Levels of Muscular Activity in Different Parts of the Body During Basic Nursing Actions

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The present study aims to describe muscular activity levels of each part of the body used in 21 basic nursing actions, and to compare two sets of techniques used for postural change: ergonomic techniques introduced by Kamiya (1991) (A method) and conventional techniques (B method). The subjects were seven young adult women with experience in nursing. In each of the 21 nursing actions, surface EMGs from 16 different muscles were recorded using portable electromyography apparatus. Maximal EMG response (EMGmax) during isometric maximal voluntary contraction for each muscle was used to normalize the EMG signal (% EMGmax). In all 21 actions, the activity level of each muscle was 30% EMGmax or less. As a result of a repeated 2-way ANOVA on 12 postural change actions, significant effects for each of the 2 factors (action and muscle) for muscular activity level and their interaction were recognized. The muscles which indicated relative higher activity levels were erector spinae, soleus, and biceps brachii. The actions of "sitting", "lying", and "half raise" (B method) also showed high muscular activity levels in each part of the body. Moreover, it was confirmed that some postural change methods which used the theory of body mechanics lowered activity levels in the arm and lower back muscles in comparison with conventional methods. The results of this study will be useful in: estimating the levels of physical fitness and techniques necessary for nurses; developing and improving nursing equipment; and in structuring exercise programs for nursing staff.

Keywords: Nursing actions, EMG, portable electromyography apparatus

1. Introduction

With Japan’s population aging rapidly, the number of people who need home care or nursing is steadily increasing. Since the nursing care insurance system started in 2000, a mechanism has been established where specialists such as care-workers, nurses and helpers provide care services to elderly people certified as being in need of care. However, as 75% of those in need of care are provided with services at home (Ministry of Health, Labor and Welfare, 2004), the reality is that not only specialists but rank-and-file family members also have to engage in long-term care as care providers. Due to the increasing aged population along with the low birthrate, it is expected that many ordinary people will have to take care of their partner as well as their parents in the future. The time will come, and is coming when care and nursing are unavoidable daily activities.

Care or nursing includes the carrying out of someone’s routine actions which were once been performed by him/herself. They range from postural changes to assistance with toileting and dressing and so on. As the actions mainly include the support and transfer of a person’s body, care providers are forced to bear a physical burden. It is reported that many care providers suffer from chronic fatigue and lower-back pains, and 80-90% of nurses experience...
lower-back pains (Chiou, et al., 1994; Karahan and Bayraktar, 2004). It has been pointed out in the field of nursing science that assisting with postural changes and the transfer of patients imposes a high load on a care provider’s skeletal muscles especially in the lumbar region (Blue, 1996; Ulin, et al., 1997; Owen, 2000; and, Menzel, 2004). Assist techniques utilizing bio-mechanical laws of body mechanics have been developed to prevent lumbar pain. Studies have examined differences in loads on care providers’ bodies according to the assist techniques (Nojima, et al.; 1992, Kumagai, et al., 1993; Ulin, et al., 1997; Yanagihashi, et al., 1999; Shibata, et al., 2000; and, Kojo and Kamiya, 2001); the height of bed (Kato, 2001; Itami, et al., 2002); and the proficiency level of nursing actions (Tabata, et al., 1990). These studies have been carried out using research techniques such as electromyograms and heart rates, video analysis and subjective estimation. However, as those studies discuss nursing techniques only the actions examined in the studies are highly limited. Little information is available in the literature which quantitatively examines care-workers’ physical load in basic care actions in general.

Research has revealed that the load or fatigue in certain areas of the body such as the lower-back muscles can be evaluated from the amount of muscle discharge (Roy, et al., 1997; Callaghan, et al., 1998; Kankaanpaa, et al., 1998; Bonato, et al., 2003; and, Elfving, et al., 2003). Moreover, a linear relation between the amount of muscle discharge and muscle tension has been confirmed (Lippold, 1952; Matsui, et al., 1969; Komi and Buskirk, 1972). By normalizing the amount of muscle discharge in a certain motion with that in maximal muscle exertion (Kern, et al., 2001; Sawai, et al., 2004), the level of muscular activity and force can be estimated. Under current circumstances in which care and nursing are becoming everyday activities, it is important to clarify what muscular activity a basic care action performed by a care provider needs. This will help formulate a strategy to decrease the physical burden in care and nursing.

The purpose of the present study is to quantitatively determine/evaluate the muscular activity levels in different parts of the body during basic care actions. A surface electromyogram was used for measuring activity in the main muscles. Basic nursing actions generally performed at home were examined. Additionally, two types of methods for postural changes in bed were compared to check whether the different methods had any influence on the care provider’s muscle activities.

2. Method

2.1. Subjects and a simulated patient

The subjects were seven females (age: 25.7±1.6 years old, height: 156.3±4.8cm, weight: 48.8±4.7kg, and clinical experience 3.9±1.3 years) who were either professional care/nursing workers engaged in routine care actions or people with experience of care/nursing (teachers and graduate students of a nursing college). A 22 year-old male was asked to be a simulated patient. His height was 173cm and his weight 61kg. He simulated being a paralytic patient requiring full assistance due to the inability to stand up on his own. Prior to the experiment, the purpose and content of the study were explained, both verbally and in writing, to the subjects and the simulated patient who signed and sealed their consent. The experiment was conducted with the consent of the ethics committee of the concerned institute.

2.2. Nursing actions

The study focused on 21 basic nursing actions performed at home. The actions included postural changes: Nos. 1 and 2; side-turns, Nos. 3 and 4; lateral-moves, Nos. 5 and 6; vertical-moves, Nos. 7 and 8; half-raise, No.9; sitting on the bed from a lying position, No. 10; lying from a sitting position, No. 11; transferring to a wheelchair and No. 12; transferring to a low chair, No. 13; gatch-up (turning the handle of the bed to elevate the bed so that the patient’s upper body could be tilted), Nos. 14 and 15; feeding (in the positions of sitting and standing), No. 16; changing diapers, No.17; changing bed sheets, Nos. 18 and 19; wiping and changing clothes (for the patient’s upper and lower body) and Nos. 20 and 21; changing clothes (from one side of the bed and from both sides of the bed). All the actions, except for operation of the bed and changing diapers, were started from a position in which the care provider stood, or sat in the case of feeding, facing the bed so that the patient’s head was lying on the care provider’s left side. The bed was adjusted up to 45% of the height of the respective care-providing
Muscular Activity Level During Nursing Actions

Table 1  Nursing actions measured by EMG
"A" and "B" being written in the column of No. show A method and B method respectively.

<table>
<thead>
<tr>
<th>Nursing action</th>
<th>Action's name</th>
<th>No.</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postural change</td>
<td>Side turn</td>
<td>A:1</td>
<td>Moving the patient onto his/her side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B:2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lateral move</td>
<td>A:3</td>
<td>Moving the patient to the edge of the bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B:4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vertical move</td>
<td>A:5</td>
<td>Moving the patient to the head of the bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B:6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Half raise</td>
<td>A:7</td>
<td>Moving the patient so that he/she is sitting in bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B:8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sitting</td>
<td>9</td>
<td>Moving the patient from sitting on the bed while both knees are extended,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>to sitting on the edge of the bed</td>
</tr>
<tr>
<td></td>
<td>Lying</td>
<td>10</td>
<td>Moving the patient from sitting on the edge of the bed to lying down</td>
</tr>
<tr>
<td></td>
<td>Wheelchair</td>
<td>11</td>
<td>Helping the patient from sitting on the edge of the bed to sitting in a</td>
</tr>
<tr>
<td></td>
<td>Low chair</td>
<td>12</td>
<td>chair of low height</td>
</tr>
<tr>
<td>Operation of nursing tool</td>
<td>Raising the bed</td>
<td>13</td>
<td>Changing the bed's position so that it is raised/tilted</td>
</tr>
<tr>
<td>Feeding</td>
<td>Feeding (sitting)</td>
<td>14</td>
<td>The nurse feeds the patient from a sitting position</td>
</tr>
<tr>
<td></td>
<td>Feeding (standing)</td>
<td>15</td>
<td>The nurse feeds the patient from a standing position</td>
</tr>
<tr>
<td>Changing equipment</td>
<td>Changing diaper</td>
<td>16</td>
<td>Changing the patient's diaper</td>
</tr>
<tr>
<td></td>
<td>Changing bed sheets</td>
<td>17</td>
<td>Changing the patient's bed sheets</td>
</tr>
<tr>
<td>Wiping a patient and changing his/her clothes</td>
<td>Wiping &amp; Changing clothes (upper)</td>
<td>18</td>
<td>Wiping and changing clothes for the patient's upper body</td>
</tr>
<tr>
<td></td>
<td>Wiping &amp; Changing clothes (lower)</td>
<td>19</td>
<td>Wiping and changing clothes for the patient's lower body</td>
</tr>
<tr>
<td></td>
<td>Changing clothes from one side</td>
<td>20</td>
<td>The nurse changes the patient's clothes from one side of the bed only</td>
</tr>
<tr>
<td></td>
<td>Changing clothes from both sides</td>
<td>21</td>
<td>The nurse changes the patient's clothes using both sides of the bed</td>
</tr>
</tbody>
</table>

subject. To prevent any inconsistent positional relationship between each subject and the simulated patient, the positional relationship between the lying patient’s head, body, upper-and lower-extremities and the distances to the head and edge of the bed were specified for each respective action. Table 1 presents each nursing action. Regarding the action of number 4, postural change on the bed, two types of techniques were adopted from among those which are frequently observed in nursing. One (A method) is a technique which has been developed utilizing the theory of body mechanics (Kamiya, 1991), and the other (B method) is a conventional technique without considering body mechanics. The A method was introduced in order to reduce the physical burden on care providers. In this method, for instance, a care provider shifts the direction of the patient’s body or raises his or her upper body with a smaller rotational inertia. The procedures of the nursing actions conducted by the care provider are as follows. In this case, for convenience of explanation "you" is the care provider:

- Side-turn (Moving the lying patient onto his/her right side from a face-up position).
  1) Draw the pillow toward you.
  2) Bending the patient’s left elbow, place his/her left arm on his/her chest.
  3) Bend the patient’s left knee so that it can be raised.
  4) (A method) Placing your one hand on his/her shoulder and the other on his/her knee, turn his/her body onto his/her right side in the order from his/her knee to shoulder.
  (B method) Placing your one hand on his/her shoulder and the other on his/her knee, turn his/her body onto his/her right side in the order from his/her shoulder to knee.
  5) Release his/her left hand from his/her chest.
  6) Check the position of his/her right shoulder and hip to make the patient feel comfortable.
- Lateral move (Moving the lying patient to the edge of the bed).
  1) Remove the pillow and place it on your side.
  2) Cross the patient’s arms on his/her chest.
  3) Insert your arms under his/her body, one under his/her upper back and the other under his/her hip, and move him/her toward you.
  (A method) You stand on the side of the bed with your legs apart parallel to the bed. Then you conduct the above mentioned actions while bending your knees and pressing them on to the bedside so that your gravity center shifts...
downward.
(B method) You stand with your legs apart perpendicular to the bedside. Then you conduct the above mentioned actions while shifting your gravity center back and forth.
4) Insert your arms under his/her body, one under his/her waist and the other under his/her knees, and move him/her toward you. (This procedure is the same as 3) in both A and B methods).
5) Draw his/her legs toward you.
- Vertical move (Moving the lying patient to the head of the bed)
  1) Remove the pillow.
  2) (A method) Cross the patient’s arms on his/her chest.
  3) Bend his/her knees to raise them.
  4) (A method) Stand facing the right side of the head of the bed, and insert your left arm under the patient’s shoulders and wrap them by using your left arm. Move him/her toward the head of the bed (to the position you are standing) while supporting the patient’s right elbow. (You do not need to turn your waist in the action).
  (B method) You stand parallel with the bedside. Insert your left arm under the patient’s shoulders and wrap them using your left arm with your right arm under his/her hip. The patient puts his/her arms around your neck and locks his/her fingers at the back of your neck. You move him/her toward the head of the bed. (You need to turn your waist in this action).
- Half-raise (Moving the lying patient so that he/she can sit on the edge of the bed)
  (A method)
  1) Place the patient’s right arm apart from his/her side, and his/her left arm on his/her abdominal area.
  2) Insert your left arm under his/her left shoulder.
  3) Support his/her right arm with your right hand.
  4) Raise his/her upper body while turning it in your direction.
  (B method)
  1) Insert your arm under the patient’s right side and reach his/her left shoulder, and support his/her head with your arm.
  2) The patient puts his/her arms around your neck.
  3) Hold his/her back with your right hand.
  4) Raise his/her upper body by using his/her waist as a supporting point.
Prior to the experiment video images of the actions were sent to the subjects so that they could preliminarily confirm the methods and procedures of the different actions (standing position, distance from the bed, width between both legs, angle of the knee joints, portion of the patient’s body to be supported and ways to shift the center of gravity etc.). On the day of the experiment, before any electromyogram measurements were taken, these methods and procedures were re-explained to the subjects who practiced the actions until they could smoothly perform them. Each action was performed at least twice while being video-recorded and its validity and repeatability were confirmed. Among the trials, only those judged as being appropriate were used for analysis.

2.3. The method of electromyogram (EMG) measurement

A portable apparatus (Muscle Tester ME6000T, Mega Electronics Ltd, Finland) was used for measuring the EMGs. It was small in size and light in weight, 181×85×35mm and 344g, including battery and cables, so that the measurement could be conducted with the minimum constraint on bodily movements. It was equipped with surface electrodes (a disposal-type Blue Sensor electrode with a diameter of 1.5cm) which were attached at three places on the surface of the measured muscle at a distance of 1.5cm between each electrode. One electrode functioned as a gland electrode as well as a preamplifier. After the signals of EMG derived with the bipolar lead were amplified 375-fold through the preamplifier, they were A/D converted through a band-pass filter (8-500Hz) and stored in a built-in memory card (256MB). The experiment derived EMGs with a 1,000Hz sampling frequency. The data signal stored in the memory card was transferred and stored to a personal computer (PC).

Sixteen muscles were measured in total; biceps brachii muscle; BB, triceps brachii muscle; TB, deltoideus muscle; DM, rectus abdominis muscle; RA, erector spinae muscle; ES, rectus femoris muscle; RF, biceps femoris muscle; BF, tibialis anterior muscle; TA and soleus muscle; Sol. Both sides of extremities were measured for upper and lower limb muscles, and the left side for trunk muscles (the portion beside the umbilicus for the rectus abdominis muscle and the lower back for the erector spiniae muscle).
2.4. Processing of EMG

The EMG data transferred to the PC was analyzed and processed with MegaWin software (ver.2.01). The times required for each caring action which were measured with the EMG were all irregular. Furthermore, the discharge patterns of active muscles did not look uniform with sporadic, continuous, and intermittent patterns all mixed together. Therefore, the present study needed to identify another indicator of muscular activity level for evaluation. In order to do so, the EMG data during each action was full-wave rectified and integrated by the measured time so as to obtain the mean value of integration per unit time. In addition, the data was normalized (% EMGmax) using the integration value (EMGmax, see below) of the EMG measured for each muscle during the time in which the muscle exerted an isometric maximal voluntary contraction (MVC).

Additionally, the variation range of muscular activity level for the entire time required for each action and the appearance frequency in each level were explored as follows. Firstly, the EMG during each action was full-wave rectified, and after that, for the purpose of normalization, the mean value for every 0.1 second was obtained and divided by that of the EMG during the MVC of the muscle. Thus, the appearance percentage (the percentage in the time required for the action) in each activity level (% EMGmax) was examined.

2.5. The measurement of EMG when a muscle exerted MVC

The EMG (EMGmax) during the time of MVC exertion was measured employing a manual method. In this method, an experimenter manually fixed the posture of the subject, applying resistance against the direction of MVC. The subject then exerted an isometric maximal voluntary contraction against the resistance. The EMGmax in each muscle was measured as follows:

BB and TB: The subject flexed her shoulder and elbow joints by 90°, and placed her upper arm on the table with her forearm in the neutral position, and exerted force to bend or extend her elbow. The experimenter applied resistance against the direction of her force so as to measure the EMGmax.

DM: The subject, with her elbow joint extended, raised her arm to frontally flex her shoulder joint by 90°, and delivered the force to elevate her arm further. The experimenter applied resistance against the direction of force in her arm so as to measure the EMGmax.

RA: The subject, with her knee joints flexed by 90°, raised her shoulder blade from a supine position, and exerted enough force to elevate her upper body further. The experimenter applied resistance against the direction of her force so as to measure the EMGmax. While the EMGmax was measured, an assistant of the experimenter supported the subject’s ankles to restrain her legs.

ES: The subject placed her hands on the back of her head in the face-down position and elevated her upper body (trunk extension). The experimenter applied resistance to prevent her shoulder elevating so as to measure the EMGmax.

RF: The subject sat on the side of the bed with her hip and knee joints flexed by 90°, and without her feet touching the floor extended her knee joints. The experimenter applied resistance on her lower legs against the direction of force in her arm so as to measure the EMGmax. While the EMGmax was measured, an assistant of the experimenter supported the subject’s trunk to restrain it.

BF: The subject elevated her lower legs upright from the floor in the face-down position with her knee joints flexed by 90° and her hip joints by 0°. She then tried to flex her knee joints further while the experimenter applied resistance against the direction of her force so as to measure the EMGmax.

TA: The subject sat on the floor with her knee joints flexed by 90° and her ankle joints dorsiflexed by 0°, and exerted the maximal dorsiflexion force against a resistance force applied on the insteps of the feet for the EMGmax to be measured.

Sol: The subject stood facing a wall with her palms on the wall and her heels slightly elevated. She then tried to raise her calves further. While she was trying this, the experimenter pressed her shoulders to apply resistance to measure the EMGmax.

The MVC in each respective muscle was exerted for 5 seconds per trial. Two trials for each muscle were conducted with a break of two minutes or more between trials. The higher mean measured value of muscle discharge per second at the moment of maximal muscle discharge was adopted as the EMGmax.
Table 2  Activity levels of 16 muscles during 21 nursing actions (mean values and standard deviations of seven subjects)

The muscular activity level is shown as % EMGmax which indicates the proportion for maximal EMG response under isometric maximal voluntary contraction. The numbers in the upper left correspond to the 21 actions which are described in the list below the table.

**BB**: Biceps Brachii muscle, **TB**: Triceps Brachii muscle, **DM**: Deltoideus Muscle, **ES**: Erector Spinae muscle, **RA**: Rectus Femoris muscle, **RF**: Rectus Femoris muscle, **TA**: Tibialis Anterior muscle, **SOL**: Soleus muscle

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>11</th>
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<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB(L)</td>
<td>5.6 ± 2.9</td>
<td>5.7 ± 3.0</td>
<td>5.0 ± 3.2</td>
<td>4.8 ± 3.1</td>
<td>5.0 ± 3.2</td>
<td>4.5 ± 3.0</td>
<td>5.5 ± 3.6</td>
<td>4.8 ± 3.4</td>
<td>4.5 ± 3.2</td>
<td>4.8 ± 3.1</td>
<td>4.7 ± 3.2</td>
<td>4.8 ± 3.1</td>
<td>4.5 ± 3.0</td>
<td>5.5 ± 3.6</td>
<td>4.8 ± 3.4</td>
<td>4.5 ± 3.2</td>
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<tr>
<td>BB(R)</td>
<td>7.4 ± 3.3</td>
<td>6.2 ± 2.5</td>
<td>7.5 ± 3.7</td>
<td>9.2 ± 3.4</td>
<td>8.6 ± 2.8</td>
<td>9.9 ± 3.3</td>
<td>13.1 ± 4.8</td>
<td>7.6 ± 3.8</td>
<td>9.3 ± 3.3</td>
<td>8.5 ± 2.7</td>
<td>7.4 ± 4.8</td>
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<td>7.4 ± 4.8</td>
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<tr>
<td>SOL(L)</td>
<td>12.9 ± 8.9</td>
<td>12.8 ± 9.7</td>
<td>16.3 ± 11.2</td>
<td>15.4 ± 9.9</td>
<td>14.7 ± 8.7</td>
<td>19.7 ± 15.8</td>
<td>12.1 ± 9.2</td>
<td>16.3 ± 11.2</td>
<td>15.4 ± 9.9</td>
<td>14.7 ± 8.7</td>
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<td>16.3 ± 11.2</td>
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<td>SOL(R)</td>
<td>14.8 ± 4.7</td>
<td>14.9 ± 4.7</td>
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<td>15.3 ± 4.5</td>
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<tr>
<td>BF(L)</td>
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</tr>
<tr>
<td>BF(R)</td>
<td>5.1 ± 2.8</td>
<td>4.1 ± 1.7</td>
<td>5.3 ± 2.7</td>
<td>5.5 ± 3.9</td>
<td>5.1 ± 2.3</td>
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<td>14.3 ± 6.7</td>
<td>20.7 ± 8.6</td>
<td>12.1 ± 5.9</td>
<td>2.1 ± 1.4</td>
<td>2.8 ± 1.5</td>
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<td>2.7 ± 1.5</td>
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<td>2.6 ± 1.1</td>
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<td>11.6 ± 3.7</td>
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<td>14</td>
<td>Feeding (sitting)</td>
<td>15</td>
<td>Feeding (standing)</td>
<td>16</td>
<td>Changing diaper</td>
<td>17</td>
<td>Changing bed sheets</td>
<td>18</td>
<td>Wiping &amp; changing clothes (upper)</td>
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<td>Wiping &amp; changing clothes (lower)</td>
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<td>Change clothes from one side</td>
<td>21</td>
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</table>

2.6. Statistical Analysis

The mean value and standard deviation were obtained for the activity level of each muscle in the 21 actions. Among those 21 actions, the postural changes had been mentioned as the actions which could impose physical burdens on care providers (Blue, 1996; Ulin, et al., 1997; Owen, 2000; and, Menzel, 2004), and in this study they were indeed the muscular activity level of each action among which muscle activity levels throughout the lower extremities were less than 10% EMGmax.

3. Results

3.1. Muscular activity levels (% EMGmax) of each part during nursing actions

Table 2 displays the mean and standard deviations of the muscular activity during each action. The mean activity level of each muscle was 30% EMGmax or lower in every nursing action. In the postural changes, the muscle whose activity level was highest compared to others was ES, with a mean of 21.1% EMGmax. The muscle with the lowest activity level was RA, which showed 5% EMGmax or lower in every action. In the postural changes, many measured muscles occasionally showed 20% EMGmax or higher. Considering nursing actions other than postural changes, no actions reached 20% EMGmax or higher, except for TB (R) during the action of getting-up and ES during the actions of changing diapers and wiping and changing clothes. Moreover, the mean activity levels in the muscles of the lower extremities were less than 10% EMGmax.
Since the muscular activity levels in postural changes were high compared to others, and as it is these kind of actions that can impose a physical strain on care providers, the repeated two-way ANOVA was applied to them.

For each factor (the type of action and the kind of muscle), significant effects in % EMGmax were recognized, and a significant interaction between the two factors was detected. The muscle with the highest % EMGmax was ES (23.3%) followed by SOL (R 20.0%) and BB (R 19.9%, L 18.0%), and those with low activity levels were RA (3.2%) and RF (L 7.5%, R 7.6%). The figures in parentheses indicate the mean value of all the nursing actions, and R and L represent right and left sides respectively. Regarding the type of action, "moving the patient from the sitting position with his/her knees extended to sitting on the edge of the bed (17.3%)" was highest in % EMGmax, followed by "moving the patient from the sitting position on the edge of the bed to the lying position with his/her face up (17.2%)" and "moving the patient from the lying position to sitting on the bed (B method)" (15.7%). "Side-turn (A method, 10.9%; and B method, 10.7%) and "half-raise" (11.9%) were low.

Tables 3 and 4 show the results of the post-hoc test, comparing % EMGmax for the kind of muscle and the type of action in each table respectively. In addition, Figure 1 illustrates the activity level in each muscle for each caring action: nine actions among 12 in ES, six in BB(R), five in BB(L), four in DM(L), two in TB(R) and one in DM(R) showed 20% EMGmax or higher. In the actions of "moving from the sitting position on the edge of the bed to the
Figure 1  Activity levels of 16 muscles during 12 postural change actions (mean values and standard deviations of seven subjects).
The vertical axis shows the 12 postural change actions. The horizontal axis shows % EMGmax.
BB: Biceps Brachii muscle, TB: Triceps Brachii muscle, DM: Deltoidmuscle, ES: Erector Spinae muscle, RA: Rectus Abdominis muscle, RF: Rectus Femoris muscle, BF: Biceps Femoris muscle, TA: Tibialis Anterior muscle, SOL: Soleus muscle (R) or (L) shows right or left side.
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3.2. Comparison between methods of the activity levels during postural changes

The nursing actions in which significant differences between A and B methods in % EMGmax during postural changes were "vertical move" and "half-raise". Both of them showed significantly higher activity levels in the B method which does not take body mechanics into consideration. In the action of "vertical move", the muscles showing significant differences in % EMGmax between methods were BB(L and R) and TB(R). In "half raise", they were ES, BB(R), TB(R) and DM(R) (Figure 2).

The method evaluating muscular activity levels using mean value per unit time is not sensitive enough to judge whether the muscular activity moves from high to low levels or maintains a certain range of activity level throughout the nursing action. For this reason, in order to compare the qualitative differences of muscular activity in each nursing action, the appearance frequency for each activity level throughout the EMG measurement was examined regarding the muscles and nursing actions with significant differences between the A and B methods. The results are indicated in Figure 3. In all muscles, the muscular activities adopting the A method were concentrated at a much lower level (5% EMGmax or lower) than those adopting the conventional B method (40% EMGmax or higher).

4. Discussion

The present study examined various actions performed routinely in nursing (postural changes, feeding, helping change clothes, wiping and changing diapers and sheets) with the aim of quantitatively evaluating the extent to which these actions physically constrain care providers. The indicator used was mean muscular activity level per unit of time. The findings showed that the one muscle which was used at a comparatively higher activity level in all the measured nursing actions was the erector spinae muscle, reaching almost 30% EMGmax in the action of "moving from the sitting position on the edge of the bed to the lying-down position". Prior to the present experiment, the researchers of lying-down position", "moving the patient from the sitting position with his/her knees extended to sitting on the edge of the bed" and "moving the patient from the lying position to sitting on the bed (B method)", the muscles of ES, BB and DM (L) commonly surpassed 20% EMGmax. Among the muscles of the lower extremities, those which reached the level of 20% EMGmax or higher were six actions in SOL(R) and one in RF(R) and TA(L). All three muscles showed the highest activity level in "helping the patient move from standing to sitting on a low chair".

Figure 2 A comparison between A method and B method in activity levels of the arm and lower back muscles during two nursing actions ("Vertical move" and "Half raise")

The mean values and standard deviations of the activity levels of the arm and lower back muscles in each method are drawn. The muscular activity level is shown as % EMGmax. The A method is a technique which applies the theory of body mechanics and The B method is a conventional technique for used in the nursing profession. An asterisk (*) shows that there is a significant statistical difference between two methods.

BB: Biceps Brachii muscle, TB: Triceps Brachii muscle, DM: Deltoideus Muscle, ES: Erector Spinae muscle (R) or (L) shows right or left side of upper arm.
the present study had previously explored muscular activity levels of different parts of the body in basic daily actions such as postural maintenance and change and weight transfer (Sawai, et al., 2004). The subjects were females in approximately the same age group and used the same methods as the current study. According to the results of that previous study, among the daily actions measured, only the half-squat position resulted in an EMGmax above 20%. Furthermore, other than "side turn" and "vertical move" (A method), only the postural change actions numbered 3, 4 and 6 to 10, in which a care provider lifted and moved the patient’s body, surpassed 20% EMGmax in the mean muscular activity level of upper extremities as well. As a result of the % EMGmax conversion of mean EMG integration value per 0.1 second (Figure 3), some instances in which the activity levels of BB and DM came close to EMGmax were observed. In the nursing actions such as Wheelchair or Low chair (Nos. 11 and 12), RF indicated the highest activity level of all the nursing actions. Moreover, the activity levels of the lower extremities were relatively high in the action of moving on to a low chair. This was because the care provider does a squat movement while she carries the patient. In this action, the lower she squats, the larger the dorsiflexed angle of her ankle became, which elevated her heels, and this might result in the high activity levels in her lower extremities.

The muscular activity levels of each part of the body used in the nursing actions, other than postural changes, were low except for TB(R) in "gatch up" in which the subjects turn the handle with their dominant hand; and, ES in the actions of "changing

**Figure 3** A comparison between the A and B methods in two nursing actions (Vertical moves and Half raise) and the effect on muscular activity levels for each muscle measured.
The horizontal axis shows % EMGmax. The vertical line shows the proportion of total time reached for each muscle activity level for the action time required as a whole. Each graph shows the mean value and standard deviation of The A method and B method, respectively. The A method is a technique which applies the theory of body mechanics and The B method is a conventional technique for used in by the nursing profession.

BB: Biceps Brachii muscle, TB: Triceps Brachii muscle, DM: Deltoides Muscle, ES: Erector Spinae muscle
(R) or (L) shows right or left side.
diapers" and "wiping and changing clothes" which the subjects perform in a stooped position. This was because those nursing actions did not include weight-bearing and were actions performed by the upper extremities with little movement in the joints of the lower extremities. As an example, when changing bed sheets, a care provider changes her posture many times while moving around a bed, but although the time required throughout the action is relatively long (approximately 4 minutes on average), muscular activity only occurs intermittently and mean values over time are not very high. Taking this example into consideration, it can be inferred that the action of moving a patient on to a wheelchair may cause fatigue and disorder in the lumbar area of a care provider’s back, not only because the time required for the action surpassed the mean of 40 seconds, but also because the ES’s activity level per-unit time was high.

In a comparison between nursing actions and actions in daily life, the activity levels in the lower extremities were equivalent to walking and climbing up or down a slope at a natural or slow speed. The levels did not surpass those seen when climbing stairs, walking at a fast speed and running (30% EMGmax or higher). Therefore, comparing a situation in which an independent person shifts his/her own body in daily life, nursing actions to supporting another person’s daily activities, though requiring less force in the muscles of a nurse’s lower extremities, exert force equal to that necessary to maintain a half-squat position, in the muscles of the lower back region. In particular, when carrying out postural change, the muscles in the upper extremities, especially in the right arm and hand, will undergo momentary high forces. Of all routine nursing actions, postural changes are one of the most frequent. Although nursing textbooks instruct nurses to carry out postural change every two hours, it is recommended that this nursing action should be conducted at least every 90 minutes to prevent bed sores (Yuki and Mito, 2001). Thus, postural changes not only require high muscular activity level at the time when they are performed but should also be performed frequently. Moreover, more females engage in nursing than males and female muscle force (especially in the upper extremities) is generally weaker than that of males (Wilmore, 1974; Laubach; 1976; Miller, et al., 1993). Considering these facts, postural change actions impose a considerably heavy physical load on female care providers.

Among the postural changes seen at nursing sites, the actions of moving a patient toward the head of the bed and of raising a patient’s upper body on the bed show significant differences between the nursing methods in the activity levels of the muscles in the lumbar back and the upper extremities. However, no significant differences between methods were seen in the actions of turning the patient on his side and of moving him toward the side of the bed. A possible reason is that not very much force is needed in either method because a care provider does not need to lift up the patient’s body. In addition, in the case of moving the patient toward the side of the bed, as the care provider separately moved the patient’s upper body and lower body over a short distance, it is considered that no significant differences due to the different methods appeared. On the contrary, in the actions of "vertical move" and "half-raise", since a care provider needed to lift up most of the patient’s body weight and transfer it over a relatively long distance, it is possible that the difference between methods greatly influenced the efficiency of force used. Specifically, in the A method of "vertical move", the care provider, standing on the floor at the side of the bed head prior to the action, drew the patient’s body toward her. Therefore, in this movement, a care provider could make use of her weight and muscles of her back and upper and lower extremities. However, in the B method, the care provider stood at the side of the patient, and, supporting his body using both her hands, transferred him sideward while twisting her own upper body. In this case, it is suggested that she solely depended on the muscle force of her upper extremities, resulting in the high muscular activity level in the upper extremities. Regarding the A method of "half-raise", the care provider supported the patient’s right elbow with her right hand in order to use his arm as a supporting point, and then the care provider raised and turned the patient’s upper body towards her using her left hand. The rotation moment in this method was smaller than in the B method in which the care provider raised the patient’s upper body using his hip as a supporting point while holding his upper body with both her arms. As a result, it is estimated that for the A method less muscular activity was needed in the upper extremities, especially in the right arm and lower back.

Previous research has already found that less muscular activity was required in actions using
methods adopting body mechanics than those of conventional methods without any consideration of body mechanics (Kumagai, et al., 1993; Yanagihashi, et al., 1999; Shibata, et al., 2000; Kojo, et al., 2001). The present study could clarify to what extent the difference in method could change muscular activity in certain parts of the body by using a relative indicator, % EMGmax, to measure the amount of muscular activity. Take the action of raising the upper body of a patient lying on the bed as an example. The biceps brachii muscle in a care provider’s arm needed to exert 26% of maximal torque in the method without consideration of body mechanics, while less than 10% of maximal torque was enough to carry out the action in the method adopting body mechanics. A care provider with a larger body size and stronger physical strength than a patient could easily change a patient’s posture regardless of method type. However, in the case in which a wife of small stature takes care of her well-built husband, or when an elderly person with declining physical strength nurses his/her elderly spouse, nursing techniques that can reduce the physical load on a care provider as much as possible are required. The findings from this study show which actions require more muscular activity in a care provider’s upper extremities and lumbar back, and so it is possible to know when to choose alternative methods such as using an assistant or an assisting device.

However, the indicator used in this study, namely mean muscular activity level per unit of time, is not able to explain all the reasons for fatigue or burden on parts of the body such as the lumbar back. Previous research has demonstrated that bionic factors such as moment in the lumbar area, pressure in the lumbar disks, and shear force in the vertebra (Herrin, et al., 1986; Marras, et al., 1995; Norman, et al., 1998), as well as psychosocial factors such as job satisfaction (Bigos, et al., 1986; 1991, Marras, et al., 1993) have an impact on the occurrence of lumbar disorders. It is important to point out that a care provider cannot prevent disorder in his/her lumbar back solely by acquiring knowledge and techniques of body mechanics (Nevada-RNformation, 2003). A care/nursing specialist would need to have the physical capacity to tolerate the bodily burden at a nursing site. Cross-sectional studies (Nicolaensen and Jorensen, 1985; Alaranta, et al., 1994) have reported that a worker’s back extension endurance declines when the worker is suffering from disorder in their lumbar back. Aerobic exercises have long been considered useful in reducing damage in the lumbar back (Cady, et al., 1979) and curing patients with lumbar disorders (Juker, et al., 1998). Aerobic exercise, stretching and strength training are recommended for nurses to control fatigue and lower-back pains, and specialized books have introduced such methodologies (Blue, 1996; McGill, 2005), though their operational effects have not necessarily been verified. The findings of this study will help formulate guidelines for the contents of such exercise programs for care providers.

5. Summary

This study aimed at quantitatively evaluating muscular activity levels of different parts of the body during basic, domestic nursing actions; and, examining whether a care provider’s muscular activity could be changed by using different methods to change a patient’s postures in bed. The subjects were seven females with experience of the care/nursing profession. Their mean age was 26.0±1.7 years old. They performed 21 types of nursing actions. Among the 21, four postural changes on the bed adopted two methods which are frequently seen in care/nursing sites. The first was a method developed utilizing the theory of body mechanics so as to reduce physical stress on care providers (A method), and the other is a conventional method conducted without considering body mechanics (B method). Using a small-size electromyography apparatus, surface electromyograms (EMG) were derived from 16 places on the body surface. The mean integrated value per time in the EMG recorded for each respective action was normalized by an EMG integrated value obtained during MVC exertion by the isometric muscular activity in each muscle in order to acquire the % EMGmax so that muscular activity level could be estimated. The findings show that muscular activity levels in the upper extremities and lumbar-back were higher than those in the lower extremities in nursing actions. In particular, those in the upper extremities and lumbar-back in the actions of postural changes were relatively high. The highest % EMGmax appeared in the erector spinae muscle followed by the soleus muscle and the biceps brachii muscle. The following three actions produced the highest activity levels: "moving from sitting with a
patient's knees extended on the bed to sitting on the edge of the bed"; "moving from sitting on the edge of the bed to lying down on the bed"; and, "raising a patient's upper body on the bed (B method)". Among the actions of postural change, significant differences in % EMGmax between methods were recognized in the following two actions: "moving a lying patient toward the head of the bed" and "raising a patient's upper body on the bed". The results quantitatively verified that methods adopting the theory of body mechanics could impose less physical load on a care provider's upper extremities and lumbar-back portion.

The results of this study suggest the following considerations in order to prevent disorders in a care provider's musculoskeletal system such as lumbar-back pain:
- Utilize body mechanics methods as they help reduce the physical burden on care providers in actions in which they lift or transfer a patient.
- Try to strengthen the muscles in the lumbar-back and upper extremities which are mainly used at the time of postural changes.
- Strengthen the muscle groups in the lower-extremities when actions supporting transfer are included.
- Consider utilizing an assistant as well as an assist tool.
- Provide health education and training for care providers to acquire the knowledge, techniques and physical strength mentioned above.

6. Postscript

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Nevada-RNformation, 12: 13.


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