : tidal volume; Te: expiratory time; Ti: inspiratory time; HR: heart rate; LF/HF: Low Frequency/High Frequency ratio; <sup>†</sup> $p < 0.05$ ; <sup>††</sup> $p < 0.01$ ; \* $p < 0.05$  (Natural vs. Deep breathing during NB); <sup>‡</sup> $p < 0.05$  (NB vs. DB during Natural breathing).

**Table 3.** Comparison of the two instructions for deep breathing in women

	NB		DB		2-way ANOVAs
	Natural	Deep breathing	Natural	Deep breathing	Significant effects
$Vo_2$ (ml/min)	199 $\pm$ 20	191 $\pm$ 13	204 $\pm$ 23	189 $\pm$ 14	Phase <sup>††</sup>
$Vco_2$ (ml/min)	170 $\pm$ 27	231 $\pm$ 66	160 $\pm$ 24	212 $\pm$ 68	Phase <sup>††</sup>
VE (l/min)	6.8 $\pm$ 1.1	7.7 $\pm$ 3.6	6.3 $\pm$ 1.1	7.7 $\pm$ 3.9	
VE/ $Vco_2$	40.1 $\pm$ 5.2	32.2 $\pm$ 6.4	39.5 $\pm$ 4.0	35.1 $\pm$ 7.9	Phase <sup>††</sup>
f (/min)	14.4 $\pm$ 3.0	5.4 $\pm$ 2.3*	13.6 $\pm$ 2.3	7.8 $\pm$ 3.6** <sup>§</sup>	Phase <sup>††</sup> ; Interaction <sup>†</sup>
$V_T$ (/ml)	483 $\pm$ 76	1507 $\pm$ 579*	464 $\pm$ 61	1057 $\pm$ 509** <sup>§</sup>	Instruction <sup>†</sup> ; Phase <sup>††</sup> ; Interaction <sup>†</sup>
Te (s)	2.79 $\pm$ 0.92	8.37 $\pm$ 4.00*	2.82 $\pm$ 0.53	5.25 $\pm$ 2.31** <sup>§</sup>	Instruction <sup>†</sup> ; Phase <sup>††</sup> ; Interaction <sup>†</sup>
Ti (s)	1.63 $\pm$ 0.43	4.51 $\pm$ 1.70	1.69 $\pm$ 0.33	3.67 $\pm$ 1.08	Phase <sup>††</sup>
HR (bpm)	69.1 $\pm$ 7.6	71.7 $\pm$ 8.9	68.5 $\pm$ 7.6	70.1 $\pm$ 8.5	
LF/HF	0.57 $\pm$ 0.43	0.35 $\pm$ 0.78	0.71 $\pm$ 0.48	0.23 $\pm$ 0.16	Phase <sup>†</sup>

NB: Non-specific breathing pattern; DB: Diaphragmatic breathing pattern;  $Vo_2$ : oxygen uptake;  $Vco_2$ : carbon dioxide output; VE: minute ventilation; f: respiratory rate;  $V_T$ : tidal volume; Te: expiratory time; Ti: inspiratory time; HR: heart rate; LF/HF: Low Frequency/High Frequency ratio; <sup>†</sup> $p < 0.05$ ; <sup>††</sup> $p < 0.01$ ; \* $p < 0.05$  (Natural vs. Deep breathing during NB); \*\* $p < 0.05$  (Natural vs. Deep breathing during DB); <sup>§</sup> $p < 0.05$  (NB vs. DB during Deep breathing).

Te demonstrated significant interactions ( $p$ 's<0.05, Table 3), with a significant effect of phase ( $p$ 's<0.01) for  $f$ ,  $V_T$ , and Te, and a significant effect of instruction for  $V_T$ , and Te ( $p$ <0.05, Table 3). In women,  $f$  was significantly lower during the deep breathing phase compared to that during natural breathing for both instructions, and was decreased to a greater extent during the deep breathing phase of NB compared to that in DB (Table 3). In addition,  $V_T$  and Te were significantly greater during the deep breathing phase compared to that during natural breathing for both instructions, but to a greater extent in NB compared to that in DB (Table 3).

## DISCUSSION

In the present study, we compared the effectiveness of two instructions for a deep breathing exercise in terms of ventilatory and autonomic-related parameters in healthy young adults. Our results suggest that emphasizing diaphragmatic movement is not necessary when instructing clients on deep breathing exercises; deep breathing can be improved by simply instructing individuals to breathe “slowly and deeply”, using their non-specific breathing pattern. We confirmed from the participants' breathing patterns that the participants had adequately performed the deep breathing exercises, following the provided instructions. Although half of the participants used mixed and upper costal patterns during NB, most of the parameters presented a similar response during the deep breathing phase for both instructions. Ventilatory efficiency was not disadvantaged during NB compared to that during DB. In addition, NB was subjectively more comfortable than DB, especially for women.

The present study also confirms that the HR response is not influenced by the instruction given for the breathing exercise. In contrast, the LF/HF ratio, which is an index of sympathetic nervous activity<sup>12, 14</sup>), was decreased during deep breathing compared to that during natural breathing, under both instructions and for both men and women. Therefore, deep breathing appears to have the additional benefit of inducing relaxation, as well as increasing ventilatory efficiency.

Previous studies have reported that diaphragmatic breathing reduces breathing effort, improves ventilatory efficiency, reduces dyspnea, and improves exercise tolerance<sup>7</sup>). In the present study, we only evaluated the effects of breathing exercise on the work of breathing and ventilatory efficiency. A reduction in the work of breathing is reflected by a decrease in oxygen consumption ( $V_{O_2}$ ). For men, the work of breathing was reduced by deep breathing during NB but not during DB, while women exhibited a decrease in  $V_{O_2}$  with deep breathing, regardless of instruction.

Improvement in ventilatory efficiency is reflected as an increase in  $V_T$  and a decrease in respiratory rate or  $VE$ <sup>7</sup>). In men, demonstrated an overall improvement in ventilatory efficiency with deep breathing, with increased  $V_T$  and decreased respiratory rate compared to that with natural breathing, regardless of instruction. For women, the improvement in ventilatory efficiency with deep breathing was superior during NB compared to that during DB. Generally, the relationship between  $VE$  and alveolar ventilation ( $VA$ ) is represented by a formula:  $VE = V_T \times f$  and  $VA = (V_T - \text{anatomic dead space}) \times f$ . Assuming that  $VE$  is a constant value, a decrease in respiratory rate and an increase in  $V_T$  would be indicative of an improvement in  $VA$ . As we did not identify a significant interaction or significant main effect in men or women, the  $VE$  for the two instructions appears to be equal. In women, the respiratory rate was lower during NB compared to that during DB, combined with an increase in  $V_T$ . Therefore,  $VA$  may have contributed to increased ventilatory efficiency in women during deep breathing during NB.

We found it interesting that some parameters presented with gender differences, as we have observed that diaphragmatic breathing is particularly difficult for elderly women. Previous studies on natural breathing are divided in terms of the influence of gender. Although some studies have failed to identify gender differences in thoracoabdominal motion<sup>15, 16</sup>), other studies have reported greater abdominal motion in men compared to that in women<sup>17-19</sup>). The sitting position in the present study is similar to that in Romei et al.<sup>17</sup>) and Binazzi et al.<sup>20</sup>), and participants were kinematically inclined to have dominant upper costal motion. If men already use greater abdominal motion as part of their natural breathing pattern, then instructed diaphragmatic breathing may not have influenced their natural pattern. This interpretation is consistent with results of the oral questionnaire regarding comfort.

Ventilatory efficiency might be specifically affected by the pattern of breathing in women. Bellemare et al.<sup>21</sup>) reported that women have a smaller rib cage dimension in relationship to height compared to that in men, combined with a greater inclination of the ribs. These anatomical differences could result in significant effects of the posture in which the deep breathing exercises are performed<sup>15-17</sup>). Although we measured breathing in a sitting position with back support, in reality, breathing exercises are postoperatively performed in various positions, including the supine position. Therefore, future research is needed to more completely describe the interactions, if any, between posture, deep breathing pattern, and ventilatory efficiency.

There are several limitations in the present study. First, age-related differences were not taken into consideration, as the participants were relatively young, healthy adults. Because most of the clients receiving perioperative breathing exercise are middle-aged, future studies should include older participants, including elderly individuals. In addition, the instructions for deep breathing were given prior to data collection and data was collected over a single 5-min period. We assumed that the participants were receiving breathing exercise instructions for the first time. Therefore, the results may differ when breathing exercises are more than 5 minutes long or are performed several times.

In conclusion, performing deep breathing within an individual's non-specific breathing pattern produces the similar or greater effects on the work of breathing and ventilatory efficiency compared to that with instructed diaphragmatic breathing.

## Conflict of interest

None.

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