Differences between Novice and Experienced Caregivers in Muscle Activity and Perceived Exertion while Repositioning Bedridden Patients

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Abstract  The aim of this study was to investigate the impact of caregiver knowledge and experience on muscle activity and perceived exertion while repositioning bedridden patients. Subjects were 40- to 65-year-old female caregivers divided into novice and experienced groups. Subjects from both groups performed home-care repositioning techniques on bedridden patients while muscle activity was recorded via electromyogram. Recordings were made from four muscles on the subjects’ dominant side: the latissimus dorsi, the biceps brachii, the erector spinae, and the rectus femoris. The subjective burden involved in repositioning was also assessed using the rate of perceived exertion (RPE) and visual analog scales (VAS). Rectus femoris percentage of maximum voluntary contraction (%MVC) values were significantly lower than latissimus dorsi, erector spinae, and biceps brachii values in the novice group. %MVC values from the latissimus dorsi and biceps brachii were significantly higher among the novice group compared to the experienced group. RPE ratings from the novice group were significantly higher than those of the experienced group, and there was a non-significant trend for higher VAS values for the low back, arms, and legs in the novice group compared to the experienced group. Novice caregivers tended to change the patient’s position by pulling with the upper limbs without using the lower limbs. In contrast, experienced caregivers exerted less energy by communicating with the patient and utilizing the patient’s own movements. They used large, distributed muscle groups that effectively harnessed body mechanics and prevented excess exertion. J Physiol Anthropol 27(6): 333–339, 2008 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.27.333]

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Introduction

In 1994, the Japanese Ministry of Labor issued “Guidelines on the Prevention of Lumbago in the Workplace,” which described the several factors leading to work-related lumbago. These factors include those associated with postures and movements required by the job, the workplace environment, individual predisposing characteristics and conditions, and preventive measures taken by the employer. Although more than ten years have passed since the publication of those guidelines, the prevalence and incidence of work-related lumbago remain high. In the medical and nursing fields, lumbago can result from a complex interaction between movement factors such as unnatural posture, the lifting of heavy objects, sustaining the same posture, momentary load bearing, inadequacies of the physical environment in medical treatment facilities, and individual caregiver factors such as lack of knowledge and experience. To address these problems, facilities for patients requiring total assistance, such as those afflicted with severe motor or intellectual disabilities, have actively introduced support devices to assist with patient movement and have implemented educational training (Kaneda et al., 1995; Kaneda et al., 1996; Kitanishi and Najima, 1995; Kokubo et al., 2000; Kose et al., 1999; Kumagai et al., 2005).

The situation of lumbago among medical and nursing practitioners is severe throughout the world. In the UK in 1993, regulations were put into effect to combat lumbago in the workplace. These regulations forbid a patient from being moved by a single caregiver, require the use of support devices for lifting when there is no available help, and mandate the participation of medical practitioners in lectures on the management of patients. Since the implementation of these regulations, the incidence of lumbago in the UK has dropped dramatically. In addition, considerable research is currently being conducted on appropriate methods for the transfer of bedridden patients, a direct cause of lumbago and stress on the low back (Hartvigsen et al., 2005; Hui et al., 2001; Kamal and Tai, 2004; Keir and MacDonell, 2004; Kingma et al., 2001; Marras et al., 1999; Owen, 2000; Silvia et al., 2002; Skotte et al., 2002; ).

While measures against lumbago for medical and nursing practitioners are expanding and improving, measures aimed at those who care for their family members at home remain insufficient. For those who are suddenly forced to care for their
family members at home, individual factors such as lack of knowledge and experience may play an important role in the high burden of lumbago among family caregivers. Still, labor laws do not protect those who care for their family members, and these individuals have less opportunity to participate in relevant lectures or coursework. Family caregivers typically suffer from a lack of spare time as well as psychological burdens from homecare nursing. Therefore, these families must rely on their own care methods and experience. As a result, they often incur physical hardships including lumbago.

As such, improving lumbago-associated factors is critical for both professional caregivers and nonprofessional family caregivers. We propose that understanding the relationships between knowledge, experience, movement factors, personal care methods, and the degree of perceived physical exertion will lead to useful insights into the problem.

Unfortunately, unnatural postures are often adopted during the repositioning of bedridden patients. These include anterior inclination, anteflexion, twisting, and kneeling position factors, and cause more than half of lumbago cases. The purpose of this study was to examine relationships between experience and knowledge of patient repositioning techniques and muscle activation and body coordination during the execution of these techniques. We furthermore sought to compare muscle activity patterns during patient repositioning and the subjective fatigue experienced between those who had received training in nursing care techniques and those who had not.

**Method**

**Subjects**

Subjects were 34 healthy, right-handed females between 40 and 65 years old. They were divided into a novice caregiver group (18 subjects) and an experienced caregiver group (16 subjects). Novice caregivers had no homecare experience while experienced caregivers were nurses and nurse instructors. All subjects were free from musculoskeletal and functional mobility problems.

The average age of novice caregivers was 52.4±7.1 years and that of experienced caregivers was 47.3±6.3 years. Novice caregivers were significantly older than experienced caregivers ($p=0.032$). Height, weight, percentage of body fat, body mass index (BMI), and upper limb length did not differ significantly between groups (Table 1). Experienced caregivers had been licensed nurses for an average of 25.6±7.0 years. On average, they had 10.6±7.1 years of clinical experience and 10.3±6.9 years of providing guidance and instruction.

**Experimental task**

Load placed on the low back during the forward bending posture is an important causative factor in the development of lumbago. Forward bending is frequently necessary due to the height of patient beds (Kato, 2001). Accordingly, we set the height of beds to 42–49% of the subjects’ height. The room temperature was set to 22±2°C.

**Table 1** Characteristic of subjects

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All subjects</th>
<th>Novice caregivers</th>
<th>Experienced caregivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>50.0±7.1</td>
<td>52.4±7.1</td>
<td>47.3±6.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>157.6±4.9</td>
<td>157.1±3.2</td>
<td>158.2±6.3</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>54.8±8.0</td>
<td>56.7±9.1</td>
<td>52.8±6.1</td>
</tr>
<tr>
<td>Percentage of body fat (%)</td>
<td>26.5±5.3</td>
<td>30.5±5.5</td>
<td>26.5±5.3</td>
</tr>
<tr>
<td>Body mass index (Kg/m²)</td>
<td>22.0±3.5</td>
<td>23.0±4.0</td>
<td>21.1±2.6</td>
</tr>
<tr>
<td>Upper limb length (cm)</td>
<td>66.9±3.3</td>
<td>67.0±2.5</td>
<td>66.7±4.2</td>
</tr>
</tbody>
</table>

Values are mean± standard deviation. * $p<0.05$ by Mann-Whitney U-test.

The experimental task performed by each subject was the act of changing the position of a bedridden patient. Patient repositioning is required in almost all care techniques. Specifically, subjects repositioned a supine patient into a side-lying position. The patient was maneuvered into a side-lying position facing the subject, with the subject’s dominant hand supporting the patient’s shoulder.

All subjects performed the tasks on the same female patient (height: 158 cm, weight: 48 kg) who was trained prior to experimentation. The patient’s activity was not limited by disease or paralysis. The patient was directed to remain relaxed and refrain from voluntary movement during the experiment. She wore an eye mask to eliminate visual influences on her sense of equilibrium. Subjects were allowed to verbally communicate with the patient.

**Electromyogram recordings**

Muscle activity in the upper limbs, lower limbs, and trunk were measured concomitantly during the patient repositioning maneuver using disposable surface electrodes. Recordings were made from the following four muscles on each subject’s dominant side: latissimus dorsi, biceps brachii, erector spinae, and rectus femoris. Latissimus dorsi electrodes were placed at the T7 level. Biceps brachii electrodes were placed over the muscle belly. Erector spinae electrodes were positioned approximately 5 cm lateral to the midline at the L4 level (Kojo et al., 2001; Seo et al., 1993). The skin was abraded and cleansed with alcohol prior to electrode attachment to minimize impedance. Electrodes were fixed in place with tape over the muscle belly along the muscle fibers 25–30 mm apart.

Electrical signals from contracting muscles were recorded and analyzed with a computerized system (MP SYSTEM Acknowledge 3.7.3, BIOPAC Systems, U.S.A.). A 50 Hz notch filter was used to eliminate the 50/60 Hz line noise. We set the high-pass filter to 5 Hz, low-pass filter to 500 Hz, and sampling rate to 1000 Hz.

An aluminum board was set up on the bedside to prevent noise interference during the experimental task. The lead lines were grouped together with vinyl tape to evenly distribute movement-related noise throughout lead lines to reduce motion artifacts.

Corrected surface electromyogram (EMG) signals were full-wave rectified and integrated over the duration of the
experimental task. Because overall muscle activity varies idiosyncratically, the percentage of maximum voluntary contraction (%MVC) during the experimental task was calculated using the maximum voluntary contraction (MVC) values measured prior to the experimental task for each subject. EMG activity for each muscle was expressed as %MVC. %MVC values from both groups that exceeded the theoretical maximum value of 100% were excluded.

**Evaluation of perceived exertion**

Subjects evaluated perceived exertion and fatigue using two rating scales immediately after performing the experimental task. Perceived physical exertion was rated with Borg’s 15-point scale (range 6–20) (Borg, 1982). Physical fatigue during the repositioning maneuver was rated separately for the back, low back, arms, and legs using a visual analog scale (VAS: range 0–10) (Huskisson, 1974).

**Protocol**

Subjects provided written informed consent after listening to an explanation of the study. They changed clothes for the experiment and EMG electrodes were affixed. Before performing the experimental task, muscles were tested for MVC using a manual muscle test. EMG data was normalized to 100% MVC based on a series of maximum contraction trials. Enough practice time to determine the repositioning method was provided. Subjects were required to rest for five minutes in a seated position prior to initiating the experimental task. EMG was repeatedly measured during the experimental task according to cue. After performing the task, subjects rated RPE and VAS. The general physical condition of each subject was measured on the day of task performance using a questionnaire.

**Statistical analysis**

%MVC from each muscle was averaged across subjects and standard deviations (SD) were calculated. RPE and VAS ratings were expressed as maximum, minimum, and median values.

Group-level comparisons between the novice and experienced groups were performed for %MVC values using independent-samples t tests and two-way analysis of variance (ANOVA). Post-hoc comparisons were performed using Fisher’s PLSD multiple-comparison test. RPE and VAS values were analyzed using the Mann-Whitney U test. Statistical analyses were performed using Stat View Ver.5.0 software (SAS Institute, Inc., Tokyo). The significance threshold (type I error rate) was set to 0.05.

**Protection of individual information and ethical treatment**

This study was approved by the ethical review board of the Department of Medicine, Tokyo Medical and Dental University. The purpose of the research was explained to each subject orally and in writing. Written consent was obtained from all subjects, and they were free to withdraw from the study at any time. Subject identities were protected using codes such that the researchers performing statistical analysis could not identify individual subjects. Subjects were informed that the data would be used only for this research project and for no other purpose.

**Results**

The self-reported physical condition on the experimental day did not differ between the novice and experienced groups.

MVC of the biceps brachii were highest among the four recorded muscles in both groups, at $59.9 \pm 12.3 \text{ mV}$ and $37.9 \pm 3.4 \text{ mV}$ for the novice and experienced groups, respectively. MVC of the rectus femoris were lowest among the recorded muscles in both groups, at $11.6 \pm 11.0 \text{ mV}$ and $8.7 \pm 9.0 \text{ mV}$ for the novice and experienced groups, respectively.

In the novice group, the %MVC for the latissimus dorsi, erector spinae, biceps brachii, and rectus femoris were $32.0 \pm 19.7\%$, $31.8 \pm 10.4\%$, $28.8 \pm 19.5\%$, and $15.2 \pm 7.5\%$, respectively. Values for the rectus femoris values were significantly lower than those for the latissimus dorsi, erector spinae, and biceps brachii ($p=0.0009$, 0.0014, and 0.0074, respectively). There were no further significant differences in %MVC among other muscle groups.

In the experienced group, the %MVC for the latissimus

**Fig. 1 Protocol**
dorsi, erector spinae, biceps brachii, and rectus femoris were 19.9 ± 9.6%, 38.6 ± 13.2%, 15.4 ± 8.7%, and 20.9 ± 13.8%, respectively. Values for the erector spinae were significantly higher than those for the latissimus dorsi, biceps brachii, and rectus femoris (p = 0.0002, < 0.0001, = 0.0003, respectively). There were no further significant differences in %MVC among other muscle groups.

%MVC for the latissimus dorsi and biceps brachii were significantly higher in the novice group compared to the experienced group (p = 0.0405 and 0.0188, respectively). Differences between the erector spinae and rectus femoris did not reach statistical significance (p = 0.1329 and 0.1745, respectively).

The median RPE value for the novice group was 12, with a range of 7 to 15. The median RPE value for the experienced group was 9, with a range from 6 to 12. RPE values for the novice group were significantly higher compared to the experienced group (p = 0.0004).

VAS scores were significantly different between the two groups for low back, arms, and legs (p = 0.0013, 0.0060, and 0.0209, respectively). The back score difference did not reach statistical significance (p = 0.0513).

**Discussion**

The physical burden placed on nurses and the effectiveness of their movements has been evaluated experimentally using biological and psychological indicators. Many studies have assessed the influence of bed height, the changing position, and patient transportation on the care techniques being used. Subjects in these studies included nurses alone (Kojo et al., 2001; Shinohara et al., 1998; Sugimoto et al., 2005), teachers alone (Miyakoshi et al., 1987), students alone (Hosono et al., 1982; Kobayashi et al., 1998; Shibata et al., 2000; Yanagihashi et al., 1998; Yanagihashi et al., 1999; Yanagihashi et al., 1999), both nurses and students (Itami et al., 2003; Kato, 2001; Sawai, 1998; Suzuki and Ogawa, 2002), or both teachers and students (Itami et al., 2001). In another study, subjects were chosen on the basis of sex and age (Kato and Fukada, 2000). For example, a male whose occupation is unrelated to nursing (Shibata et al., 1996), and a nurse and novice whose ages were not matched as strictly as in this study (Hidaka, 2003) were chosen.

A comparison of integral EMG upon performance of three different types of changing position was described by Hidaka (2003). The findings suggested that adopting a position that allows for easy movement of the center of gravity is appropriate for novices. This is supported by our finding that muscle activity in the rectus femoris of novice caregivers was significantly less than in the other three recorded muscles. In addition, activity in the latissimus dorsi and biceps brachii were significantly greater in the novice group compared to the experienced group. Thus, it could be predicted that novice caregivers limited muscle use to specific areas rather than using the entire body for changing position. Novice caregivers used the rectus femoris as a fixator muscle. In other words, they repositioned the patient by using the pulling function of the latissimus dorsi and biceps brachii. They failed to coordinate use of the upper- and lower-body by flexing the knees and moving the legs. Our findings underscore the necessity of coordinating usage of the entire body and are in agreement with that of Hidaka (2003) concerning the importance of adjusting the center of gravity during repositioning.

Arm muscles were rated highest on the VAS for novice caregivers. This value was greater than that for the back, the low back, and the legs. When considering results of both muscle activity and VAS, we conclude that novice caregivers repositioned the patient to the side-lying position mainly by pulling with their arms.

In contrast to the patient repositioning method used by novice caregivers, experienced caregivers moved the patient to the side-lying position with minimal effort by utilizing the patient’s own movements. Thus, the amount of activity needed for patient repositioning was solely the amount needed to support the patient’s natural movement. This resulted in significantly lower activity levels in the latissimus dorsi and the biceps brachii compared to the novice group. The experienced
caregivers thus assisted the patient using the patient’s natural movements, increased the surface area of the support base, and used the muscle power of their lower limbs. It was clear that they effectively harnessed body mechanics.

There was a tendency for higher rectus femoris muscle activity in the experienced group compared to the novice group. This was a result of the widening of the support base and use of a posture that allowed easy movement of the center of gravity. From these observations, we suggest that experienced caregivers effectively use muscles from the entire body to coordinate body mechanics.

Research into influences on physiological burdens on the nurse’s body suggests that, in addition to making use of the mechanical attributes of “the leverage principle” of the upper limbs, active use of the lower limb muscle groups could decrease muscle activity in the upper limbs and reduce systemic physiological burden (Shibata et al., 2000). Thus, coordinating the usage of muscles from the entire body decreases the physical load. Itami et al. (2003) used an electromyogram to determine the physical load associated with nursing tasks. A large difference was observed in muscle activity in those who could not efficiently use body mechanics due to bed height. Furthermore, significant differences were reported in muscle activity based on tiredness levels. Kato and Fukada (2000) reported that efficiently using body mechanics while caring in the half-sitting posture reduces the load to the waist line of the backbone and the inside hamstring muscle.

Kato (2001) has indicated that repetition of a posture of anterior inclination in which the low back is bent can trigger lumbago. When such a posture is adopted, the lower body is more slanted than the upper body in order to bend the lower back as little as possible. We estimate that the experienced caregivers fixed the position of their trunk by tensing the erector spinae, which are antigravity muscles, and adjusted the position of their center of gravity by bending their knee joints. Our results are thus similar to Kato’s.

In this study, %MVCs of the latissimus dorsi and biceps brachii in the novice group were more than twice that of the rectus femoris. This indicates that novice caregivers moved the patient to the side-lying position using predominantly their upper limbs. In contrast, there was no difference between %MVCs of the latissimus dorsi, the biceps brachii, and the rectus femoris in the experienced group. Rather, the experienced caregivers used the muscles of their entire body to move the patient to the side-lying position. In addition, RPE, which measured subjective fatigue after completion of the experimental task, was significantly greater for the novice group than for the experienced group.

These results suggest that perceived exertion was large because novice caregivers could not coordinate the entire body, leading to higher local muscle activity of the latissimus dorsi and biceps brachii. As a result, the physical load increased as well. For experienced caregivers who can coordinate the entire body, perceived exertion and physical load were not extensive. Therefore, the factor that determines physical load is not the extent of muscle activity, but rather coordination of the entire body and perceived exertion.

In homecare, there are no absolute methods for ensuring that caregivers incur minimal physical burdens. Here, we have confirmed the importance of physiological evaluation in examining the balance of muscle activity across the entire body, and also in assessing effective utilization of body mechanics that makes full use of the lower body when repositioning bedridden patients.

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