

# Low Back Load Produced by Changing a Diaper at Various Bed Heights Experienced by Female Care Workers in a Nursing Home

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**Abstract.** [Purpose] Muscle activities and subjective evaluations were compared while changing diapers at various bed heights to investigate working techniques and bed heights for reducing low back load. [Subjects] The subjects were 21 skilled caregivers. [Methods] Bed height was adjusted to the level at which the subjects usually changed diapers, their preferred level, and 45% of the subject's height. The activities of eight muscles and subjective evaluation were compared among the various heights. [Results] The bed height at which subjects usually changed diapers was 51.7 cm, the preferred bed height was 63.4 cm, and 45% of subjects' height was 71.0 cm, showing significant differences. Right erector spinae activities were significantly different among three heights, as were subjective evaluations. The diaper-changing fulcrum differed: it was set at the thighs and knees at the routine height; at the thighs, knees, and lower abdominal region at the preferred height; and at the thighs at 45% of the subject's height. [Conclusions] Skilled caregivers mastered adjustment of the diaper-changing fulcrum corresponding to the bed height. It was also suggested that the erector spinae muscle activity level and subjective low back load may not be consistent when 45% of the subject's height.

**Key words:** Bed height, Low-back load, Surface electromyogram

*(This article was submitted Nov. 5, 2012, and was accepted Dec. 4, 2012)*

## INTRODUCTION

The incidence of low back pain among high in hospital nurses, care workers of nursing homes, and caregivers in families<sup>1-6)</sup>. Low back pain is a major health problem for female nurses because their physical strength is generally weaker than that of males, and the strength of the upper half of their body is insufficient<sup>7,8)</sup>. Changing a diaper, cleaning, changing postures, and assisting with bathing by lifting and transferring patients requiring long-term care have been reported to be the main causes of low back pain<sup>1,4,5)</sup>. Diapers have to be changed frequently regardless of the time of day or night, and caregivers do it mostly in a forward-bent posture. More than 20 degrees of anteflexion of the trunk deviates from the stable posture. The resultant load on the erector spinae muscle is greater than that in the standing position<sup>9)</sup>.

To reduce the load on the dorsolumbar muscles while nursing on a bed, the use of optimum work techniques and adjustment of the bed height to an appropriate level are recommended as ergonomic countermeasures<sup>10)</sup>. Work techniques producing a mechanically smaller load on the dorso-

lumbar muscles include the Stockholm training concept and the Halvor Lunde technique<sup>11,12)</sup>. These techniques involve movement units, but the optimum diaper change movement, and its load on the dorsolumbar region of caregivers using these techniques have not been clarified. Shogenji et al.<sup>13)</sup> set the bed height at 50 cm and compared the trunk flexion angle and %MVC of erector spinae muscles of nurses between diaper change movements with one knee placed and not placed on the bed, based on the recommendation of kneeling on one knee on a 50-cm-high bed. For nurses, Pheasant<sup>14)</sup> recommended kneeling on one knee on the bed when performing familiar patient handling activities and stated that, anthropometrically, kneeling on one knee is difficult when the bed height is 70 cm or higher. In hospitals and nursing homes, the bed height varies depending on the activity of the workers and the preference of patients requiring long-term care, and several workers care for each patient. Therefore, it is necessary to identify the bed height at which caregivers can kneel on one knee and adjust their position during each nursing session. However, the optimum bed height for kneeling on one knee has not been identified, and work techniques corresponding to the bed height have not been established.

Lee and Chiou<sup>15)</sup> set the bed height at 70 and 80 cm and the iliac crest height (mean: 90.7 cm) based on anthropo-

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metrics, and compared a patient-handling task involving nurses. They observed that the maximum acceptable capacity in the patient-handling task was noted at the iliac crest height. In a study performed by Caboor et al.<sup>16)</sup>, the bed height was set at the standard 51.5 cm or adjusted by nurses (mean: 57.9 cm, range: 49.5–65.5 cm), and muscle activity while performing a patient-handling task was compared; however, they found no significant differences in the heights of two beds. De Looze et al.<sup>17)</sup> set the bed height at the standard height in academic hospitals in Brussels (71.5 cm) and at bed heights selected by the nurses (42.5–46.1% of subjects' height) and compared the time-integrated compression and peak shear force while they performed a patient-handling task. The parameters significantly decreased when the nurses adjusted the bed height to one that they thought was appropriate. Caboor et al.<sup>16)</sup> and De Looze et al.<sup>17)</sup> compared the standard height and the height chosen by subjects to identify the height producing the smaller low back load, but the optimum bed height has not yet been identified. The bed height producing the smallest low back load while nursing has not been established in Japan or in other countries. In Japan, a bed height of 45% subject height is easy to care. However, there are no available studies with objective data that confirm that a bed height of 45% subject height is the optimal height.

Skilled caregivers frequently change diapers of many patients requiring long-term care but do not develop low back pain. The skilled caregiver may conduct care movements producing a small lumbar stress<sup>18)</sup>. We assume that their diaper change movement is close to the optimum work technique, and they practice it while experiencing only a small load on the dorsolumbar muscles. Elucidation of the diaper change movements of skilled caregivers may clarify the work technique corresponding to the bed height and the bed height producing a small low back load on the dorsolumbar region.

Panjabi<sup>19)</sup> described an active subsystem of the stabilizing system of the spine. This subsystem is led by a flexor group, including the abdominal muscles, and an extensor group, including the erector muscles of the spine. In the present study, we chose the rectus abdominis muscle, which is involved in spinal column flexion through progressive lumbar erector spinae muscle activity, as a muscle associated with stability of the lumbar trunk. We selected the vastus lateralis muscle as a muscle of lower limb activity; it connects with the semitendinosus muscle. Because these muscles function when subjects changed a diaper, we hypothesized that the spinal column might be stable. Core stability<sup>19, 20)</sup> can be used to support low back loads and prevent low back pain.

The recently developed TeleMyo2400 (Noraxon, Scottsdale, AZ, USA) is capable of simultaneously measuring muscle activity and video-recording. It quantitatively analyzes the load on the dorsolumbar region in real time during a movement. Using this device, we have established a method to continuously measure agonistic muscle activities of the trunk and lower limbs during a series of nursing movements<sup>21)</sup>. The biomechanical load on the dorsolumbar region of skilled caregivers while changing a diaper can be

analyzed at each bed height using this method. The results of this study may help to establish a definitive work technique and appropriate bed height for preventing low back pain among care workers, contributing to the promotion of the health of care workers of nursing homes.

In this study, skilled caregivers changed a diaper at the bed height set in their routine practice, the height preferred by them, and the height corresponding to 45% of their height. Imaging analysis of the diaper change movement was performed, and dorsolumbar agonistic muscle activity and subjective fatigue and perceived exertion of the low back were assessed to identify the bed height resulting in the smallest low back load. In addition, the nursing movement producing the smallest low back load corresponding to the bed height was investigated.

## SUBJECTS AND METHODS

### *Subjects*

The objective of this study was to investigate diaper change movement producing a small low back load involving skilled caregivers, subjects were skilled caregivers who did not have low back pain and had never been treated for lumbago during work as a caregiver who met the following criteria: 1) female certified care workers working at nursing homes for the elderly for 3 years or longer, 2) workers who frequently changed diapers almost every day, and 3) healthy workers without low back pain.

Participation in the study was publicly advertised at seven nursing homes near the study facility in north Japan, and 21 subjects gave their consent to participation. Their mean±SD age was 38.7±11.6 years (24–59 years), height was 159.0±5.4 cm, body weight was 53.8±7.0 kg, and body mass index (BMI) was 21.7±3.0. Eighteen (85.7%) and three (14.3%) subjects were right- and left-handed, respectively.

### *Methods*

Pre-survey, the years of professional experience, frequencies of diaper changes in day and night shifts, use of a low back protector belt, and performance of stretching exercises were surveyed by interviewing the subjects. In addition, the subjects' diaper change movements and the bed height were observed during day shifts at the nursing home where they were working to investigate the bed height in their routine diaper change work. The grade of requirement of long-term care of their patients was also surveyed.

Subjects performed their usual diaper change movements three times in a laboratory at Kanazawa University and nursing home to clarify the state of the low back load in changing a diaper and the height of the bed was set at the following three levels: 1) a height corresponding to 45% of the subject's height, 2) the bed height used in their routine diaper change work, 3) the bed height the subject preferred. The nursing movement was repeated three times at 5-min or longer intervals. The bed width was 80 cm, the height included the mattress thickness, and manually removable bed fences were attached to both sides.

Seven healthy certified care workers or nurses aged 21–54 years were collected by public advertisement (height:

160.5±5.2 cm, body weight: 55.0±6.7 kg, BMI: 21.5±3.4) and gave their consent to act out the role of patients requiring long-term care. We assumed that patients' handicaps and environment would influence the nurses' lumbar load during the diaper change, and thus established a handicap (right hemiplegia) for all patients and performed measurements on the same bed. The acting patients wore a pair of front-opening pajamas and a rectangular paper diaper under the trousers. To similarly limit the movement of all the seven subjects acting as a female patient with severe right hemiplegia requiring long-term care, they wore an experience simulator of elderly right hemiplegia. Each caregiver changed a diaper three times for the same simulated patient requiring long-term care.

A surface electromyograph, TeleMyo2400 (Noraxon), was attached to the subjects while changing a diaper three times. The sampling frequency and frequency band were set at 1,500 and 10–500 Hz, respectively. As the agonists of the trunk and lower half of the body, the bilateral lumbar erector spinae, rectus abdominis, lateral vastus, and semitendinosus muscles (eight muscles) were selected, and muscle activities were measured while changing a diaper. MVC of each muscle was measured and the muscle activity data were normalized (%MVC). %MVC was multiplied by the time required for changing a diaper to calculate the integrated value of muscle activity during the diaper change movement. These measurement data were analyzed using MyoResearch XP software (Noraxon). Video was simultaneously recorded, and the movements and muscle activities were analyzed in real time.

After changing a diaper three times, the strength of subjective fatigue of the low back was measured using a visual analog scale (0–100 mm)<sup>22</sup>. The strength of perceived exertion of the low back was measured using Borg's CR-10 scale (0–10)<sup>23</sup>.

The pre-survey was performed in July–November 2011 at nursing homes at which the subjects were working. The main survey was performed in October–December 2011 after completion of the pre-survey of each subject in a home nursing experiment room of the School of Health Sciences, Kanazawa University or nursing home.

For comparison of the three bed heights (the bed height at which the subjects usually change diapers, the bed height preferred by the subjects, and the bed height corresponding to 45% of the subject's height), the time required for changing a diaper, bed height, and muscle activity were analyzed using repeated measures analysis of variance (repeated measures ANOVA) and the Bonferroni test. For comparison of subjective fatigue and perceived exertion of the low back, Friedman's test and multiple comparisons were employed. Statistical analysis was performed using IBM SPSS Statistics 20. The significance level of the Bonferroni test and Friedman's test was set using the Bonferroni correction:  $0.05/3=0.0167$ . The significance level of the other tests was set at 5%. In addition, using MyoResearch XP Software, diaper changing movements were simultaneously videotaped to perform real-time analysis of care movements and muscle activity.

This study was approved by the Medical Ethics Commit-

tee of Kanazawa University (No. 324, June 7, 2011). First, the objective and methods of the study were explained orally using documents to representatives of the nursing homes where the subjects were working, and their written consent to cooperation in the study was obtained. The study was then similarly explained to the subjects, and their written consent to participation in the study was obtained. The objective and methods of the study were explained orally using documents to the subjects who acted out the role of patients requiring long-term care, and their written consent to participation in the study was obtained.

## RESULTS

Pre-survey, the 21 subjects had 7.5±3.4 years of professional experience, and the frequencies of diaper changes on the day and night shifts were 5.7±3.5 and 16.2±12.5, respectively. One subject (4.8%) used a low back protector belt every day, 3 (14.3%) subjects had previously used one, and 17 (81%) subjects had never used one. Nine subjects (57.9%) performed stretching exercise every day. The patients' grade of requiring long-term care was 4.5±0.6.

The bed height before changing a diaper was 48.1±5.7 cm (range: 38–65 cm) for all 21 subjects. Six subjects (29%) adjusted the bed height for changing a diaper, and 15 (71%) did not. The bed height at which a diaper was changed was 51.7±7.2 cm (range: 46–65 cm), which corresponded to 32.5±4.7% (range: 27–42%) of subject's mean height.

The diaper changing procedure of the 21 subjects was similar: The trousers were pulled down in a lateral position without lifting the patient's body, the genital region was washed and cleaned, the used diaper was changed to a new one, and the trousers were pulled up without lifting the patient's body. The characteristics of diaper change movements were divided into three types: eight subjects (38%) made contact with the bed frame with their thighs, knees, or lower limbs throughout changing a diaper; seven (33%) made contact with the fence or frame with their abdomen or thighs; and six (29%) knelt on one knee on the bed.

The bed height at which the 21 subjects usually changed diapers was 51.7±7.2 cm (range: 46–65 cm), and it corresponded to 32.5±4.7% (range: 27–42%) of their height (height rate) (Table 1). The height preferred by the subjects was 63.4±8.9 cm (range: 44–79 cm), which was 40.0±5.5% (range: 28–51%) of subjects' height. The bed height corresponding to 45% of subject's height (hereafter, the 45% bed height) was 71.0±2.5 cm (range: 67–77 cm). Significant differences were noted among these three heights (repeated measures ANOVA;  $F(2,40)=53.51$ ,  $p<0.001$ ). In the Bonferroni test, the bed height of routine work was significantly lower than that preferred by the subjects, and the height preferred by the subjects was significantly lower than that of the 45% bed height.

The time required for changing a diaper was 3.2±0.7 minutes at the routine height, 3.1±0.1 minutes at the preferred height, and 3.4±1.0 minutes at the 45% bed height, showing significant differences among the three heights (repeated measures ANOVA,  $F(2,40)=5.79$ ,  $p=0.006$ ). In Bonferroni multiple comparison, the time required at the

**Table 1.** Three bed heights

	Routine bed height	Preferred bed height	45% bed height	Repeated measures analysis of variance p	Bonferroni test <sup>a</sup>
Bed height (cm)	51.7±7.2 (46–65)	63.4±8.9 (44–79)	71.0±2.5 (66–77)	***	Routine bed height < Preferred bed height Preferred bed height < 45% bed height Routine bed height < 45% bed height
Height rate (%)	32.5±4.7 (27–42)	40.0±5.5 (28–51)	45	-	-

n=21, mean±SD, \*\*p&lt;0.01, \*\*\*p&lt;0.001

<sup>a</sup> In the Bonferroni test, the significance level was set at 0.05/3=0.0167**Table 2.** Comparison of activity levels of eight muscles among the three bed heights

		Routine bed height	Preferred bed height	45% bed height	Repeated measures analysis of variance p	Bonferroni test <sup>a</sup>
Erector spinae	Left	3955.3 ± 2072.5	3969.9 ± 1698.6	4488.9 ± 2053.8	*	-
	Right	4124.2 ± 1790.5	4174.8 ± 1462.6	4612.1 ± 1688.2		
Rectus abdominis	Left	1185.5 ± 809.2	1094.5 ± 715.2	1214.1 ± 774.5		-
	Right	1336.0 ± 1114.0	1234.7 ± 979.1	1383.0 ± 1105.8		
Vastus lateralis	Left	651.3 ± 362.9	573.9 ± 289.1	615.8 ± 399.2		-
	Right	614.4 ± 304.2	578.8 ± 278.6	616.0 ± 339.2		
Semitendinosus	Left	2801.0 ± 932.4	2630.7 ± 952.2	2659.3 ± 1158.3		-
	Right	2925.0 ± 1116.9	2665.5 ± 1240.9	2650.3 ± 1192.4		

n=21, Integrals of muscle activity (%), mean±SD, \*p &lt;0.05

<sup>a</sup> In the Bonferroni test, the significance level was set at 0.05/3=0.0167

preferred height was shorter than that at the 45% bed height.

The integrated values of %MVC of the bilateral erector spinae, rectus abdominis, lateral vastus, and semitendinosus muscles during diaper change movements were determined at each bed height. The right erector spinae activity level significantly differed among the three bed heights (repeated measures ANOVA,  $F(2,40)=3.67$ ,  $p=0.034$ ) (Table 2). The muscle activity level increased in the order of the routine height, preferred height, and the 45% bed height, but no significant differences were noted in Bonferroni multiple comparisons. No significant differences were noted in the left erector spinae, bilateral rectus abdominis, lateral vastus, or semitendinosus muscle activity levels among the three bed heights.

At a bed height of 45% of subjects mean height, all 21 subjects made contact with the bed mattress with their thighs to form a fulcrum throughout changing a diaper. At the routine height, most subjects (13, 62%) made contact with the mattress or bed frame with their thighs or knees throughout changing a diaper, and the bed height and its height relative to subjects' height were 54.5±7.9 cm (range: 47–65 cm) and 34.4±5.0% (range: 29–42%), respectively. Seven subjects (33%) knelt on one knee on the bed, and two knelt on one knee throughout changing a diaper. Among the seven subjects who knelt on one knee on the bed, three did so when they pulled down the trousers, five when they opened the tape of the used diaper, five when they folded the used diaper and spread out a new diaper, six when they placed the patient in the supine position and fixed the new

diaper, six when they removed the used diaper, five when they fixed the tape of the new diaper, five when they cleaned the genital region, and five when they pulled up the trousers. The bed height and height relative to subjects' height were 47.4±2.1 cm (range: 46–65 cm) and 29.4±2.1% (range: 27–33%) for these seven subjects, respectively. The remaining subject (5%) fixed her abdominal region over the knees to the fence throughout changing a diaper, and the bed height and height relative to the subject's height were 46 cm and 30%, respectively. At the preferred bed height, most subjects (17, 81%) made contact with the mattress or bed frame with their thighs, knees, or lower abdominal region throughout changing a diaper, and the bed height and height relative to subjects' mean height were 65.8±7.4 cm (range: 54–79 cm) and 41.3±4.7% (range: 34–51%), respectively. Of the three subjects (14%) who knelt on one knee on the bed, two did so when they pulled down the trousers, one when she opened the tape of the used diaper, three when they folded the used diaper and spread out a new diaper, two when they placed the patient in a supine position and fixed the new diaper, three when they removed the used diaper, two when they fixed the tape of the new diaper, one when she cleaned the genital region, and two when they pulled up the trousers. The bed height and height relative to subject's height were 54.7±9.3 cm (range: 44–61 cm) and 34.7±6.1% (range: 28–40%) for these three subjects, respectively. The remaining subject (5%) fixed her abdominal region over the knees to the fence throughout changing a diaper, and the bed height and height relative to the subject's height were



**Table 3.** Comparison of subjective fatigue and perceived exertion of the low back among the three bed heights

	Routine bed height	Preferred bed height	45% bed height	Friedman's test p	Multiple comparison <sup>c</sup>
Subjective fatigue of the low back <sup>a</sup>	24.0 ± 22.7	9.5 ± 12.5	8.9 ± 13.4	***	45% bed height < Routine bed height Preferred bed height < Routine bed height
Perceived exertion of the low back <sup>b</sup>	2.6 ± 2.1	1.5 ± 1.6	1.5 ± 1.5	**	-

n=21, mean±SD, \*p<0.05, \*\*p<0.01, \*\*\*p<0.001

<sup>a</sup> Visual analog scale (0–100 mm)

<sup>b</sup> Borg's CR-10 scale (0–10 points)

<sup>c</sup> In the multiple comparison, the significance level was set at 0.05/3=0.0167

32 cm and 32%, respectively.

The levels of subjective fatigue of the low back after changing a diaper were 24.0±22.7, 9.5±12.5, and 8.9±13.4 out of 100 mm at the routine height, preferred height, and the 45% bed height, respectively, showing significant differences among the three bed heights (Friedman's test,  $\chi^2=27.22$ ,  $p<0.001$ ) (Table 3). In multiple comparison, the fatigue level at the 45% bed height was lower than that at the routine height, and that at the preferred height was lower than that at the routine height. The levels of perceived exertion of the low back were 2.6±2.1, 1.5±1.6, and 1.5±1.5 out of 10 points at the routine height, preferred height, and 45% bed height, respectively, showing significant differences among the three heights (Friedman's test,  $\chi^2=13.09$ ,  $p=0.001$ ), but no significant difference was detected in multiple comparison.

## DISCUSSION

It has been reported that occupational low back pain is experienced by 50% of nurses at hospitals and care workers at nursing homes<sup>1–5</sup>). In nursing homes, caregivers assist with the activities of daily life for patients requiring nursing care, and the lumbar load of these caregivers is high. In terms of preserving the health of caregivers, prevention of low back pain is very important. Using an actual value of agonist trunk and lower-limb muscle activity, we made an estimate of low back spinal compression. By evaluating skilled caregivers with no low back pain despite the fact that they frequently changed diapers every day, we elucidated their diaper change movements and investigated the low back load while changing a diaper at different bed heights to identify the movements producing the smallest low back load. It is thought that these results will contribute to the prevention of low back pain.

The bed height in routine diaper changes was lower than that preferred by the skilled caregivers. The bed height may have been adjusted to assist with transfer to a wheelchair because the patients' grades of requiring long-term care were high. However, the time required for changing a diaper was shorter when the height was adjusted to the preferred level, suggesting that caregivers can more efficiently change a diaper at their preferred bed height.

The right erector spinae muscle activity level of the 21 skilled caregivers while changing a diaper was significantly different among the three bed heights (about 52, 63, and

71 cm), but no significant difference was detected in multiple comparison. This may have been due to the fact that the subjects adjusted their movement to the bed height to reduce the low back load. Caboor et al.<sup>16</sup>) compared muscle activities and perceived exertion of 16 nurses while nursing patients requiring long-term care other than diaper changes, such as attaching a bedpan and foot bath, at the standard bed height (51.5 cm) and at the height chosen by the subjects (mean height: 57.9 cm [range: 49.5–65.5 cm]). They observed no significant differences in the bilateral erector spinae, femoral biceps, or external oblique muscle activity level or perceived exertion between the two heights. In a study reported by De Looze et al.<sup>17</sup>), 22 nurses performed a patient-handling task at the standard bed height (71.5 cm) of academic hospitals in Brussels and at heights selected by the subjects: 1) 46.1% of subjects' height for turning in the bed, 2) 44.7% for pulling upward, 3) 42.5% for lifting from the bed. The time-integrated compression and peak shear force were compared, and both parameters were significantly lower when the subjects adjusted the bed height to their preferred height. As noted above, there have been few studies on the load on the spinal muscles associated with bed height during patient care, and the clarification is insufficient. The present study focused on skilled caregivers and investigated their diaper change movements and the lumbar erector spinae muscle activity during movements at various bed heights.

At the 45% bed height, all 21 subjects made contact with the bed mattress with their thighs to form a fulcrum throughout changing a diaper. At the routine height, some subjects made contact with the bed mattress or frame with their thighs or knees throughout changing a diaper, and others temporarily knelt on one knee on the bed. At the preferred height, 81% of the subjects made contact with the bed mattress or frame with their thighs, knees, or lower abdominal region throughout changing a diaper, and 14% temporarily knelt on one knee on the bed. In a study reported by Skotte<sup>24</sup>), one nurse performed seven different handling tasks excluding changing a diaper, such as lifting and repositioning, with their knees in contact with the bedframe to form a fulcrum or without forming a fulcrum by keeping away from the bed. The L4/L5 moment was measured using force platforms placed on the floor and a force transducer bar attached to the bedframe. The low back load was smaller when a fulcrum was formed on the bed. In a study performed by Iwakiri et al.<sup>25</sup>), a thick round, or small or

large rectangular cushion was attached to a kitchen counter, and nine female subjects washed dishes with their tibia in contact with the cushion attached to the counter. The muscle activity level and subjective fatigue were lower when the round cushion was attached. Based on these findings, caregivers adopt a forward-bent posture while changing a diaper to get close to the patient, and the center of gravity and body weight loaded on the anterior region of the body are supported by the low back, which causes excess tension of in the erector spinae muscle. The skilled caregivers made contact with the bed mattress or frame with their thighs, knees, and lower abdominal region to form a fulcrum, through which the force loaded on the dorsolumbar region may have been dispersed, reducing the low back load.

At the routine height, 7 of the 21 subjects temporarily knelt on one knee on the bed while changing a diaper; the height at which they could easily kneel on one knee while changing a diaper was about 52 cm (about 32% height rate). By kneeling on one knee while pulling down the trousers, changing a used diaper to a new one, cleaning the genital region, and pulling up the trousers, they may have been able to retain a posture to easily get close to the patient and move. Shogenji et al.<sup>13)</sup> compared the trunk flexion angle of 13 nurses while changing a diaper with and without temporarily kneeling on one knee on the bed at the standard bed height used in nursing homes (50 cm) and observed that the angle was smaller when one knee was placed on the bed. They concluded that kneeling on one knee while changing a diaper is useful at the standard bed height used in nursing homes (50 cm). A 52-cm bed height corresponded to about 32% of the height of the caregivers. Pheasant<sup>14)</sup> pointed out that patient handling while kneeling on one knee on a bed is difficult when the bed height is 70 cm or higher, and suggested that temporarily kneeling on one knee on a bed is useful when the bed height corresponds to about 32% of the caregiver's height.

The right erector spinae muscle activity level was higher at the 45% bed height rate than at the routine and preferred heights, but subjective fatigue and perceived exertion of the low back were smaller, suggesting that the low back load accumulates when caregivers change diapers at the 45% bed height because subjective symptoms are mild. It is necessary to take a sufficient rest after diaper changes in consideration of the load on the dorsolumbar muscles.

As limitations of this study, it is possible that the erector spinae muscle activity level was underestimated in electromyography, because a flexion-relaxation phenomenon may occur due to the absence of muscle activity in a forward-bent posture<sup>26)</sup>, for which measurement of the low back load based on the trunk inclination angle<sup>9, 27)</sup> is necessary, in addition to electromyography. It is also necessary to determine the effect of the weight and height of the different patients on the lumbar load. This was an experimental study, and the conditions were prepared to faithfully reproduce the usual nursing movement of the subjects; however, the physical condition of patients requiring long-term care and the nursing environment were limited, and only female subjects and patients were involved.

In conclusion, significant differences were noted in the

right erector spinae muscle activity level of skilled caregivers when changing a diaper at bed heights of about 52, 63 and 71 cm. Significant differences were also noted in subjective fatigue and perceived exertion of the low back. Skilled caregivers altered the way of forming a fulcrum for diaper change movement depending on the bed height. They formed a fulcrum by making contact with the mattress with their thighs at the 45% bed height (about 71 cm), their thighs and knees at the routine height (about 52 cm, about 32% of subjects' height), and their thighs, knees, and lower abdominal region at the preferred height (about 63 cm, about 40% of subjects' height). It was suggested that kneeling on one knee on a bed for pulling down the trousers, changing a used diaper to a new one, cleaning the genital region, and pulling up the trousers is easy at the routine height. It was also suggested that the erector spinae muscle activity level and subjective low back load may not be consistent when the bed height is 45% of the caregiver's height.

## ACKNOWLEDGEMENTS

We are grateful to representatives of all the cooperating nursing homes and all the subjects who participated in this study. This study was supported by the France Bed Medical Home Care Research Subsidy Public Interest Incorporated Foundation of Japan, 2011.

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