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An Assessment of Workload on Upper Limbs when Caregiver Change the Nursing Trousers

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Abstract

In this research, movements of the upper limbs of caregivers when putting on/removing the dummy's nursing care clothes with different designs were measured using electromyography (EMG) and video filming. Caregivers' sensory assessments of the burden caused by their services were also investigated to determine how the physiological burden in the upper limbs and sensation of burden relate to each other. Subjects were 10 healthy women aged 23 ± 3 years, with a height of 159.7 ± 8.7 cm and weight of 50.5 ± 8 kg. None of the women had ever provided nursing care to anyone. For this experiment, four kinds of samples were used. By combining EMG and questionnaires, it was made possible to quantify the burden on the upper limbs, which cannot be assessed solely according to work time. Differences in the workload associated with trousers having different designs were also studied. Also, the possibility was suggested that by taking such an approach, nursing care clothes may be developed that would further reduce the burden on caregivers while providing nursing care.

Keywords: Nursing Care; Trousers; Workload; EMG

1 Introduction

In Japan 2007, the percentage of elderly people aged 65 or older exceeded 21% of the total population [1]. With Japan's ageing population situation, nursing care has become a significant social issue. When preparing for the national exams to gain a license, nursing care workers are required to posses basic job techniques, ergonomic knowledge, and an understanding to body mechanics that will help them to ease the burden of nursing care [2]. It is, however too much to ask the general public, who often provide home-based care for their family members, to acquire such basic techniques and expert knowledge [3]. Such being the case, there has been a growing demand for the development of nursing care goods that ordinary people can use effectively in their homes without a great deal of expert techniques or knowledge.

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According to the guidelines set by the Ministry of Health, Labour and Welfare of Japan, daily nursing services for Level 3 – Level 5 recipients of nursing care ("bedridden persons") include meals [4], excretion, and changing clothes. Of these services, the caregiver must change the position of the recipient for excretion and changing clothes, and this is feared to cause strain in their lower back. Since such actions also involve procedures that use one's hands, a burden is placed on the upper limbs and shoulders of the caregiver as well.

In many of the studies on nursing care movements and their associated burden, the strain on the lower back and the degree of burden on the entire body are assessed [5, 6], only a few takes into the consideration of the measurement and assessment of the burden associated with the upper limb movements. This area of study should not be taken lightly as it is impossible for caregivers to carry out their jobs without using their upper limbs [7]. If the relationship between movements of the upper limbs and the resultant burden can be made clear, it may be possible to gain knowledge that would be useful for designing nursing care clothes and diapers that can be easily put on and removed.

In this research, the upper limb movements of caregivers when putting on/removing the dummy's nursing care clothes with different designs were measured using electromyography (EMG) and video filming. Caregivers' sensory assessments of the burden caused by their services were also investigated to determine how the physiological burden in the upper limbs and the sensation of burden relate to each other. In other words, the caregivers' burden was not only assessed using motion and EMG analysis, but also their sensation of burden was taken into account in order to gain a full insight of the knowledge that maybe useful for designing caregiver-friendly nursing care goods.

2 Methodology

2.1 Subjects and Experiment Samples

Subjects were 10 healthy women aged 23 ± 3 years, with a height of 159.7 ± 8.7 cm and weight of 50.5 ± 8 kg. None of the women had any nursing care experience. For this experiment, four kinds of samples were used: Sample 1 consisted of ordinary pajama-type trousers (Fig. 1), Sample 2 was a pair of trousers with a fastener on the side of each leg (Fig. 2), Sample 3 had an opening under the crotch secured by Velcro for ease of changing diapers, strings on both sides that could be tied at the center, and narrow cuffs (Fig. 3), and Sample 4 was identical to Sample 3 except that its cuffs were wider (Fig. 4).

Fig. 1: Sample 1

Fig. 2: Sample 2

Fig. 3: Sample 3

Fig. 4: Sample 4

2.2 Experiment Procedures and Measurement Parameters

For this experiment, a silicon dummy named "Koharu-san" (Mitaka Supply Co., Ltd.; Height: 150 cm; Weight: 12 kg) was placed supine on a bed and the subjects were asked to put on and remove four different kinds of trousers on the dummy. Prior to the experiment, the subjects were briefed on the structures of each sample and the experiment procedures, and were given a chance to rehearse one time. To put on the clothes, the subjects were asked to put the sample that was laid out by the dummy's feet onto the dummy. To remove the clothes, the subjects were asked to take the sample that the dummy was wearing and place them by the dummy's feet. Each subject was asked to follow this process of putting on/removing the clothes once for each of the four samples (a total of eight procedures). The height of the bed was approximately 60 cm (Fig. 5).

In order to assess the workload caused by movements during the procedures based on the amount of muscle activity, EMG measurements were taken from the right forearm at: 1. the extensor digitorum muscle (function: dorsal flexion of the hand joint) and 2. the palmaris longus muscle (function: palmar flexion of the hand muscle) (Fig. 6). To analyze the procedures in detail, the experimental process was recorded on video (Panasonic DMC-FX-60) from the head of the dummy. After the experiment was over, in order to assess the sensation of burden from the set of movements, a questionnaire using the semantic differential (SD) method (scores: -2 to $+2$ pts.) was conducted for the four parameters of: ease of pulling up/down the trousers, fatigue when pulling up/down the trousers, ease of putting the trousers on around the hips, and fatigue when putting on the trousers around the hips. For EMG measurements, active electrodes (Delsys DE2-1) were used. Muscle potential signals were imported to a notebook PC at a sampling frequency of 1 kHz via an A/D converter (BIOPAC System MP150).

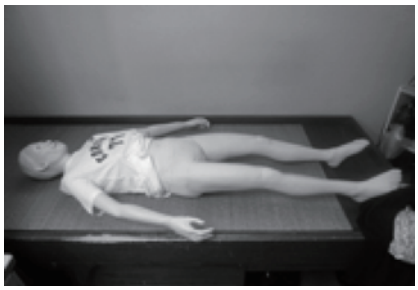

Fig. 5: "Koharu-san" on the bed

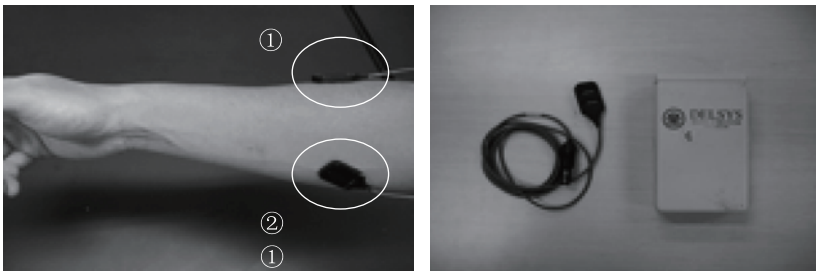

Fig. 6: Electrode attachment points and the electrodes

2.3 Analytical Method

For the purposes of this research, in order to assess the physiological burden of the subjects, time integrated values of rectified EMG (electromyogram) and IEMG (integrated electromyogram) of the muscles being experimented on were calculated, and were then standardized with the value of maximum voluntary contraction (MVC) of voluntary movement as a reference to calculate a percentage of IEMG (%IEMG) per unit time. Additionally, in the three work processes described below, %IEMG was calculated to assess workload. For voluntary movement, the subjects were asked to clench their fists with maximum force while reaching straight outward.

$$\mathrm{IEMG} = \int_{-\mathrm{T}}^{\mathrm{T}} |\mathrm{e(t+T)}| \mathrm{dt}$$

$$\mathrm{e(t)} : \text{EMG signal}$$

$$\%\mathrm{IEMG} = \frac{\text{IEMG per unit time}}{\text{MVC per unit time}}$$

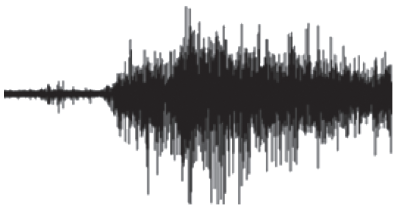

Fig. 7: EMG data

Fig. 8: Voluntary movement for EMG standardization

For video analysis, the time for putting on and removing nursing care trousers was measured using the recorded footage. The work process was divided into three parts and the times for each sub-process were compared: procedures around the ankles (Process 1), intermediate procedures from the ankles to the hips (Process 2), and finishing procedures such as tying the strings (Process 3). For Sample 2, Process 3 was finished when the work was completed with the fasteners closed, and for Samples 3 and 4, Process 3 corresponded to the procedures from tying the strings, etc. to the completion of the job. When removing the trousers, the order of the processes was reversed (Process 3 -> Process 2 -> Process 1), except that Process 3 is not necessary for removing Sample 1 (Process 2 -> Process 1).

For assessment of the sensation of burden, statistical analysis was made of scores from the four questions on the SD method questionnaire.

3 Results

3.1 EMG Measurement

Fig. 9 shows the results of EMG measurement. The %IEMG of the amount of muscle activity is shown on the vertical axis. The higher the value, the greater the muscle load.

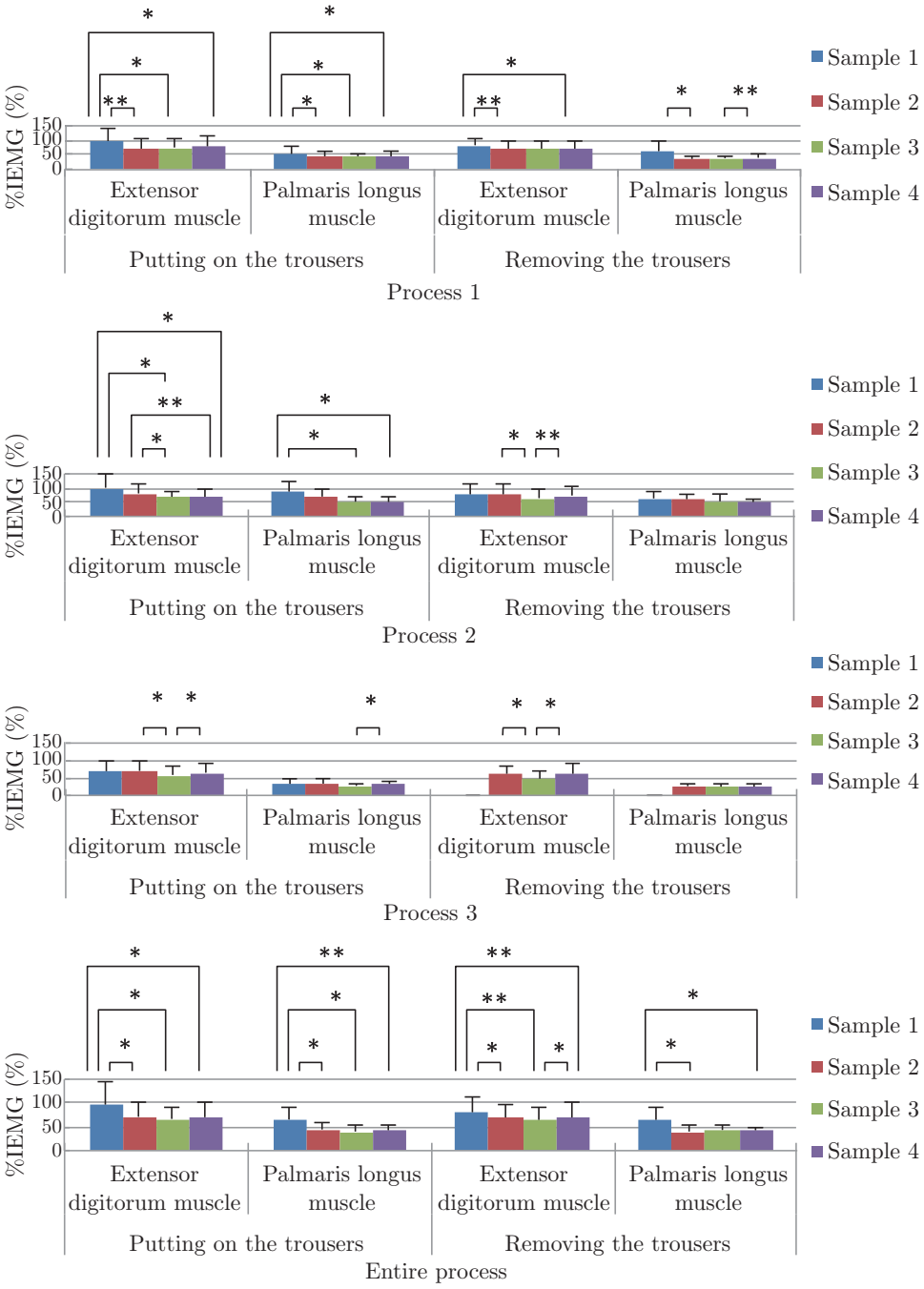

Fig. 9: Comparison of %IEMG

If we look at each sub-process during the act of putting on the trousers, the values for both the extensor digitorum and palmaris longus muscles were highest for Sample 1 in Processes 1 and 2.

The value of %IEMG for the extensor digitorum muscle was significantly higher than those for other samples. In Process 3, the %IEMG values for both the extensor digitorum and palmaris longus muscles were significantly smaller for Sample 3.

When removing the trousers, the value of %IEMG for the extensor digitorum muscle was significantly lower for Sample 3 in Processes 2 and 3, whereas in Process 1 the values of %IEMG for both the extensor digitorum and palmaris longus muscles were highest for Sample 1 and that for the palmaris longus muscle was lower than those of other samples for Sample 2.

For the entire process, the values of %IEMG for both the extensor digitorum and palmaris longus muscles were significantly higher than those of other samples for Sample 1 when putting on and removing the trousers. For the process of removal, the value of %IEMG of the extensor digitorum muscle was significantly lower than that of other samples.

3.2 Work Time

Analysis results of work time when putting on the trousers are shown in Fig. 10, and those for removing the trousers are shown in Fig. 11.

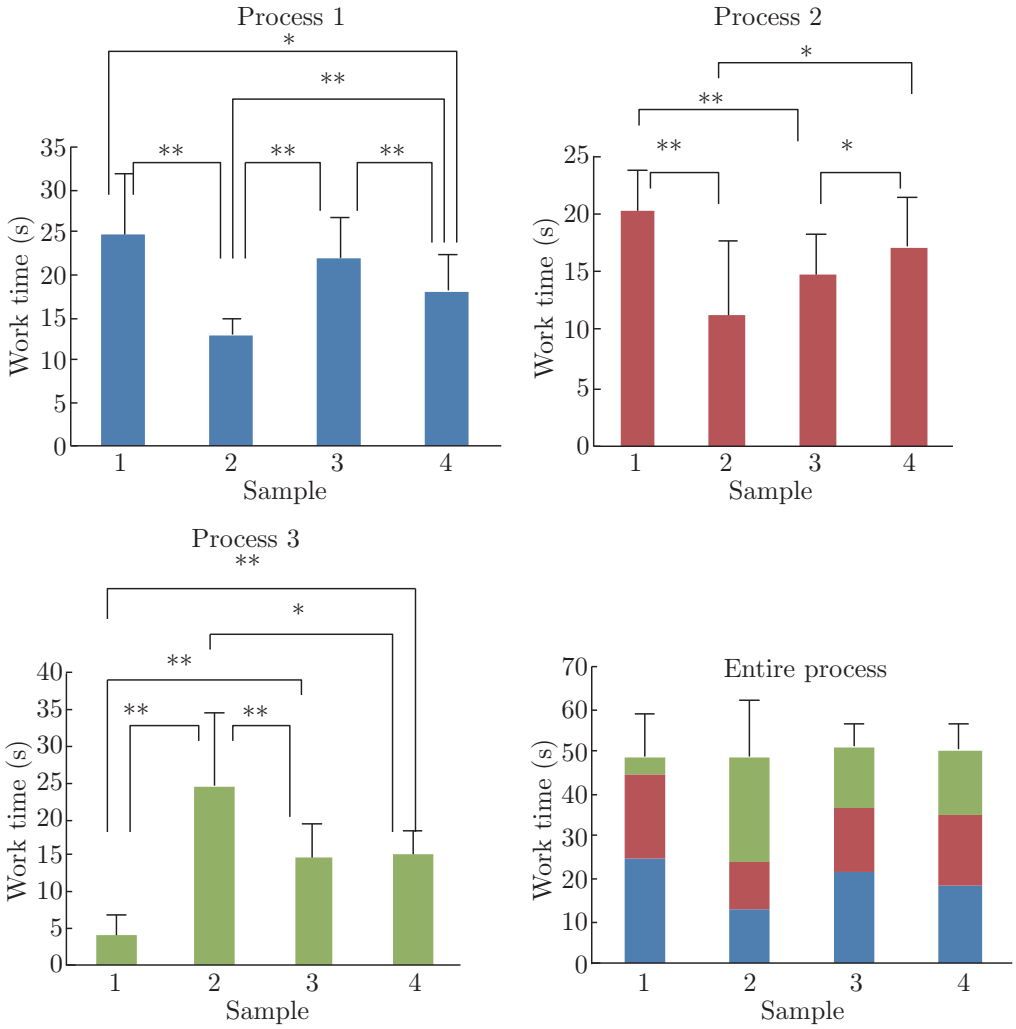

Fig. 10: Average work time for each sample (when putting on the trousers)

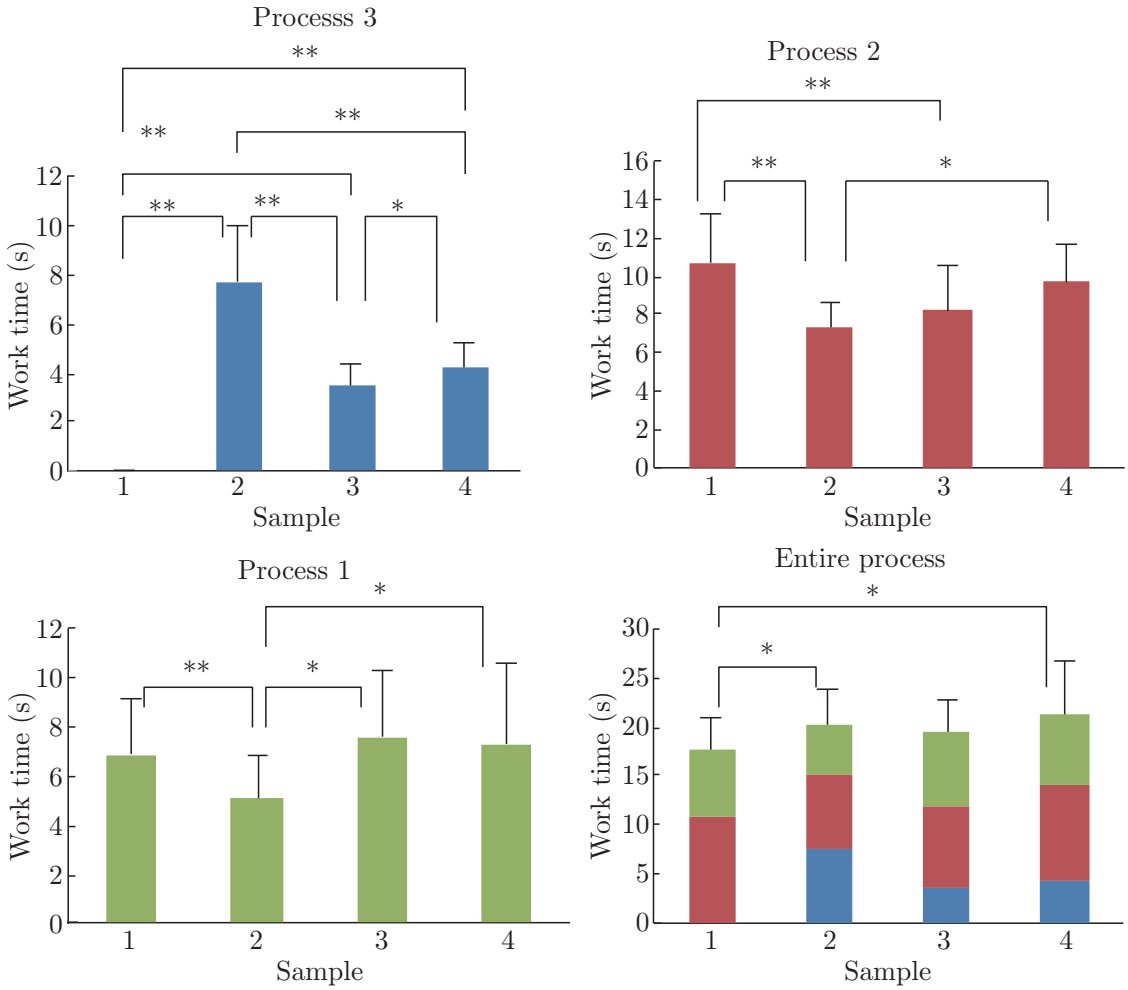

Fig. 11: Average work time for each sample (when removing the trousers)

When putting on the trousers, the work times for Sample 2 during Processes 1 and 2 were significantly shorter than those for other samples, while the time was significantly longer during Process 3. For the entire process, no significant differences could be observed among the different samples.

When removing the trousers, the work time for the entire process for Sample 1 was significantly shorter than those for other samples, since it did not include Process 3. The work time for the entire process for Sample 4 tended to be long because Process 2 was time-consuming.

3.3 Sensation of Burden

Shown below are the results of the questionnaire. By using the SD method, the questionnaire responses were translated into scores according to 5 grades (−2 to +2 pts.) with Sample 1 as a reference (0 pts.). There were significant differences in scores for fatigue felt when pulling up the trousers (Fig. 12) and ease of putting on the trousers around the hips (Fig. 14). Specifically, fatigue (burden) was less likely to be felt when pulling up the trousers for Sample 3 than Sample 2 (and Sample 1). Also, procedures around the hips tended to be easier for Samples 3 and 4 than for Samples 2 and 1.

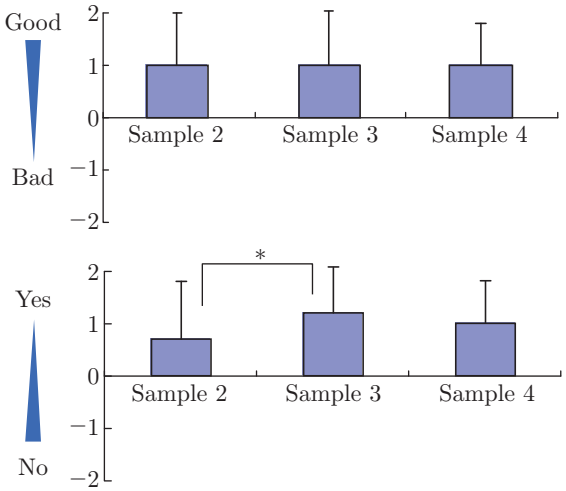

Fig. 12: Questionnaire responses on pulling up the trousers (top: ease, bottom: fatigue)

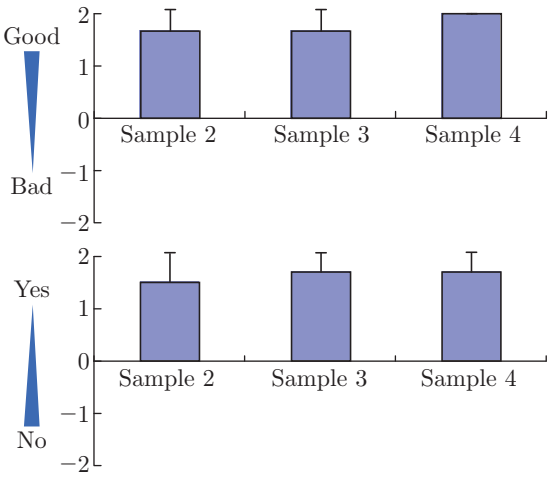

Fig. 13: Questionnaire responses on pulling down the trousers (top: ease, bottom: fatigue)

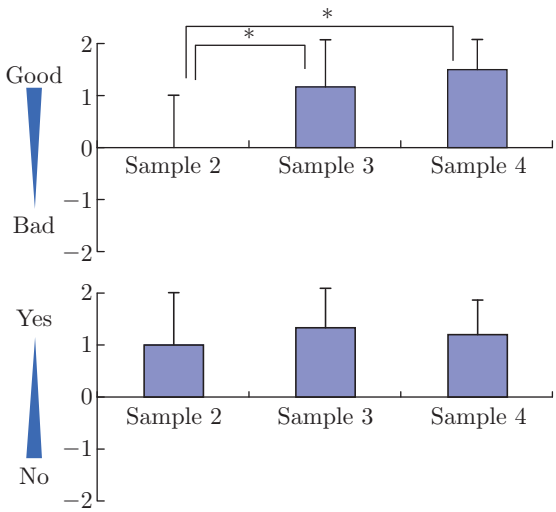

Fig. 14: Questionnaire responses on work around hips (top: ease, bottom: fatigue)

4 Discussion

4.1 Assessment of the Burden on the Upper Limbs When Putting on/Removing the Clothes

As shown in Figures 10 and 11, comparisons of the work times for four different samples throughout the entire process did not show any significant differences. If we are to compare the activities of the two muscles in the upper limbs when putting on/removing the clothes, the amount of such activities for Sample 1 shows significant differences compared to the other samples. Also, the %IEMG value for Sample 1 was high, which suggests that the physiological burden on the upper limbs is great.

If we are to compare muscle activity (%IEMG) when putting on/removing the clothes in each sub-process of putting on the clothes, Sample 1 shows significant differences from other samples for both muscle activities for Process 1, Process 2, and the entire process, so it can be said that Sample 1 results in heavy muscle load. Similarly, when removing the clothes, a comparison among the samples for all of the sub-processes showes that Sample 1 puts a greater load on the muscle for the entire process. In this way, the physiological and by-process analyses have made it possible to make a quantitative comparison of the burden on the upper limbs, which could not be assessed based solely on the work time. Also, the results of subjective assessment revealed that Samples 2 – 4 earned higher scores than Sample 1 for most of the parameters, which leads to the belief that the physiological burden and psychological assessment largely correspond to each other. In light of this, it would be important to combine physiological measurement (EMG) and psychological assessment (questionnaires) when making qualitative evaluations of the burden caused by movements when providing nursing care.

4.2 Designing Nursing Care Trousers

As indicated by the results shown in Figures 10 and 11, the two muscle activities for Sample 1 placed a large burden on the upper limbs during Processes 1 and 2 when putting on nursing care trousers. In other words, the large physiological burden suggests that the procedure of pulling up the trousers and squeezing the hips into them has a significant influence on the burden experienced. This also points to the importance of the trousers' design from the waist to the thigh. For example, if an opening is made in the upper part of the trousers as in Samples 3 and 4, a moderate degree of freedom is allowed when conducting the procedure around the hips, thus reducing the workload.

Concerning the burden on the upper limbs, there is a possibility that movements like lifting the body, places a greater burden on caregivers both physiologically and psychologically when compared to tying strings or other precision works. In other words, it is assumed that designing trousers that decrease movements such as lifting the body to change the nursing care recipients' positions would be effective in reducing the burden on the upper limbs when putting on/removing nursing care trousers.

5 Conclusion

In this research, the burden on the upper limbs when putting on/removing nursing care trousers

was analyzed by EMG measurement, questionnaires, and videos. By combining EMG and questionnaires, it was made possible to quantify the burden on the upper limbs, which cannot be assessed solely according to work time. Differences in the workload associated with trousers having different designs were also studied. Also, the possibility was suggested that by taking such an approach, nursing care clothes may be developed that would further reduce the burden on caregivers while providing nursing care.

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