Abdominal obesity augments further reduction in the cough capacities by supination of middle-aged and elderly women

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Abstract
The present study aimed to examine whether abdominal obesity and different postures (sitting or supine) affected the cough capacities of middle-aged and elderly women. Method: Twenty-four middle-aged and elderly women with (n = 10; obese group) or without (n = 14; non-obese group) abdominal obesity were included. We evaluated changes in vital capacity (VC) and cough peak flow (CPF) in sitting and supine positions. Results: CPF and VC were significantly lower in the supine versus the seated position in both the non-obese and obese groups. Although no difference was found in VC or CPF between the groups in either position, decreases in both VC and CPF consequent to a change from seated to supine were greater in the obese versus the non-obese group (-5.1 ± 4.4% vs. -3.7 ± 5.3% for VC and -10.8 ± 5.6% vs. -6.7 ± 5.6% for CPF, respectively; p < 0.05). In the obese group, the decrease in CPF with supination correlated with the waist circumference (r = 0.64, p < 0.05). Conclusion: Our results suggest that cough capacity in the supine position was more affected in the subjects with abdominal obesity because their diaphragmatic resistance was further increased by supination consequent to excessive abdominal fat contents.

Keywords: abdominal obesity, cough peak flow, vital capacity, position, elderly women

1. Introduction
In recent years, pneumonia has become a serious threat to life concomitant to the global acceleration of population aging, as host defense function decreases with age¹,². Coughing plays an important role in host defense function by clearing the airways via sputum expectoration. Forceful and effective coughing successfully removes invading organisms along with respiratory tract secretions. Therefore, a decreased cough capacity augments the risk of developing pulmonary complications²⁻⁵.

The vital capacity (VC) and respiratory muscle strength (maximal expiratory mouth pressure: PEmax; maximal inspiratory mouth pressure: PImax) are the most important contributors to the cough capacity⁶⁻⁸. Posture is also known to affect the cough capacity, which is greater while sitting than while in a supine position⁹,¹⁰.

Obesity has been increasing recently, even in the elderly, and this condition leads to various lifestyle-related diseases such as diabetes, hypertension, and cardiovascular disease¹¹,¹². Obesity also impairs respiratory function¹³,¹⁴, and fat accumulation, particularly in the visceral and chest subcutaneous areas, reduces the lung capacity and ventilation efficiency, which is represented by a decrease in the forced expiratory volume in 1 s (FEV₁.₀)¹⁵⁻¹⁷.

The cough peak flow (CPF) is known to adequately reflect the cough capacity. Bach et al.¹⁸ reported that a CPF ≤ 270 L/min during a respiratory infection and ≤160 L/min under normal conditions indicates compromised sputum expectoration. Furthermore, the CPF is correlated with the VC and respiratory muscle strength, as represented by the PImax. Therefore, the CPF is considered a simple and reliable indicator of the cough capacity and has been used in clinical settings to practically evaluate cough capacity¹⁸.

We hypothesized that the cough capacity of person with abdominal obesity would be smaller than

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non-obese person and that a decrease in the cough capacity consequent to a change from a sitting to supine position would be greater in person with abdominal obesity than in non-obese person. In this study, we examined the effects of visceral fat accumulation and postural changes on cough capacity, measured via the CPF, in middle-aged and elderly women.

2. Materials and Methods

2.1. Approval from the Ethics Committee
This study protocol was approved by the research ethics committee of Aino University (Aino2012-007).

2.2. Subjects
Twenty-four middle-aged and elderly women from among the members of a local female choral club in Osaka City were included in this study. None of the subjects had histories of smoking, respiratory disease, or cardiovascular disease. The subjects were divided into 2 groups according to their waist circumferences as follows: the obese (≥90 cm, Guideline of Japan Society for the Study of Obesity, n = 10) and non-obese groups (<90 cm, n = 14). Prior to entry into the study, written consent was obtained from all subjects after the provision of thorough written and oral explanations of the purpose, methods, and risks of the study.

2.3. Measurement of waist circumference
The waist circumference, a surrogate index of visceral obesity, was measured using a tape measure at the height of the umbilical region while the subjects were in a standing position and at a resting expiratory level.

2.4. Evaluation of respiratory function
As shown in Fig. 1, we evaluated the respiratory function in all the subjects with an electronic spirometer (AS-307, MINATO). The VC and CPF were measured in both sitting and supine positions, whereas the other parameters were measured only while sitting. For the sitting measurements, the subjects sat on a backless chair and rested both hands on their thighs. For the supine measurements, the subjects laid on a bed, keeping their knees in an extended position, and placed both arms at the sides of their body. The 2 measurements were performed in a random order. Each measurement comprised 3 trials, and sufficient rest time was provided before the next trial to prevent fatigue. The maximum values were used for the analysis.

During the measurements, the subjects wore nose clips and held a mouthpiece that was connected to the spirometer in their mouths. We evaluated each respiratory function parameter as described previously. Briefly, after practice, the VC was determined while the subjects breathed slowly from the maximum inspiratory level to the maximum expiratory level.

We also calculated the %VC, the VC expressed as the percentage of the reference value according to age and body height. The forced expiratory volume in 1 s (The FEV1.0) was assessed with a flow volume curve and expressed as the percentage of forced vital capacity (FEV1.0%). Regarding the CPF, the subjects were instructed to inhale as deeply as possible and then spontaneously cough with maximum effort.
2.5. Changes in the VC and CPF with postural change

Changes in the VC and CPF with postural change were expressed as rates of change, using the sitting value as a reference; the following formulas were used:

\[ \text{Change in VC} = \frac{\text{VC}_{\text{sup}} - \text{VC}_{\text{sit}}}{\text{VC}_{\text{sit}}} \times 100 \] and

\[ \text{Change in CPF} = \frac{\text{CPF}_{\text{sup}} - \text{CPF}_{\text{sit}}}{\text{CPF}_{\text{sit}}} \times 100, \]

where

- VC\text{sup}: VC in supine position,
- VC\text{sit}: VC in sitting position,
- CPF\text{sup}: CPF in supine position, and
- CPF\text{sit}: CPF in sitting position.

2.6. Statistical analysis

Paired \( t \) tests were used to compare the VC and CPF in the sitting and supine positions. Unpaired \( t \) tests were used to compare the respiratory parameters, including the CPF and VC, and the changes in the VC and CPF between the obese and non-obese groups.

Correlations between the waist circumference and other parameters in each group were assessed with Pearson’s correlation coefficient.

A significance level of <5% was used for all evaluations, and the analysis was performed with the StatView 5.0 software for Windows (SAS Institute, Cary, NC, USA).

3. Results

The clinical characteristics of the subjects are shown in Table 1. There was no significant difference in age between the obese and non-obese groups. The body mass index (31.8 ± 3.6 vs. 23.1 ± 3.6, \( p < 0.01 \)) and waist circumference (103.5 ± 9.9 vs. 75.7 ± 7.3, \( p < 0.01 \)) were significantly greater in the obese group than in the non-obese group. No differences in FEV1.0% and %VC were observed between the groups.

<table>
<thead>
<tr>
<th>Table 1. Subject characteristics</th>
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<tr>
<td>Number</td>
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<tr>
<td>Age (yr)</td>
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<td>Height (cm)</td>
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<td>Weight (kg)</td>
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<td>BMI (Kg/m²)</td>
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<td>WC (cm)</td>
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<tr>
<td>FEV1.0% (%)</td>
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<td>%VC (%)</td>
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Values are means ± SD.

Abbreviations: NG, non-obese group; OG, obese group; WC, waist circumference;FEV1.0%, the forced expiratory volume in 1sec expressed as the percentage of forced vital capacity; %VC, the vital capacity expressed as the percentage of the reference value according to age and body height. p-value, OG vs NG

3.1. Comparison between the VC and CPF in the sitting and supine positions

Both the CPF and VC were significantly lower in the supine position than in the sitting position in both the non-obese (298.1 ± 82.3 L/min vs. 316.8 ± 77.3 L/min for CPF and 2.82 ± 0.49 L vs. 2.92 ± 0.44 L for VC, respectively; \( p < 0.05 \)) and obese groups (280.6 ± 66.1 L/min vs. 313.1 ± 70.2 L/min for CPF and 2.76 ± 0.37 L vs. 2.91 ± 0.36 L for VC, respectively; \( p < 0.05 \); Table 2).

3.2. Comparison of changes between the VC and CPF with postural change in the non-obese and obese groups
Although no differences were directly observed in the VC or CPF between the groups at each position, the changes in both the VC and CPF with postural change were greater in the obese group than in the non-obese group (-5.1 ± 4.4% vs. -3.7 ± 5.3% for VC and -10.8 ± 3.0% vs. -6.7 ± 5.6% for CPF, respectively; p < 0.05; Table 2).

Table 2. Influence of posture on VC and CPF

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>NG</th>
<th>OG</th>
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<tr>
<td>VC&lt;sub&gt;sit&lt;/sub&gt; (L)</td>
<td>2.92 ± 0.41</td>
<td>2.92 ± 0.44</td>
<td>2.91 ± 0.36</td>
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<tr>
<td>VC&lt;sub&gt;sup&lt;/sub&gt; (L)</td>
<td>2.79 ± 0.43&lt;sup&gt;*&lt;/sup&gt;</td>
<td>2.82 ± 0.49&lt;sup&gt;*&lt;/sup&gt;</td>
<td>2.76 ± 0.37&lt;sup&gt;*&lt;/sup&gt;</td>
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<tr>
<td>Change in VC (%)</td>
<td>-4.3 ± 4.9</td>
<td>-3.7 ± 5.3</td>
<td>-5.1 ± 4.4&lt;sup&gt;§&lt;/sup&gt;</td>
</tr>
<tr>
<td>CPF&lt;sub&gt;sit&lt;/sub&gt; (L/min)</td>
<td>315.1 ± 72.7</td>
<td>316.8 ± 77.3</td>
<td>313.1 ± 70.2</td>
</tr>
<tr>
<td>CPF&lt;sub&gt;sup&lt;/sub&gt; (L/min)</td>
<td>290.8 ± 74.9&lt;sup&gt;§&lt;/sup&gt;</td>
<td>298.1 ± 82.3&lt;sup&gt;§&lt;/sup&gt;</td>
<td>280.6 ± 66.1&lt;sup&gt;§&lt;/sup&gt;</td>
</tr>
<tr>
<td>Change in CPF (%)</td>
<td>-8.4 ± 5.1</td>
<td>-6.7 ± 5.6</td>
<td>-10.8 ± 3.0&lt;sup&gt;§&lt;/sup&gt;</td>
</tr>
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</table>

Values are means ± SD.

Abbreviations: VC, vital capacity; CPF, cough peak flow; VC<sub>sit</sub>, vital capacity in sitting position; VC<sub>sup</sub>, vital capacity in supine position; CPF<sub>sit</sub>, cough peak flow in sitting position; CPF<sub>sup</sub>, cough peak flow in supine position. The other abbreviations are as in Table 1.

*<sup>p</sup> < 0.05, supine position vs sitting position. §<sup>p</sup> < 0.05, OG vs NG.

3.3. Correlations between waist circumference and respiratory parameters

No significant correlations were observed between the waist circumference and the VC and CPF in either group. In the obese group, the waist circumference correlated significantly with the decrease in the CPF with supination (r = 0.64, p < 0.05; Fig. 2D). In contrast, the decrease in the VC tended to increase as the waist circumference increased, but this correlation was not statistically significant (r = 0.59, p = 0.07; Fig. 2C). In the non-obese group, no correlations were observed between the waist circumference and decreases in the VC and CPF with supination (Fig. 2A and B).

![Fig. 2. Relationships between WC and changes in VC and CPF with supination](image-url)

A, WC vs. change in VC in NG. B, WC vs. change in CPF in NG. C, WC vs. change in VC in OG. D, WC vs. change in CPF in OG.

The abbreviations are as in Table 1 and 2.
4. Discussion

In the present study, we demonstrated that the cough capacity, as evaluated by the CPF, was lower in the supine than in the sitting position in both the obese and non-obese women and therefore expanded the results of our previous study, which presented a similar effect of postural change on the CPF in healthy subjects\(^6\)-\(^8\). In addition, we have shown for the first time that the decrease in the CPF with the supine position was greater in the subjects with abdominal obesity than in the non-obese subjects.

The coughing mechanism comprises the following 3 phases\(^1\): a large inhalation (inspiratory phase of cough), a forced exhalation against a closed glottis (compressive phase of cough), and an intense airflow from the lungs following the opening of the glottis, usually accompanied by a peculiar sound (expulsive phase of cough). To date, several reports have shown that the VC is an important factor, associated with the first phase of coughing, that determines the individual coughing force\(^6\)-\(^8\). Vilke et al. and we previously reported that the VC was obviously reduced in response to a postural change from a sitting to a supine position\(^9\),\(^10\). The VC might decrease in the supine position because while lying on one’s back, the rib cage is dorsally compressed and cannot expand sufficiently to inspire deeply. Furthermore, diaphragmatic movement is restricted by supination due to increased pressure from the abdominal internal organs on the diaphragm. These conditions might affect deep inspiration during the first phase of coughing. In fact, we demonstrated for the first time that not only the VC but also the cough capacity itself, as evaluated by the CPF, was impaired while in the supine position, regardless of the degree of obesity.

Our results showed that the decreases in the VC and CPF in response to a postural change from a sitting to a supine position were significantly greater in the obese group than in the non-obese group, although the VC and CPF alone at each position did not differ between the groups. We also revealed a significant positive correlation between the waist circumference and the degree of change in the CPF with supination in the obese group. These results possibly indicate that the abdominal internal organs are pushed up toward the diaphragm in response to a change from a sitting to a supine posture, leading to a further increase in the diaphragmatic contraction resistance. Watson et al. reported that in obese subjects, the total respiratory resistance while breathing via the mouth, as evaluated by the forced oscillation method, was originally approximately twice as strong as that in non-obese subjects regardless of position, and was further increased in a supine position than in a sitting position\(^11\). In addition, oropharyngeal airway narrowing, followed by a reduction in the expiratory flow, occurs with supination in obese subjects\(^12\). These findings might explain why a decrease in the VC, a determinant of the first phase of coughing, and CPF with supination is greater in obese subjects than in non-obese subjects.

As mentioned earlier, a decrease in the VC is considered a cause of the impaired cough capacity with supination. Respiratory muscle strength is another essential element of the cough capacity because it is necessary for violent expiration during the final phase of coughing. Rib cage expansion produces muscle tension, which induces the ensuing powerful respiratory muscle contraction via the length-tension relationship\(^23\),\(^24\). Furthermore, there is reportedly a positive correlation between respiratory muscle strength and the VC\(^25\). In addition, the VC is possibly affected by supination because the respiratory muscle strength decreases with the supine position in comparison to the sitting position, as described earlier. This might also explain why a decrease in the VC with supination impairs the cough capacity.

On the other hand, no report has elucidated whether obesity per se affects the respiratory muscle strength, and in the present study, we did not actually evaluate the subjects’ respiratory muscle strength. The excessive volume of soft tissue around the upper respiratory tract caused by obesity, including the tongue, is generally known to affect the respiratory function via airway narrowing, decreased lung capacity, and decreased thoracic wall compliance, accompanied by fat accumulation on the thoracic wall\(^13\)-\(^17\). In addition, as Zerah et al. previously reported, the resting expiratory level is reduced with a diaphragm shift toward the thoracic cavity along with intra-abdominal fat accumulation in obese subjects\(^15\)-\(^17\). However, abdominal obesity did not directly affect the VC or CPF in either the sitting or supine position in the present study. According to our results, obesity did not seem to directly impair the respiratory muscle strength. The respiratory muscle strength might be stronger in obese subjects than in non-obese subjects due to the “training effect” because obese subjects preserve their VC despite their increased diaphragm resistance, even while sitting. Furthermore, a characteristic respiratory pattern for obese subjects while sitting such as abdominal respiration might also
compensate for diaphragmatic resistance. This issue remains to be resolved.

According to the above-mentioned reasons, obese individuals are at a high risk of developing respiratory tract infections consequent to decreased coughing force, especially in supination, once they are unable to maintain respiratory muscle strength and compensate for diaphragmatic resistance, for instance, in case they have open-heart surgery. Therefore, during respiratory physical therapy after surgery, obese patients should be encouraged to be repositioned frequently and rise from bed as soon as possible. For elderly patients with obesity, lifestyle modifications, including dietary therapy and physical activity, is important to reduce the harmful influence of abdominal obesity on the cough capacity and to effectively promote a healthy daily life.

4.1. Limitations

Limitations of this study include its relatively small cohort comprised of only female subjects. Subcutaneous fat obesity is generally predominant among women, although we could not unfortunately assess the abdominal fat distribution of the subjects. Thus it merits further investigation to elucidate the different effects of visceral and subcutaneous types of abdominal obesity on cough capacity.

Previous studies found a correlation between the VC or CPF and respiratory muscle strength, and the results of our study might have been influenced by individual variations in respiratory muscle strength. However, we did not evaluate respiratory muscle strength in this study; therefore, future studies are needed to clarify this relationship, especially in obese subjects.

5. Conclusion

We demonstrated that a decrease in the cough capacity, as evaluated with the CPF, consequent to a change from a sitting to supine posture was greater in obese subjects than in non-obese subjects and that the waist circumference was positively correlated with the decrease in CPF with supination in obese subjects. Our results have clinical implications for the characteristic dynamics of breathing in subjects with abdominal obesity and for the prevention or management of respiratory tract infections, as obesity is currently very common, even among the elderly.

6. Acknowledgements

We are grateful to members of Aino University for their important contributions to this experiment.

7. Conflicts of interest statement

The authors have declared no conflicts of interest.

8. References
