Electrical Stimulation of the Abdomen Preserves Motor Performance in the Inactive Elderly: A Randomized Controlled Trial

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Abdominal muscle strength declines easily with the process of aging and/or disuse, and it is difficult to strengthen weak abdominal muscles in the inactive elderly. In the present study, we applied surface electrical stimulation (ES) to the abdomen of inactive elderly people to investigate its chronic effects. Twenty inactive elderly people (65-89 years) who spent most of the day in their bedroom participated in the study. The subjects were assigned to ES and non-ES groups in a random order. In addition to conventional physical therapy and occupational therapy, ES was applied to both sides of the flank of 10 subjects (ES group) for 8 weeks. For evaluation of the abdominal muscles, the cross-sectional area (CSA) was measured with computed tomography and the electrical muscle activity (iEMG) was measured by electromyography. Functional examinations were performed at 2, 4, and 8 weeks after the beginning of the study with the following parameters: grip strength; maximum walking speed (WS); movement time for sitting up (MSU); number of trunk flexions (NTF); flexibility of the trunk; sit-to-stand time (STS); and Barthel index (BI) score. In the ES group, the NTF and MSU were significantly improved at 4 weeks and thereafter. Furthermore, the STS and WS were also improved significantly after 8 weeks ($p < 0.05$). The CSA and iEMG both increased significantly ($p < 0.05$). However, the flexibility of the trunk and BI score did not change. In conclusion, ES to the abdomen has the potential to improve motor function in the inactive elderly.

Keywords: abdominal muscles; inactive elderly; motor function; rehabilitation programs; surface electrical stimulation

In recent years, with the increasing number of elderly people in Japan, preventive care has become of considerable importance (Ishibashi and Ikagami 2010). Loss of muscle strength with aging has been suggested to be one of the main factors causing functional limitations in activities of daily living (ADL), such as rising from a chair or climbing up and down stairs (Guralnik et al. 1995; Odding et al. 1995; Schenkman et al. 1996). The strength of the abdominal muscles declines easily with the process of aging and/or disuse (Chen and Kuo 1989; Buchman et al. 2009), and these muscles have important roles for not only trunk function, but also the whole body motor function (Buchman et al. 2008; Simões et al. 2010). The subscore of the functional independence measures relating to locomotion transfers in stroke subjects at discharge was reported to be positively correlated with the trunk muscle torque values, except for isometric extension (Karatas et al. 2004). However, it is difficult to strengthen weak abdominal muscles in the inactive elderly.

Machine training, aerobics, and other activities are recommended for health promotion in the elderly, but there are few programs available for inactive elderly people to strengthen their weak abdominal muscles (Freiberger et al. 2011). Some methods of physical therapy, including electrical stimulation (ES) (DiMarco and Kowalski 2008), have been used for muscle strengthening (Gerovasili et al. 2009). In particular, ES has been adopted to improve not only muscle atrophy, but also impaired motor function in hemiplegic patients (Gerovasili et al. 2009) and spinal cord-injured patients (Popovic et al. 2006; Popović et al. 2009) since the 1980s, and its safety and effectiveness have been confirmed (Gordon and Mao 1994; Hillegass and Dudley 1999; Winslow et al. 2003; Coghlan et al. 2008; Ochi et al. 2010). Furthermore, it was reported that ES of the abdo-
men improved the function of the abdominal muscles in tetraplegic patients (DiMarco et al. 2008; Lee et al. 2008). In the present study, we applied surface ES to the abdominal muscles of inactive elderly people and investigated its local and general effects, such as changes in the abdominal muscle activity and motor performance. We also investigated the changes in the volume of the abdominal muscles after ES.

**Methods**

**Subjects and overall design**

This prospective randomized study was carried out in 20 elderly people (9 males and 11 females) who were admitted to an institute or a hospital for nursing care. We defined inactive elderly people as those who spent most of the day in their bedroom (Nashimoto et al. 2002). The subjects had prolonged decreases in muscle contractile activity, such as those associated with a sedentary lifestyle, periods of prolonged bed rest, and inactivity as a consequence of congestive heart failure, stroke, chronic obstructive pulmonary disease, limb casting, and muscle unloading (i.e., microgravity). They were randomly divided into two groups. ES to the abdominal muscles was performed in one group in addition to the physical/occupational program (ES group; \( n = 10 \)), while the physical/occupational program alone was performed in the other group as a control (Ctrl group; \( n = 10 \)). The conventional physical and occupational therapeutic program included range of motion exercises, muscle strengthening exercises, ADL exercises, and so on, which were performed depending on the physical activity of each individual. The demographic and clinical parameters of the subjects at the beginning of the study are summarized in Table 1. There were no differences between the two groups for any of the items. All of the subjects underwent a standard physical/occupational therapy program twice a week during the study period. Owing to their poor physical condition on the day of examination (fever, blood high pressure, headache, arthralgia, and so on), a few subjects were not able to perform some of the tasks and examinations. The subjects were fully informed about the protocol, and provided informed consent to participate in the study. The study protocol was approved by the Institutional Review Board of Tohoku University Graduate School of Medicine and included the ethical rules for human experimentation stated in the Declaration of Helsinki.

**Procedures**

Bidirectional rectangular pulses of 0.2-ms duration were used and the frequency of the pulse train was 30 Hz in each direction. We placed the stimulation electrodes on both sides of the flank. Bidirectional rectangular pulses of 0.2-ms duration were used and the frequency of the pulse train was 30 Hz in each direction. We placed the stimulation electrodes on both sides of the flank to stimulate more abdominal muscles. We could palpate the same contraction of the abdominal muscles located between the two electrodes in all of the subjects. The stimulation intensity was set at the maximum level just below the pain threshold, so that the subjects never perceived any unpleasant feelings.

<table>
<thead>
<tr>
<th></th>
<th>ES group ((n = 10))</th>
<th>Ctrl group ((n = 10))</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>78.5 ± 13.5</td>
<td>73.5 ± 8.2</td>
<td>.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>152.2 ± 9.8</td>
<td>154.8 ± 12.1</td>
<td>.83</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>55.1 ± 10.4</td>
<td>49.9 ± 10.3</td>
<td>.17</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>23.7 ± 2.9</td>
<td>20.9 ± 3.7</td>
<td>.17</td>
</tr>
<tr>
<td>BI</td>
<td>53.8 ± 20.8</td>
<td>56.9 ± 21.4</td>
<td>.67</td>
</tr>
<tr>
<td>Time from onset to start of the study (months)</td>
<td>26.3 ± 13.5</td>
<td>27.3 ± 21.0</td>
<td>.75</td>
</tr>
</tbody>
</table>

Values are presented as the mean ± s.d. No significant differences between the two groups were noted for the characteristics at baseline. BMI, body mass index; BI, Barthel index.

![Fig. 1. Positions of the electrodes. The stimulation electrodes were placed on both sides of the flank. Bidirectional rectangular pulses of 0.2-ms duration were used and the frequency of the pulse train was 30 Hz in each direction. The bidirectional rectangular pulses stimulated both sides of the abdominal muscles equally. The stimulation intensity was set at the level just below the pain threshold so that the subjects never perceived any unpleasant feelings.](Image)
**ES to the Abdomen Improves Motor Function of Inactive Elderly**

**Performance tests**

The number of trunk flexions (NTF) until the inferior angles of the scapulae were off the table for 30 sec in the supine position (Vera-Garcia et al. 2008), movement time required for sitting up (MSU) from the supine position as fast as possible (Bramell-Risberg et al. 2005), grip strengths of both sides (Nijland et al. 2010), movement time for sit-to-stand (STS) performed as soon as possible (Schenkman et al. 1996), walking speed (WS) for a 10-m distance with maximum effort, flexibility of the trunk (finger-toe distance: FTD) (Czaprowski et al. 2012), and ADL score (Barthel index: BI) were measured by physical therapists or occupational therapists who were unaware of the information of the two groups.

**Measurement of the cross-sectional area**

Previous studies reported there was a significant relationship between muscle strength and muscle cross-sectional area (CSA) (Dal Corso et al. 2007). We examined the morphological changes of the abdominal muscles using computed tomography. The CSA of the abdominal muscles were measured at the level of the umbilicus. The CSA of the Rc and flank muscles, including the EO, IO, and Tr, were calculated on each side by drawing the external margin of each muscle group. These methods were described previously (Mitsiopoulos et al. 1998; Goodpaster et al. 2000).

**Measurement of electric muscle activity**

Surface EMG was used to assess the physiological changes. The EMG signals for the Rc and EO were collected from bipolar surface electrodes on both sides. The electrodes on each muscle were placed at 3 cm lateral to the umbilicus for the Rc and at 10 cm lateral to the umbilicus for the EO according to a previously described method (Ng et al. 1998). EMG signals were continuously recorded during five trunk flexions. The raw EMG signals were sampled at 1,000 Hz and filtered to eliminate the electrical activities below 30 Hz (high pass) and above 100 Hz (low pass). Each EMG wave was integrated by calculating the area under the rectified curve during the middle 3 sec. Each integrated value was averaged to provide a parameter of the total amount of electric muscle activity (iEMG).

**Statistical analysis**

All data are presented as means ± s.d. Statistical analyses were performed using Wilcoxon’s signed-rank test to compare within-group values before and after the study. The Mann-Whitney U test was used to compare unpaired data. Differences between the two groups were evaluated by two-way ANOVA using Stat Cel QC for Windows (OMMS Co., Saitama, Japan). Values of $p < 0.05$ were considered to indicate statistical significance.

## Results

Among the 20 subjects, one subject gave up because of lower abdominal pain, and some subjects could not be evaluated because of their poor physical condition (fever, headache, high blood pressure, low back pain, and so on). The numbers of subjects who were able to be evaluated are shown in Tables 2-5.

### Changes in the functional parameters

The results of the performance tests for the two groups at each time point are shown in Tables 2 and 3. There were nonsignificant differences between the two groups for all of the functional parameters at the beginning of the study.

The NTF was significantly increased from 12.7 ± 4.4 to 14.2 ± 5.8 in the ES group after 4W ($p < 0.05$), while a nonsignificant change was observed in the Ctrl group (Fig. 2). One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, and arthralgia).

In the ES group, the MSU was significantly decreased from 23.5 ± 15.6 sec to 15.2 ± 12.9 sec after 4W ($p < 0.01$), while the Ctrl group showed a significant increase from 16.3 ± 14.3 sec to 22.6 ± 19.5 sec at 2W ($p < 0.05$) (Fig. 3). The significant decrease in the ES group from 23.5 ± 15.6 sec to 16.3 ± 14.3 sec after 8W was more prominent than that after 4W. One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, and arthralgia).

The STS was significantly increased from 29.2 ± 14.2 sec to 25.1 ± 12.5 sec in the ES group after 8W ($p < 0.05$), while a nonsignificant change from 35.4 ± 25.2 sec to 26.8

### Table 2. Changes in motor performance parameters.

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
<th>2W</th>
<th>4W</th>
<th>8W</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ES group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTF (ES n = 8, Ctrl n = 9)</td>
<td>12.7 ± 4.4</td>
<td>14.2 ± 4.5</td>
<td>14.9 ± 5.8</td>
<td>15.6 ± 6.0</td>
</tr>
<tr>
<td>MSU (sec) (ES n = 8, Ctrl n = 9)</td>
<td>23.4 ± 15.6</td>
<td>15.6 ± 13.4</td>
<td>15.2 ± 12.9</td>
<td>12.7 ± 11.2</td>
</tr>
<tr>
<td>STS (sec) (ES n = 9, Ctrl n = 8)</td>
<td>29.2 ± 14.2</td>
<td>30.5 ± 17.1</td>
<td>25.1 ± 12.9</td>
<td>25.1 ± 12.5</td>
</tr>
<tr>
<td>WS (m / min) (ES n = 8, Ctrl n = 8)</td>
<td>13.0 ± 11.5</td>
<td>17.9 ± 17.2</td>
<td>17.0 ± 17.2</td>
<td>25.3 ± 18.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
<th>2W</th>
<th>4W</th>
<th>8W</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ctrl group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTF (ES n = 8, Ctrl n = 9)</td>
<td>11.1 ± 7.5</td>
<td>10.5 ± 7.6</td>
<td>12.1 ± 7.2</td>
<td>10.5 ± 7.7</td>
</tr>
<tr>
<td>MSU (sec) (ES n = 8, Ctrl n = 9)</td>
<td>16.3 ± 14.3</td>
<td>22.6 ± 19.5</td>
<td>20.3 ± 16.4</td>
<td>15.4 ± 9.2</td>
</tr>
<tr>
<td>STS (sec) (ES n = 9, Ctrl n = 8)</td>
<td>35.4 ± 25.2</td>
<td>30.3 ± 16.9</td>
<td>25.1 ± 12.5</td>
<td>26.8 ± 17.9</td>
</tr>
<tr>
<td>WS (m / min) (ES n = 8, Ctrl n = 8)</td>
<td>12.1 ± 10.0</td>
<td>9.9 ± 8.9</td>
<td>10.1 ± 8.3</td>
<td>14.3 ± 6.0</td>
</tr>
</tbody>
</table>

Values are presented as the mean ± s.d.

*p < 0.05. **p < 0.01, significant difference from the value at the beginning of the study.

Start, at the beginning of the study; NTF, number of trunk flexions; MSU, movement time required for sitting up; STS, movement time required for sit-to-stand; WS, walking speed for a 10-m distance with maximum effort.
± 18.3 sec was observed in the Ctrl group during the study (Fig. 4). One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, low back pain, and arthralgia).

Compared with the initial value, the WS was significantly increased from 13.0 ± 11.5 m/min to 25.3 ± 18.1 m/min in the ES group after 8W ($p < 0.05$), while a nonsignificant change was found in the Ctrl group during the study (Fig. 5). One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, low back pain, headache, and arthralgia).

**Changes in CSA**

The CSAs of the Rc and flank muscles did not differ Table 3. Non-significant changes in motor performance parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ES group (n = 8)</th>
<th>Ctrl group (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td>2W</td>
</tr>
<tr>
<td>FTD (cm)</td>
<td>12.8 ± 9.6</td>
<td>13.2 ± 9.7</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rt</td>
<td>7.9 ± 5.3</td>
<td>8.3 ± 5.5</td>
</tr>
<tr>
<td>Lt</td>
<td>15.1 ± 7.8</td>
<td>15.1 ± 6.7</td>
</tr>
<tr>
<td>BI</td>
<td>53.8 ± 20.8</td>
<td>54.4 ± 21.1</td>
</tr>
</tbody>
</table>

Values are presented as the mean ± s.d.

* $p < 0.05$, ** $p < 0.01$, significant difference from the value at the beginning of the study.
Start, at the beginning of the study; FTD, finger-toe distance; BI, Barthel index.

**Table 4. Changes in cross-sectional areas of the abdominal muscles.**

<table>
<thead>
<tr>
<th>Cross sectional area (mm$^2$)</th>
<th>ES group (n = 8)</th>
<th>Ctrl group (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>start 8W $p$</td>
<td>start 8W $p$</td>
</tr>
<tr>
<td>right Rc</td>
<td>11.7 ± 2.4</td>
<td>12.3 ± 1.8 &lt; 0.05</td>
</tr>
<tr>
<td>left Rc</td>
<td>11.1 ± 3.5</td>
<td>12.4 ± 2.8 .13</td>
</tr>
<tr>
<td>right flank</td>
<td>50.4 ± 10.3</td>
<td>50.0 ± 8.6 .20</td>
</tr>
<tr>
<td>left flank</td>
<td>48.1 ± 9.2</td>
<td>47.4 ± 14.6 .33</td>
</tr>
</tbody>
</table>

Values are presented as the mean ± s.d.
Start, at the beginning of the study; Rc, rectus abdominis muscle.
The flank muscles include the obliquus externus abdominis muscle (EO), obliquus internus abdominis muscle (IO), and transversus abdominis muscle (Tr).

**Table 5. Changes in the EMG activities of the abdominal muscles.**

<table>
<thead>
<tr>
<th>iEMG (mV)</th>
<th>ES group (n = 7)</th>
<th>Ctrl group (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>start 8W $p$</td>
<td>start 8W $p$</td>
</tr>
<tr>
<td>right Rc</td>
<td>14.1 ± 7.8</td>
<td>19.5 ± 12.8 .25</td>
</tr>
<tr>
<td>Left Rc</td>
<td>14.6 ± 8.6</td>
<td>20.9 ± 10.0 &lt; 0.05</td>
</tr>
<tr>
<td>right flank</td>
<td>7.4 ± 4.4</td>
<td>7.7 ± 4.5 .30</td>
</tr>
<tr>
<td>left flank</td>
<td>8.0 ± 5.5</td>
<td>9.2 ± 4.8 .25</td>
</tr>
</tbody>
</table>

Values are presented as the mean ± s.d.
Start, at the beginning of the study; Rc, rectal abdominal muscle.
The flank muscles include the obliquus externus abdominis muscle (EO), obliquus internus abdominis muscle (IO), and transversus abdominis muscle (Tr).
significantly between the two groups before the study. The CSA of the right Rc increased significantly from 11.7 ± 2.4 mm² to 12.3 ± 1.8 mm² in the ES group ($p < 0.05$), but decreased significantly from 13.6 ± 5.8 mm² to 12.4 ± 4.5 mm² in the Ctrl group in Table 4. Nonsignificant changes were noted in the other muscles in Table 4. One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, low back pain, and arthralgia).

**Changes in iEMG**

We only performed EMG for the Rc and EO. There were nonsignificant differences in the iEMG values for the Rc and EO before the study. The iEMG value for the left Rc increased significantly in the ES group after 8W ($p < 0.05$).

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Fig. 2. Changes in the number of trunk flexions (NTF) after the intervention. The values in the ES group are significantly increased at 4W and 8W. *$p < 0.05$, significant difference from the value at the beginning of the study.

Fig. 3. Changes in the minimum time required for sitting up (MSU) after the intervention. The values in the ES group are significantly decreased at 4W and 8W, while the value in the Ctrl group shows a significant increase after 2W. **$p < 0.01$, significant difference from the value at the beginning of the study.**
but decreased significantly in the Ctrl group \( (p < 0.05) \) in Table 5. Nonsignificant differences were found in the EO in Table 5. One subject gave up because of lower abdominal pain and some subjects could not be evaluated because of their poor physical condition (fever, high blood pressure, low back pain, headache, and arthralgia).

**Discussion**

The aim of this study was to examine the chronic effects of abdominal surface ES. We evaluated the effects of ES to the abdomen on selected functional parameters in inactive elderly subjects. In summary, ES to the abdomen may be able to change inactive elderly people to active elderly people.

In this study, we confirmed the improvement of several functional parameters such as the NTF, MSU, and WS in the ES group. Improvements were noted even after 4W. Specifically, we observed significant changes in the motor
functions related to abdominal muscle activities, such as the NTF and MSU. Although the background mechanisms underlying such functional changes may be complicated, morphological and physiological changes to the abdominal muscles can be indicated.

First, the morphological changes to the abdominal muscles may provide increased muscle strength. The present results showed that the CSA of the right Rc was increased in the ES group after 8W. On the contrary, the CSA of the right Rc was significantly decreased in the Ctrl group. Although an increase in muscle volume does not necessarily mean an increase in muscle strength, there are several reports showing that muscle strength improves together with an increase in CSA in skeletal muscles (Ackermann et al. 2006; Dal Corso et al. 2007; Verdijk et al. 2009). Accordingly, it is possible that the ES group obtained more strength of the abdominal muscles than the Ctrl group, and the improvements in the NTF and MSU in the ES group may have been provided by such increases in the muscle strength.

Second, physiological changes in the abdominal muscles may be involved in an increase in muscle strength. The EMG measurements in the present study revealed that the iEMG value of the left Rc was significantly increased after the intervention in the ES group. This finding suggests that the number of neuromuscular units in the abdominal muscles was increased after ES. In other words, the strength of the abdominal muscles may have been improved by an increase in the number of neuromuscular units.

However, significant changes in the abdominal muscles from both the morphologic and physiological aspects were only found in the Rc. The EMG measurements were performed during tasks involving trunk flexion. When performing trunk flexion tasks, such as bowing, squatting down, sitting up, getting up, and so on, the subjects used muscle contraction of the Rc more than that of the flank muscles. Furthermore, it was reported that subjects used the Rc more than the flank muscles during ADL for breathing, excretion, posture adjustment, getting up, and so on (Workman et al. 2008). Therefore, the Rc may show more improvement in both the CSA and iEMG than the flank muscles.

In the ES group, a significant increase was observed in the CSA of the right Rc, while the iEMG value was significantly increased in the left Rc. The reason why such significant changes were only found on one side is unknown. Although we placed the stimulation electrodes on both sides of the flank in this study to stimulate more abdominal muscles (Rc, IO, EO, and Tr), we could palpate the same contraction of the abdominal muscles located between the two electrodes in all of the subjects. Indeed, the CSA of the left Rc was increased in five of eight subjects in the ES group. An increase in the iEMG of the right Rc was also observed in four of seven subjects. Therefore, the observation of significant differences on one side only may have been caused by the small number of subjects.

In general, increased muscle strength is provided by changes in neural factors (iEMG) and hypertrophy of muscle fibers (CSA) (Moritani and de Vries 1980). Although it was recently reported that muscle strength is often brought about by hypertrophy through exercise (Folland and Williams 2007), an increase in muscle strength during the early period of training can be caused by an increase in the number of muscle fibers participating in the muscle contraction (Cormie et al. 2007). According to Moritani and de Vries (Moritani and de Vries 1980), both young and elderly groups showed an increase in muscle strength as a result of muscle-strengthening exercises for 8W, but muscle hypertrophy was only observed in the young group. Consequently, the authors concluded that the increase in muscle strength in the elderly group after exercise occurred through an increase in the number of neuromuscular units, rather than muscle hypertrophy. In the present study, we found early improvement of the NTF and MSU in the ES group, even after intervention for 4W. Eriksson and Häggmark (Eriksson and Häggmark 1979) reported that ES required 8W to bring about muscle hypertrophy. Therefore, it is indicated that the early improvement of motor function after intervention with ES was caused by physiological changes in the abdominal muscles, similar to the case for physical exercise.

The WS and STS were significantly changed after 8W in the ES group, but not in the Ctrl group. From the viewpoint of normal development, standing and walking can be realized on the basis of motions on a bed, such as the MSU. Therefore, it is valid to consider that the late improvements in the WS and STS followed the early improvements in the NTF and MSU, reflecting motions on a bed. The increase in abdominal muscle strength obtained during the first 4 weeks after the initiation of ES may contribute to the subsequent facilitation of standing and walking. On the other hand, the grip strengths and FTD showed no changes during the study period. Grip strength is an indicator of muscle strength in the whole body, while the FTD reflects whole body flexibility. Furthermore, no change was found in the BI score despite the improvements in the WS and STS in the ES group. Nevertheless, it is said that a WS of more 20 m/min, similar to the result in the ES group, may be associated with a higher probability of being independent in ADL (Vermeulen et al. 2011). Consequently, the BI as a scale for assessing ADL is too inaccurate to evaluate precise changes. The findings for the grip strengths and FTD suggest that global changes relating to the whole body function did not occur in the present study. Therefore, the effects of ES to the abdomen are limited to the local functions executed by the abdominal muscles.

The abdominal muscles have important roles for not only trunk function, but also the whole body motor function, and contribute to breathing, speaking, and defecation. However, the strength of these muscles declines easily with the process of aging. It has been reported that muscle atrophy is based on the aging characteristics of type II fibers.
elderly people. The present results revealed functional
the effectiveness of surface ES to the abdomen for inactive
people. As one of the rehabilitation programs for inactive elderly
face ES to the abdomen should be taken into consideration
to the abdomen.

Larger numbers of subjects and longer observation times are
required to reveal the long-term effects of ES. Future studies with
sidered. First, this study involved a relatively small number
of subjects, and therefore positive effects on muscle strength cannot be expected with such programs.
Several investigators have examined the responses of mus-
cle strength to repeated sessions of ES, and reported
increased strength of the skeletal muscles, improved muscle
contraction in patients after knee surgery, and reduced atro-
phy (Kondrashin et al. 1975; Eriksson and Häggmark 1979;
Romero et al. 1982; Currier and Mann 1983). These find-
ings indicate that ES can prevent and improve disuse owing
to immobilization. ES also produces immediate changes in
the motor units, by increasing the recruitment number and
action potential velocity and establishing the selective
recruitment of type II fibers (Montes Molina et al. 1997).
The safety and efficacy of ES to the skeletal muscles have
recently been confirmed, even for heart failure patients
(Dobsak et al. 2006). Therefore, ES to the abdominal area
has good potential for improving the motor function of inactive elderly people through abdominal muscle strength-
ening.

Problems specific for ES to the abdomen include the poten-
tial to cause local skin burns or irritation, electrode
sensitivity, autonomic dysreflexia, and problems with use
over healing wounds (Gorman 2000). However, we could
not confirm such side effects in this study.

Some potential limitations of our study should be con-
considered. First, this study involved a relatively small number
of subjects. Second, the period of the study was too short
to reveal the long-term effects of ES. Future studies with
larger numbers of subjects and longer observation times are
necessary to clarify the precise and long-term effects of ES
to the abdomen.

Conclusion

This study is the first randomized trial aiming to show the
effectiveness of surface ES to the abdomen for inactive
elderly people. The present results revealed functional
improvements in the ES group. We conclude that the sur-
face ES to the abdomen should be taken into consideration
as one of the rehabilitation programs for inactive elderly
people.

Conflict of Interest

The authors declare no conflict of interest.

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