

Low back load differences between novice and skilled caregivers when changing a diaper on a futon and a bed

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Abstract

Objectives: To clarify the difference in low back load between novice and skilled caregivers in diaper changing on a futon and a bed.

Methods: Agonist trunk and lower-limb muscle activity during diaper changing in 26 novice and 21 skilled caregivers was examined using a surface electromyograph attached to 8 agonist muscles, including the left and right lumbar erector spinae, rectus abdominis, vastus lateralis, and semitendinosus. The low back loads during diaper changes on the futon and bed were measured. The maximum voluntary contractions of the 8 muscles were normalized (%MVC) to compare their mean integrals between the novice and skilled caregivers on the futon and bed, and analyzed using t-tests, paired t-tests, and two-way analysis of variance. Using MyoResearch XP Software, diaper changing measurements were simultaneously videotaped to perform real-time analysis of movements and muscle activity.

Results: For care time, novices took significantly longer to perform a diaper change on the futon and bed compared with skilled caregivers. The bilateral erector spinae in the novice caregivers was significantly greater on the bed than on the futon, but there was no significant difference in the rectus abdominis. In skilled caregivers, there was no significant difference in erector spinae and the rectus abdominis between the futon and bed. On the futon, no significant differences were observed in the left and right erector spinae and rectus abdominis between the novice and skilled caregivers. On the bed, the right erector spinae was significantly greater in novice compared with the skilled caregivers. For the bilateral vastus lateralis and semitendinosus, muscle activity in novice caregivers was significantly greater compared with skilled caregivers on the futon and bed. Skilled caregivers tended to maintain their posture by standing with their femora supported by the bed mattress throughout care activity on the bed.

Discussion: It may be necessary for novice caregivers to acquire higher-level skills, such as creating a supporting point on the bed throughout caring activity. This will allow care activities to be performed efficiently with a reduced lumbar load, while making full use of the convenience of beds and the lower height difference from caregiver to receiver.

Key words

surface electromyogram, caregiver, low back load, changing a diaper, core stability

Introduction

Low back pain frequently occurs among nurses, caregivers of nursing home, and families engaged in home care¹⁻⁷. In novice caregivers such as novice care workers and family caregivers, low back load is likely to be great because of their novice skill level⁵⁻⁷. Low back pain in caregivers is

often the result of myofascial low back pain and lumbar vertebrae degeneration⁸).

Work tasks, postures, techniques, and environments are risk factors for care-related low back pain. Diaper changing frequently performed throughout the day while adopting a forward-leaning posture are high-risk work tasks that involve lumbar

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muscles. Similarly, a continuous severe forward-flexed posture during activities is a high-risk work posture, and the low back load increases to compensate for the force in the forward direction. The Stockholm Training Concept and Halvor Lunde movement techniques⁹⁻¹⁰, in which the unit is described in “movements,” are recommended as effective work techniques to reduce low back load. However, the most appropriate diaper changing technique while adopting the guidelines and the associated low back load have not yet been examined. For care movements on a bed, a method¹¹⁻¹² using the knee of the caregiver placed on the bed as a fulcrum is recommended. It may be that a fulcrum applied elsewhere by the same or another part of the body on the bed would be better. Shogenji et al¹¹ set 50 cm as the optimal height of the bed for nurses to use with one knee on the bed, and found that during diaper changes low back load was low, but the height of the bed was limited with 50 cm. The height of the bed is modified depend on the physical characteristics of a caregiver and the care receiver, therefore it is uncertain for the caregiver to where and when they should make a fulcrum point.

The height of a bed reportedly has an important influence on caregivers’ performance and posture¹³, opinions are divided both inside and outside Japan¹⁴⁻¹⁶. The posture that a caregiver should adopt involves a lightly bent cubital joint in the standing position¹⁷, and 45% of bed height, which allows easy care. However, there are no available studies with objective data that can confirm that 45% of bed height is the optimal percentage.

In Japan, care receivers may spend the daytime on tatami mats. In care facilities, futons are also used for some patients with cognitive impairment at risk of falling from the bed to ensure their safety during the night. In short, while both professional and family caregivers perform care activities, including diaper changing, in diverse care environments using futons and beds, no study has evaluated low back load associated with care in different environments.

The movements of skilled caregivers without lumbago are likely to be work techniques involving

a reduced low back load, despite the long-term care activities. Electromyography, as an index for physiological evaluation of muscle activity based on myogenic potential, has been used to estimate low back spinal compression. While the majority of previous studies using electromyography reported peak compression, it has recently been used to evaluate cumulative compression in work environments¹⁵⁻¹⁸⁻¹⁹⁻²⁰. The recently introduced surface electromyograph, TeleMyo 2400 (Noraxon U.S.A. Inc.), incorporates artifact-free signal processing technology to reduce the influence of artifacts and noise on the recorded signal. It facilitates muscle activity measurement using simultaneous video recording and real-time quantitative analysis of low back load during care activities.

Panjabi²¹ describes an active subsystem led by the flexor group including the abdominal, and the extensor group including the erector spine in the stabilizing system of the spine. We chose the rectus abdominis, which is involved in spinal column flexure through progressed lumbar erector spinae, as a source associated with the stability of the lumbar trunk. We selected the vastus lateralis, which connects with the semitendinosus. Because these muscles function at diaper exchange, we hypothesized that the spinal column might be stable. Core stability²¹⁻²² can be used to support low back load and prevent low back pain. We used similar equipment to measure muscle activity diaper exchange in different caregivers, and confirmed its validity and general characteristics¹⁹.

The skilled caregiver may conduct care movements producing a small lumbar stress²³, by adopting this method¹⁹, it is possible to analyze the low back load muscles of skilled caregivers without low back pain while changing a diaper to clarify care movements producing small lumbar load. Conversely, clear pain-causing movements in novice caregivers, such as novice care worker and family are made because of their novice skill level. We hypothesized that higher care skill would be associated with low lumbar erector spine muscle activity. Additionally, we also analyzed muscle activity in different care locations.

Purpose

This study aimed to identify low back load differences for diaper change movements by measuring low back agonist muscle activity in novice and skilled caregivers, when changing a diaper on a futon or bed set at 45% of the caregiver's height, and by comparing the mean integrals of the normalized maximum voluntary contraction (%MVC) of these muscles.

Methods

1. Participants

We invited public participation at a university; twenty-six healthy female university students aged 18 to 20 years without care experience or low back pain participated in the study as novice caregivers (Table 1). Novice caregivers who did not have low back pain had never been treated for low back pain.

In addition, 21 certified healthy female care workers aged 24 to 59 years without low back pain working at a nursing home for 3 years or more while frequently changing diapers near-daily participated in the study as skilled caregivers (Table1). Skilled caregivers who did not have low back pain had never been treated for lumbago during work as a caregiver. Their mean years of experience and number of diaper changes during the daytime and nighttime periods were 7.5 ± 3.4 , 5.7 ± 3.5 , and 16.1 ± 12.5 , respectively.

2. Data collection

The current study measured agonist trunk and lower limb muscle activity while changing a diaper in 26 novice and 21 skilled caregivers, using a surface electromyography attached to eight agonists. Two diaper changing care environments were compared: Japanese-style floor (futon) and home care bed (bed). We conducted measurements on

the bed after measurements on the futon. All caregivers and care receivers were provided with a written copy of the experimental protocol, and discussed the protocol with a member of the research team before starting the study. A single researcher managed and conducted all of the experiments. All care activities were performed with the care receiver placed on a futon or bed. The novice caregivers performed a diaper change after training, while skilled caregivers performed the diaper change as usual. The caregivers were allowed to rest for at least 5 minutes between the two conditions. The care training aimed to provide novice caregivers with general care skills^{10,12,17}. A written and oral explanation and demonstration of the following skills were provided for the futon and bed environments: diaper changing involved placing the care receiver in a lateral position without lifting her body, changing a rectangular diaper, wiping her genital area, and changing the trousers. When a caregiver made contact with subjects from a lateral position to a dorsal position on the bed, the caregiver opened both legs back and forth, and some part of the body physically contacted the bed. After the demonstration, an appropriate care level was confirmed by practicing once or twice, and measured for accuracy.

A 90-cm-wide 5-cm-thick futon was installed directly on the floor covered with tatami mats. The care receiver was placed at a height of 5 cm. An 80-cm-wide bed was set at 45% of the caregiver's height with manually removable bed rails on both sides. Ten healthy female students aged 18 to 19 years participated in the study as care receivers for the novice caregivers. Seven healthy females aged 21 to 52 years participated in the study as care receivers for the skilled caregivers (Table 2). Each caregiver cared for the

Table 1. Comparison of physical parameters between novice and skilled caregivers

	Novice (n=26)	Skilled (n=21)	p
Height (cm)	157.8 ± 0.1	159.0 ± 5.4	p=.480
Body weight (kg)	51.5 ± 7.7	53.8 ± 7.0	p=.301
BMI	20.7 ± 2.5	21.7 ± 3.0	p=.188

Note. t-test, mean ± standard deviation

Table 2. The physical parameters of care receivers in each group

	Novice (n=10)	Skilled (n=7)	p
Height (cm)	160.6 ± 0.1	160.5 ± 5.2	p=.970
Body weight (kg)	55.0 ± 8.6	55.0 ± 6.7	p=.997
BMI	21.3 ± 2.7	21.5 ± 3.4	p=.903

Note. t-test, mean ± standard deviation

same care receiver during the diaper changes. The care receivers wore an open-front pajama jacket, trousers, and a rectangular diaper underneath. To equally simulate limited movements of an elderly female with severe right hemiparesis requiring care, they temporarily used a right-hemiparetic elderly movement simulation device.

The caregivers were equipped with a surface electromyograph (TeleMyo 2400) during their performance. The electromyograph was set at a sampling frequency of 1500 Hz in a frequency band from 10 to 500 Hz. The activities of the following eight agonist lower limb muscles were measured during diaper changes: the left and right lumbar erector spinae, rectus abdominis, vastus lateralis, and semitendinosus. To evaluate agonist trunk and lower limb muscle activity, the maximum voluntary contraction (MVC) of the following eight muscles was measured and normalized (%MVC): the left and right lumbar erector spinae (erector spinae), rectus abdominis, vastus lateralis, and semitendinosus. The obtained %MVC values were multiplied by the time needed to perform diaper changing to calculate integrals of muscle activity during caring activities. The measurement data were analyzed using MyoResearch XP Software (Noraxon, Scottsdale, AZ, USA). The measurements were simultaneously videotaped to perform real-time analysis of care movements and muscle activity.

All measurements involving novice caregivers were performed in the Home Nursing Training Room, Department of Health Sciences, Kanazawa University from July 2008 to September 2009. All measurements involving skilled caregivers were performed in the Home Nursing Training Room, Department of Health Sciences, Kanazawa University and at a care facility from July to December 2011.

3. Analysis

We compared the physical parameters of novice and skilled caregivers, and each care receiver using t-tests. We used care time and integral calculus of the electromyogram level (% MVC), and used two-way analysis of variance (two-way ANOVA) with care location (2 standards of futon and bed) and caregiver skill level (2 standards of novices and skilled) as the two factors. Where care

location (futon and bed) and caregiver skill level (novices and skilled) significantly interacted, we used multiple comparisons test (t test, paired-sample t test) to compare main effects. The level of significance of multiple comparisons was calculated using Bonferroni's inequality as $.05/4 = .0125$. The level of significance in other analyses was set at $p < .05$. All statistical analyses were performed using IBM SPSS Statistics 20. Using MyoResearch XP Software, diaper changing measurements were simultaneously videotaped to perform real-time analysis of care movements and muscle activity.

4. Ethical considerations

Approval of the Medical Ethics Committee at Kanazawa University was obtained for this study involving the novice (February 29, 2008; 121) and skilled caregivers (June 7, 2011; 324). The representatives of the facilities to which the skilled caregivers belonged were provided with a written and oral explanation of the study objective and methods to obtain their cooperation, recommendation of participants, and written consent. The recommended caregivers voluntarily participated in the study with written consent after being provided with a written and oral explanation of the study objective and methods. All novice caregivers and their care receivers also voluntarily participated after being provided with a written and oral explanation of the study objective and methods. They were also previously informed that they were free to withdraw from the measurements without any disadvantage. We also informed the subjects that if there was any lumbago during an experiment, we were going to discontinue the experiment promptly. The surface electromyograph and right-hemiparetic elderly movement simulation device used in the study have been proven to be noninvasive. Video recorded images were reviewed by the participants to obtain their consent before storage. Ethical considerations also included privacy protection and careful management of data.

Results

1. Time needed for a diaper change

The two-way ANOVA result was significant

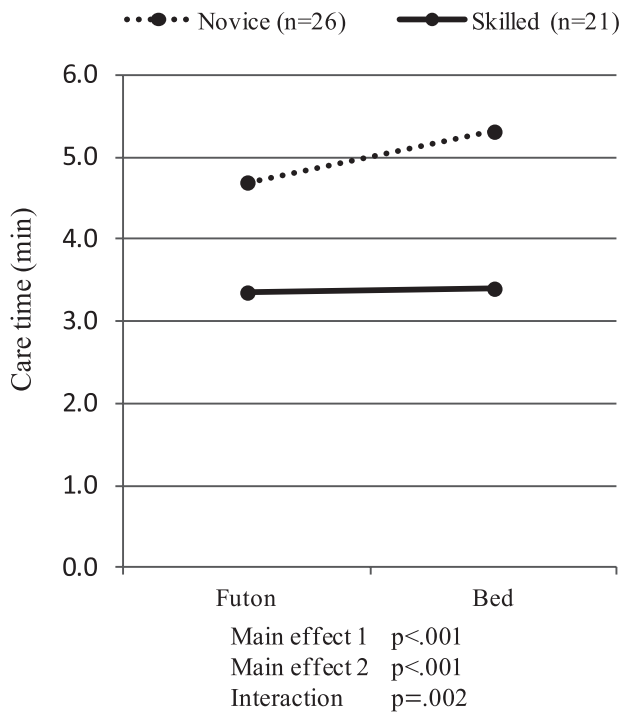


Figure 1. Comparison of care time between care location (futon and bed) and care skill level (novice and skilled)

Note. Two way ANOVAs
 Main effect 1 (care location: Futon, Bed)
 Main effect 2 (care skill level: Novice, Skilled)
 Interaction (care location \times care skill level)

[$F(1,45) = 10.69, p = .002$] with a significant interaction of care location (futon and bed) and care skill level (novices and skilled) for care times (Figure 1). A multiple comparisons test showed that novice caregivers took significantly longer to change a diaper compared with skilled caregivers on the futon and bed. For novice caregivers, a bed was associated with significantly longer care times compared with a futon. For skilled caregivers, care time was not significantly different between a futon and bed.

2. Effect of care location (futon and bed) and care skill level (novices and skilled) when changing a diaper on the activity of 8 agonist muscles

The two-way ANOVA result was significant [$F(1,45) = 11.27, p = .002$] with a significant interaction of care location (futon and bed) and care skill level (novices and skilled) for muscle activity of the left erector spinae (Figure 2). A multiple comparisons test showed that muscle activity of the left erector spinae was not significantly different between

novices and skilled caregivers in the futon. In the bed, muscle activity of the left erector spinae was not significantly different between novices and skilled caregivers. In novice caregivers, a bed was significantly greater muscle activity of the left erector spinae compared with a futon. In skilled caregivers, muscle activity of the left erector spinae was not significantly different between futon and bed environments.

Similarly, we found care environment interacted with skill level in muscle activity of the right erector spinae [$F(1,45) = 6.03, p = .018$]. Multiple comparisons test showed that muscle activity of the right erector spinae was not significantly different between novice and skilled caregivers with on the futon. In the bed, novice caregivers were significantly greater muscle activity of the right erector spinae compared with skilled caregivers. In novice caregivers, a bed was significantly greater muscle activity of the right erector spinae compared with a futon. In skilled caregivers, muscle activity of the right erector spinae was not significantly different between on the futon and bed.

The interaction of care location and care skill level with the main effects of care location and care skill level were not found for muscle activity of the left rectus abdominis. There was an interaction of care location and care skill level with muscle activity of the right rectus abdominis [$F(1,45) = 5.11, p = .029$], but no significant effect using multiple comparisons test.

Muscle activity of the left vastus lateralis was not associated with an interaction of care location and care skill level. The futon was significantly greater compared with a bed, and was associated with a main effect of care location [$F(1,45) = 5.81, p = .020$]. Novice caregivers were significantly greater than skilled caregivers and were associated with a main effect of care skill level [$F(1,45) = 20.33, p < .001$]. Muscle activity of the right vastus lateralis did not interact with care location and care skill level. The futon was significantly greater compared with a bed and was associated with a main effect of care location [$F(1,45) = 4.56, p = .038$]. Novice caregivers were significantly greater than skilled caregivers and were associated with a main

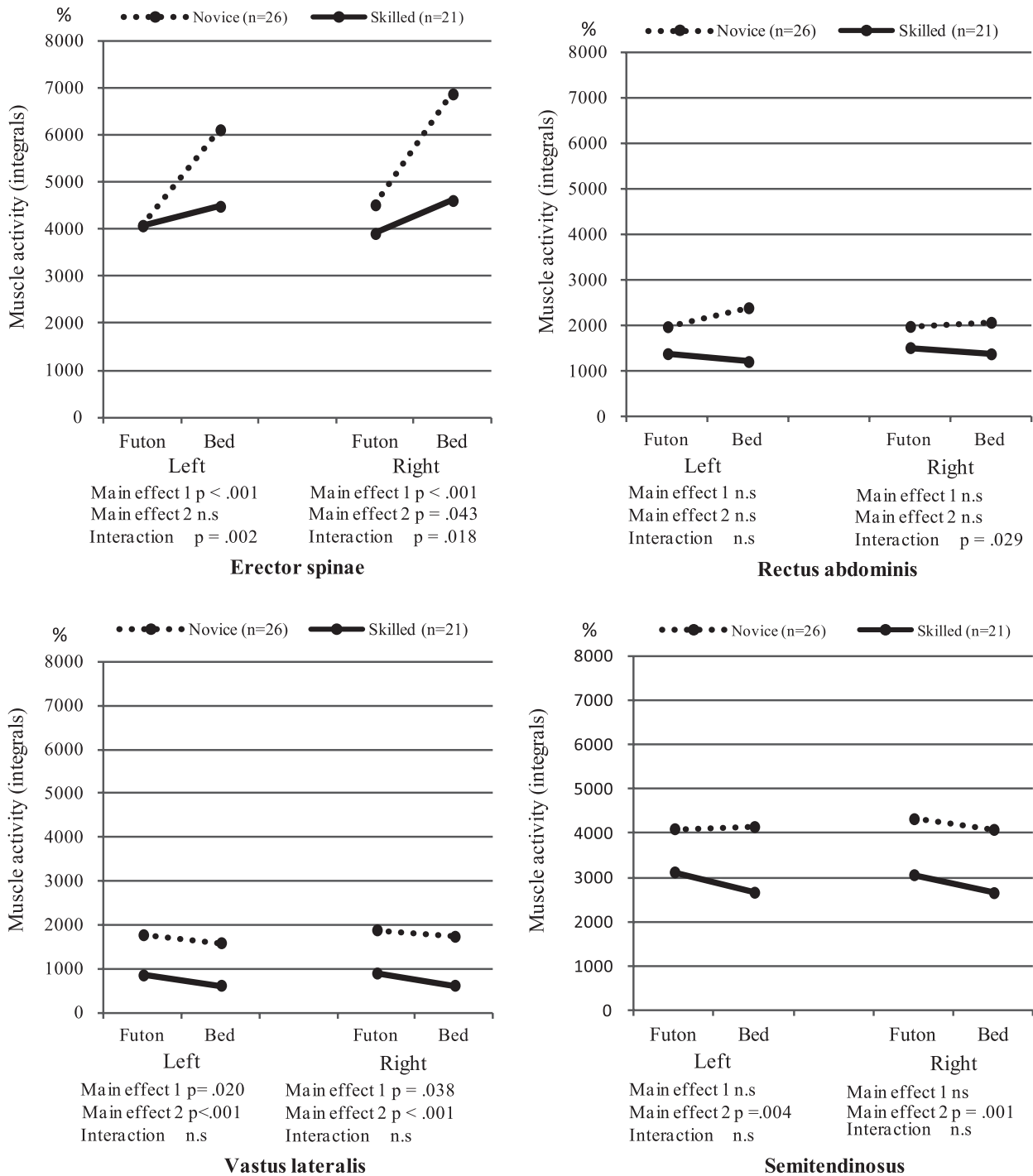


Figure 2. Comparison of muscle activity (integrals) between care location (futon and bed) and care skill level (novice and skilled)

Note. Two way ANOVAs, n.s: non-significant
 Main effect 1 (care location: Futon, Bed)
 Main effect 2 (care skill level: Novice, Skilled)
 Interaction (care location × care skill level)

effect of care skill level [$F(1,45) = 28.46, p < .001$].

Muscle activity of the left semitendinosus did not interact with care location and care skill level. Novice caregivers were significantly higher compared with skilled caregivers and were associated with a

main effect of care skill level [$F(1,45) = 8.97, p = .004$]. The main effect of care location was not significant. Muscle activity of the right semitendinosus did not interact with care location and care skill level. Novice caregivers were significantly greater

compared with skilled caregivers, and the main effect of care skill level was significant [F (1,45) = 12.36, p = .001]. The main effect of care location was not significant.

3. Difference in care movements between novice and skilled caregivers

Analysis of the images recorded during performance revealed that all novice and skilled caregivers approached the care receiver closely by almost always kneeling, while changing a diaper on the futon. The key difference between caregivers during this performance was that 23 novices moved by walking to shift from the care receiver's left to right-hand side when removing a used diaper, while none of the skilled caregivers changed their position even when removing it. The diaper exchange movement of all skilled caregivers was similar on the futon.

On the bed, 20 novice caregivers moved via walking to shift from the care receiver's right to left-hand side to remove a used diaper and replace it with a new one, while all skilled caregivers maintained their posture by standing with their femora supported by the bed mattress. The diaper exchange movement of all skilled caregivers was similar on the bed.

Discussion

1. Difference of care location in low back load

1) Difference in low back load between the novice and skilled caregivers on the futon

No significant differences in the activities of the left and right erector spinae and rectus abdominis muscles were observed between the 26 novice and 21 skilled caregivers when changing a diaper on the futon. This result suggests that it was easy, even for novice caregivers, to approach the care-receiver closely on the futon. Furthermore, in terms of the load to the trunk, novices have been able to use their acquired caring similar to skilled caregivers.

For the bilateral vastus lateralis muscles and semitendinosus, muscle activity in novice caregivers was significantly higher compared with skilled caregivers. Novice caregivers frequently stood up from the floor to shift their target sites, resulting in

a rapid increase in the activity of the vastus lateralis followed by activity of the semitendinosus. Overall, this tended to decrease protection of the lumbar region.

2) Difference in low back load between the novice and skilled caregivers on the bed

The activities of the right erector spinae muscles, when changing a diaper on the bed, were significantly greater in the novice compared with the skilled caregivers. Because the bed was 80 cm wide, all caregivers tended to adopt a forward-leaning posture during the performance. In such a posture, the erector spinae muscles of the dominant hand side may be overstressed while the low back load increases to support the forward-directed force and body weight. The skilled caregivers, however, avoided this by using the bed mattress as a supporting point to maintain their lower limb stability to disperse the load on the erector spinae muscles and consequently decrease low back stress. In contrast, novice caregivers sometimes were unable to maintain their knee in position on the bed, a novice caregiver who moved by walking to shift from the care-receiver's right to left hand in order to remove a used diaper and tape a new one.

In an experiment conducted by Skotte²⁰, a nurse was instructed to perform seven different handling tasks, excluding diaper changing, such as lifting and repositioning, as she usually did. The results demonstrated that the creation of a supporting point on the bed reduced the low back load. In a study conducted by Iwakiri et al²⁰ involving nine females to examine the creation of appropriate support for the tibia with small, large, round, and rectangular cushions installed on the side of a kitchen counter, muscle activity and subjective discomfort were shown to be lowest with round cushions. Shogenji et al¹¹ proposed a method to pick up one knee to change a diaper. Based on these findings, it was found that it is possible to decrease low back load by making fulcrums throughout the diaper exchange at 45% of bed high height.

In novice caregiver, because a change in muscle activity was not found for the rectus abdominis

muscle, it is inferred that the abdominis muscle was not significantly engaged. We suggest that it is necessary to always be conscious of the rectus abdominis muscle at the time of posture movements to keep core stability^{21,22)} during care activities.

2. Difference in care skill level and low back load

Novice caregivers are likely to bear a greater low back load because of their novice caring skills, and consequently are at risk for low back pain^{5,7)}. Thus, the importance of developing preventive measures is more urgent for novices compared with experienced care professionals.

For care time, novices took significantly longer to change a diaper on a futon and a bed compared with skilled caregivers. For novice caregivers, a bed was associated with significantly longer care times compared with a futon. The bilateral erector spinae muscle activity in the novice caregivers was significantly greater on the bed than futon, no significant difference in rectus abdominis muscle activity. In skilled caregiver, no significant difference in erector spinae muscle activity and rectus abdominis muscle activity on the futon and bed. This may be because of the use of the skilled caregiver, which controls lumbar load by rapidly performing a movement suitable for care location. Based on the results reported in this study, it may be necessary for novice caregivers to acquire higher-level skills to quickly perform care activities more efficiently with a reduced low back load; while making full use of the convenience of a bed and lower height difference from the care receiver, by creating a supporting point using the bed throughout the performance. In addition, it may be necessary for novice caregivers to undergo training that uses rectus abdominis muscle more effectively.

This study clarified the difference in low back load between novice and skilled caregivers when changing a diaper on a futon and bed set at 45% of the caregiver's height. Using an actual value of agonist trunk and lower-limb muscle activity, we found one estimated low back spinal compression data. Such findings may be novel and important both inside and outside Japan, because they

represent new and beneficial scientific knowledge.

It may be necessary to conduct further studies to evaluate muscles of the upper extremity, intervertebral compressive force²⁵⁾, trunk inclination^{26,27)}, three-dimensional motion data²³⁾, while clarifying low back load during care to obtain clearer evidence.

Limitations of this study and future challenges

In this experimental study, although the measurements were performed in a setting arranged to facilitate the skilled caregivers' usual performance, the physical condition of the care receivers was limited. Furthermore, all participants were female. In this study, university students were screened to find novice caregivers to obtain data, but it will be necessary in the future to investigate novice care workers from nursing homes and family caregivers. Furthermore, in addition to muscle activity, a study using three-dimensional motion analysis and trunk inclination will be necessary in future research.

Conclusions

For care time, novices took significantly longer to change a diaper on a futon and a bed compared with skilled caregivers. The bilateral erector spinae muscle activity in the novice caregivers was significantly greater on the bed than futon, no significant difference in the rectus abdominis muscle activity. In skilled caregiver, no significant difference in erector spinae muscle activity and the rectus abdominis muscle activity on the futon and bed. On the futon, no significant differences in the activities of the left and right erector spinae and rectus abdominis muscles were observed between the novice and skilled caregivers. On the bed, the right erector spinae muscle activity was significantly greater in novice compared with the skilled caregivers. The skilled caregivers' movements were characterized by the use of the bed mattress as a supporting point for their femora throughout the care activity.

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布団とベッド上における介護初心者と介護熟練者の おむつ交換時の腰部負荷の差異

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要 旨

【目的】 布団上とベッド上において、介護の初心者と熟練者間のおむつ交換時の介護動作と腰部負荷の違いを明らかにする。

【方法】 介護の初心者26名と熟練者21名を対象とし、表面筋電計を用いて布団上と在宅介護ベッド上でのおむつ交換時の左右の体幹及び下肢の主動作筋活量(腰部脊柱起立筋、腹直筋、外側広筋、半腱様筋)を計測した。各筋の%MVC(Maximum voluntary contraction)の積分値を算出し、t検定、対応のあるt検定、2元配置分散分析を用いて、布団上とベッド上の初心者と熟練者を比較した。MyoResearch XP Softwareを用いて、筋活量と介護動作をリアルタイムに画像分析した。

【結果】 介護時間は、布団上とベッド上で、初心者の方が熟練者よりも有意に長かった。初心者では、両側の脊柱起立筋はベッド上の方が布団上よりも有意に高かったが、腹直筋には違いがなかった。熟練者では、脊柱起立筋と腹直筋と布団上とベッド上では違いがなかった。布団上では、左右の脊柱起立筋と腹直筋は、初心者と熟練者では違いがなかった。ベッド上では、右の脊柱起立筋は初心者の方が熟練者よりも有意に高かった。両側の外側広筋と半腱様筋は、布団上とベッド上で、初心者の方が有意に高かった。熟練者は、ベッド上での介護時は常に大腿部でマットレスに支点を作っておむつ交換をしていた。

【考察】 布団上では、介護初心者は習得した介護を実践しやすかったと示唆される。ベッド上での介護時は、ベッドの利便性と要介護者との高低差が少ないことを活用して、常にベッドに支点を作っておむつ交換する技術の習得が必要である。