Extraction and Evaluation of Proficiency in Bed Care Motion for Education Service of Nursing Skill

Junki Nakagawa[1], Qi An[1], Yuki Ishikawa[1], Koshiro Yanai[1], Wen Wen[1], Hiroshi Yamakawa[1], Junko Yasuda[2], Atsushi Yamashita[1], and Hajime Asama[1]
[1] The University of Tokyo, Tokyo, 113-8656, Japan
Tel: +81 3 5841 6456, Fax: +81 3 5841 8547, E-mail: nakagawa@robot.t.u-tokyo.ac.jp
[2] Japanese No Lifting Association, Japan

Abstract
In the areas of care nursing, conventional physical skill education which has been conducted face-to-face prevents both experts and beginners from realizing the effects of their education and practice. In order to solve this problem, we aim to develop an effective skill education service of bed care motion with slide sheet which can prevent the outbreak of lumbago. In this study, we calculated the lumbar burden with measured body joint trajectory, foot reaction force, and muscle activities in the motion of experts and non-experts. Based on these analysis results, nursing skill was extracted and evaluated for skill education service.

Keywords:
Motion Analysis, Healthcare, Skill Education, Motion Measurement

1 INTRODUCTION

Aging society leads to increasing a labor burden of nurse and care worker. Especially, in nursing and care facilities, 60% of nurses and care workers has the occupational low back pain [1]. "No Lifting Policy" is one of the prevention methods of occupational low back pain for nurses and care workers. This policy was suggested by Australian nursing federation in 1996 and prohibit patient transfers with no transfer equipment [2]. Most patient transfers were performed transfer in bed, for example moving up in bed, turning or rolling in bed and moving from lying to sitting in bed [3]. For patient transfer in bed, "slide sheet" has been proposed as an useful tool (Fig. 1). Nurse spread the slide sheet between the bed and the patient, and draw the sheet in order to achieve transfer patients. The slide sheet can lighten burden of both nurse and patients, and is low-cost comparing to electric transfer machines. Thus, slide sheet for patient transfers is worth promoting in many places, such as hospitals, and ordinary homes where health care are necessary.

However, when using the slide sheet, it is important to behave appropriate care movement. Because there is a possibility to increase the burden on not only the nurse but also the patient with wrong movement. In order to disseminate appropriate care motion with slide sheet, skill education of this motion is required.

In the areas of care nursing, the former physical skill education from experts to beginners has been conducted face-to-face. However, face-to-face education is inefficient because experts and beginners have to share their time and space. To deal with this, e-learning service has been widely used in many areas, but still have some unsolved problem in skill education. Specifically, current e-learning service has difficulty to extract skills from movement and valuate skills quantitatively. Thus, it is difficult for both experts and beginners to realize the effects of their education and practice.

In order to solve these problems, we aimed to develop an effective skill education service for e-learning. Figure 2 shows the concept of our suggested skill education service. Our skill education service intends to achieve visualization of the difference between expert's motion and non-expert's motion, expert's motion, and skill for non-expert. Thus, it is necessary to measure expert's motion and non-expert's motion, analyse their motion, and extract skills from expert's motion. In particular, we focused on care motion in the bed (bed care motion) and extracted skills of this motion. This motion particularly promotes the outbreak of lumbago because the motion compels nurses to adjust their posture to the bed heights and lift up the patients, changing patients' body positions and transferring to wheelchair [3]. In the present study, we analysed bed care motion with slide sheet, especially draw sheet motion, which can prevent the outbreak of lumbago.

Fig. 1 Bed care motion with slide sheet. In this picture, Nurse is drawing slide sheet between the bed and the patient in order to achieve transfer patients.

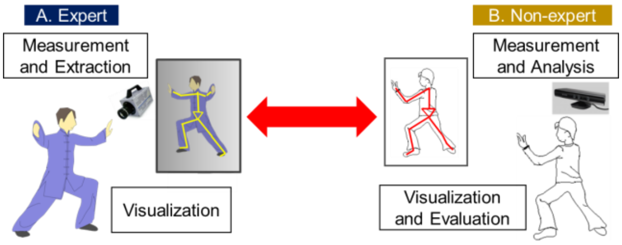

Fig. 2 Concept of skill education service. Our skill education service achieves visualization of the difference between expert's motion and non-expert's motion, expert's motion, and skill for non-expert.

Table 1 Results of skill extraction with interview and video analysis. Three skill points were elucidated, video images of expert and non-expert was compared, and we summarized the differences.

Target	Point from Interview	Expert Skill	Expert Motion from Video Analysis	Non-expert Motion from Video Analysis
Arm	Arm angle	Keep the 0°position of shoulder flex angle	Flex arm and put close arm and trunk	Keep a distance between arm and trunk
Trunk	Trunk angle	Not change of trunk angle during motion	Keep trunk vertically and not bend the body forward	Change trunk angle remarkably
Leg	Weight shift	Promote weight shift with leg motion	Utilize weight shift from toward the rear	Use not weight shift but arm power

In this study, skills of care experts of bed care motion with slide sheet were elucidated. First, we inputted measured body joint trajectory and foot reaction force data from motion before and after learning into musculoskeletal model, and calculated joint moment. With calculated joint moment and measured muscle activities, we estimated the lumbar burden to evaluate the extracted skills. Then, we analysed measured data based on our extracted skills, to assess skills before and after learning quantitatively.

Previous studies for nursing skill education extracted skills from experts' motion similarly [4]. However they did not focus on an evaluation whether or not extracted skills are appropriate. In contrast, we concluded that extracted skills were appropriate if the lumbar burden decreased after skill learning.

2 ANALYSIS METHOD

2.1 Skill Extraction

First, we extracted three important skill points of bed care motion with slide sheet with the method suggested by Hashimoto *et al*. [5]. Then, we compared motion of expert and non-expert with video images, and summarized the differences in Table 1.

In Fig. 3, video images of a specific frame are shown. Left two images shows expert motion, and right two images shows non-expert motion. Comparing the three skill points, the non-expert was found to change trunk angle remarkably, keep a distance between arms and trunk during before and after this motion. The expert was found to flex arm, put close arm and trunk, keep trunk vertically, and utilize weight shift from toward the rear. In contrast, the non-expert used only arm strength rather than weight shift, which is a critical skill for expert.

Skill points of bed care motion with slide sheet were extracted as shown in Table 1. Based on these extracted skill points, measured and calculated data from both expert motion and non-expert motion were compared.

2.2 Lumbar Burden Estimation

We estimated the lumbar burden with hip flex moment and erector spinae muscle activation. In previous studies, in order to estimate the lumbar burden, hip flex moment and erector spinae muscle activation were used [6][7].

Hip flex moment was calculated solving the inverse dynamics. Body joint trajectory data and foot reaction force data are the input to the inverse dynamics and the hip flex moment is the output. We used SIMM (MusculoGraphics Corp.), which is a software for

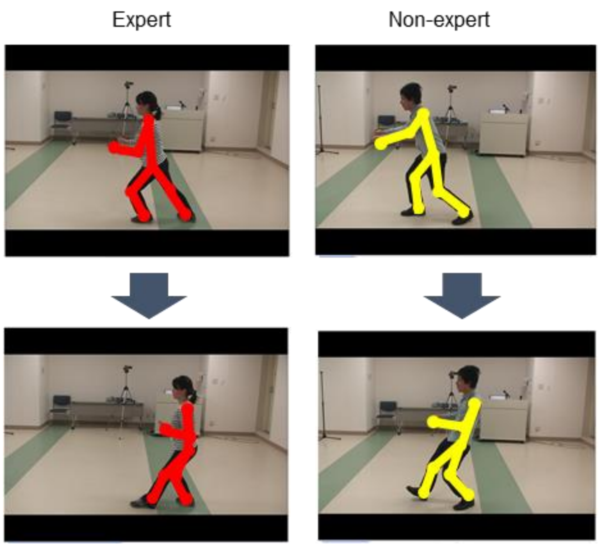

Fig. 3 Different movements of expert and non-expert from video images at a specific frame. Left two images are expert motion, and right two images are non-expert motion.

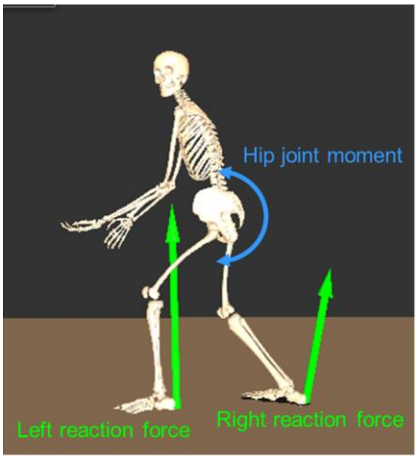

Fig. 4 3-D musculoskeletal model for motion analysis. This model was constructed on SIMM. Measured data was inputted to this model in order to calculate hip joint moment.

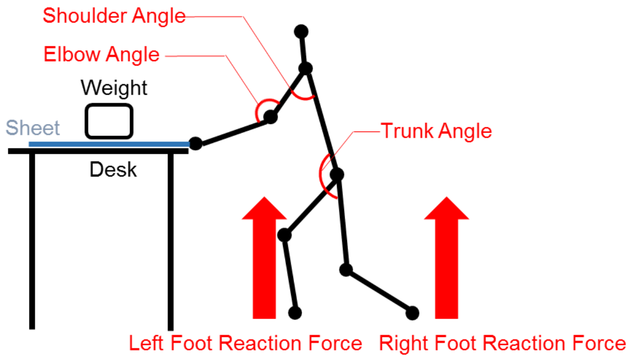

Fig. 5 Quantitative evaluation of three skill point. Arm skill is evaluated with shoulder angle and elbow angle. Trunk skill is evaluated with trunk angle. Leg skill is evaluated with left and right foot reaction force.

calculation of joint moment with inverse dynamics. We constructed a 3-D musculoskeletal model with SIMM, and implement the measured data to the model. Figure 4 shows a 3-D musculoskeletal model which we used in this study. The green arrow from left foot shows reaction force from left foot, the green arrow from right foot shows reaction force from right foot, and the blue arrow shows hip flex moment. In this simulation, hip flex moment indicates bending moment to the lumbar.

Erector spinae muscle activation was measured with surface electromyography (SEMG) sensors attached to the participant's skin. The increase of bending moment and erector spinae muscle activation lead to increase the lumbar burden and develop the lumbago [8][9].

2.3 Proficiency Evaluation

In order to evaluate a proficiency of motion, measured data were analysed based on three extracted skill points (Fig. 5). Arm angle was compared calculating the standard deviation of elbow and shoulder angle during motion before and after learning. Using these results, the proficiency was investigated focusing on whether motion after learning keep the flex position of elbow and shoulder or not. Likewise, trunk angle was analysed using the standard deviation of trunk angle during motion. The proficiency of trunk angle was investigated focusing on whether motion after learning keep trunk vertically or not. Weight shift was analysed using measured reaction force from both foot. The evaluation of proficiency on weight shift was focused on whether motion after learning utilize weight shift from toward the rear or not.

3 EXPERIMENTAL SETUP

3.1 Equipments

In order to investigate the effect on hip flex moment by motion difference. Figure 6 shows our experimental environment. Optimal motion capture system (MAC3D) with eight cameras (HMK-200RT; Motion Analysis Corp.) was used to measure body trajectories in 200 Hz. Based on Helen Hayes marker set, measured body parts were decided. In addition, the reaction force sensor (Nitta Corp.) was used to measure foot reaction force from both foot in 64Hz. Muscle activation was measured in 1000Hz from muscle of lumbar, especially erector spinae muscle, in DL-3100 (S&ME Corp.).

3.2 Subject

One healthy male (age: 23, height: 1.73 m, weight: 70 kg) participated in our experiment. This experiment was conducted with approval of the ethics committee of

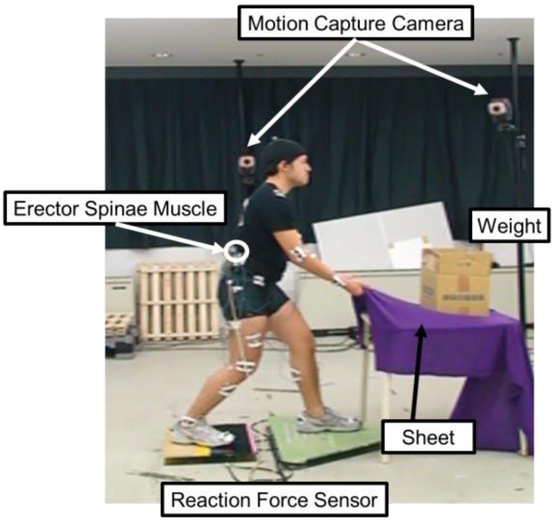

Fig. 6 Experimental environment. There are optimal motion capture system with eight cameras, reaction force sensor, weight and sheet

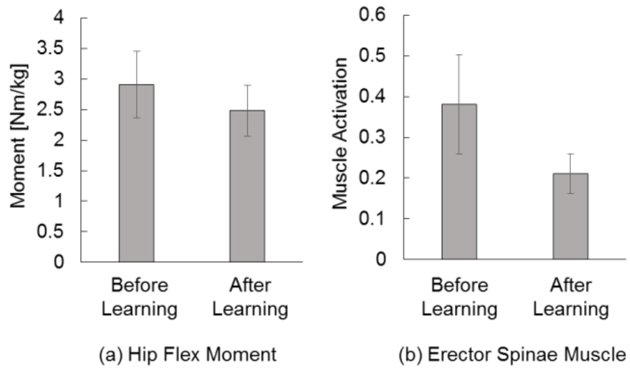

Fig. 7 Lumbar burden between expert and non-expert motion. Compared with expert motion, non-expert motion increased hip flex moment and erector spinae muscle activation.

Faculty of Engineering, The University of Tokyo, and informed consent was obtained from the participant.

3.3 Procedure

In this experiment, a desk height was set to 1.0 m as bed and fabric sheet on the desk was used. Additionally, on the sheet, weight (5.0 kg) was put. Improvised environment was constructed using slide sheet and patient on bed. In the first experiment, the participant drew slide sheet with no experience and skill of drawing slide sheet. After the first experiment, the participant was informed extracted skills in Table 1 and watched the video image of expert's draw sheet motion. In the second experiment, the participant drew slide sheet with information of expert's skill.

3.4 Data Processing

In the case of data unavailability of body trajectory, spline interpolation was conducted. Measured body trajectory data was filtered with low-pass filter in 10 Hz. Likewise, foot reaction force data from both foot was filtered with low-pass filter in 25 Hz and resampled from 64 Hz to 200 Hz. Muscle activation data is centred and filtered using 300 Hz low-pass and 10 Hz high-pass filters. In addition, these data were rectified and normalized using maximum values which measured respectively before our experiment.

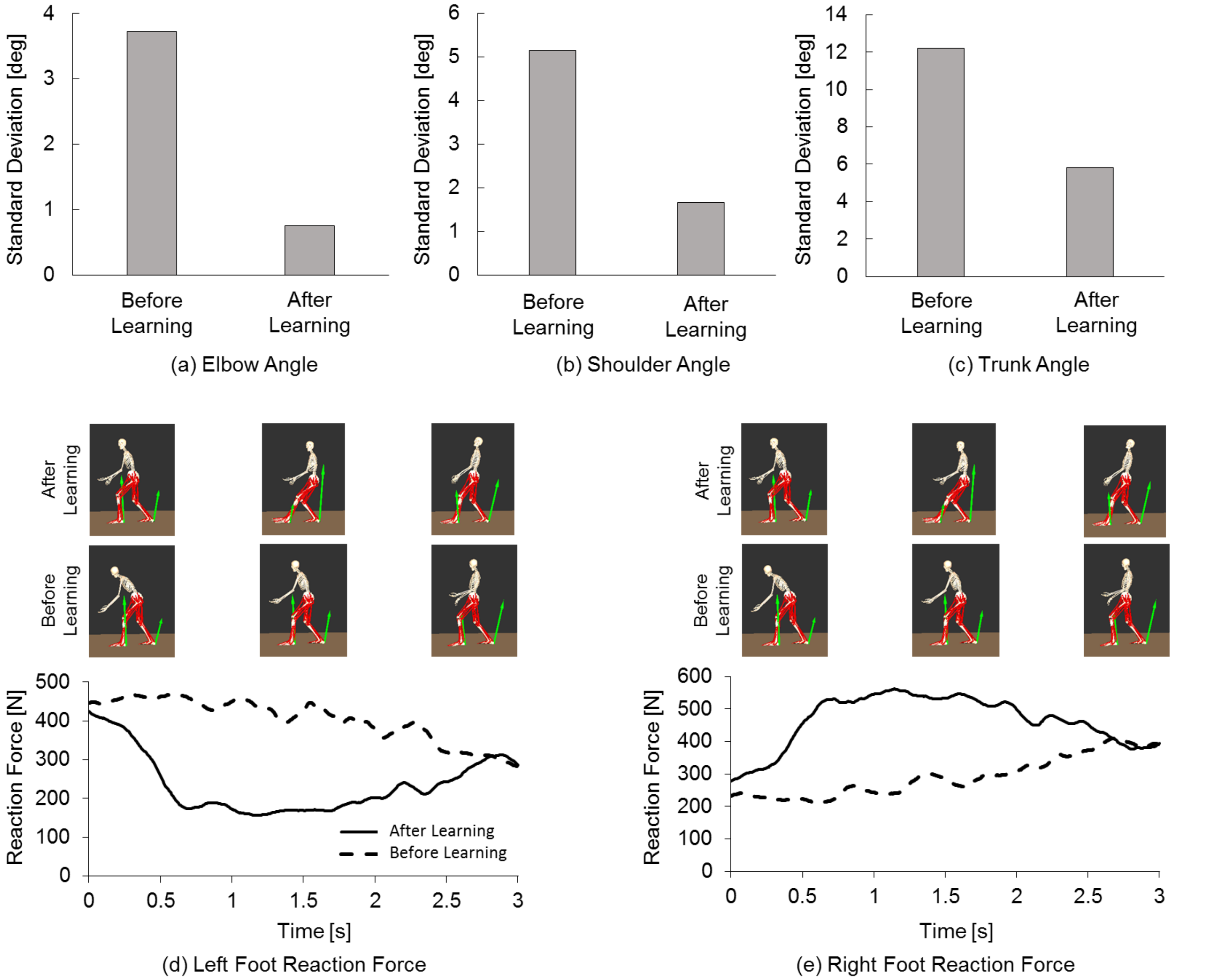

Fig. 8 Measured body data comparison between expert and non-expert motion. (a)-(c) shows the standard deviation of elbow, shoulder and trunk angle during draw sheet motion respectively. (d)-(e) shows reaction force from left foot and reaction force from right foot during draw sheet motion.

4 RESULT & DISCUSSION

4.1 Lumbar Burden

Figure 7 (a) shows the average of hip flex moment with difference between motion after learning and motion before learning. Compared with motion after learning, motion before learning increased hip flex moment. In addition, Fig. 7 (b) shows the average of erector spinae muscle activation during motion before and after learning. Error bars indicate standard deviation during one draw sheet motion. Motion after learning decreased erector spinae muscle activation in comparison with motion before learning. In the previous research, erector spinae muscle is related to the lumbago [9]. Thus, these results indicate that non-expert motion induced the increase of the lumbar burden and is possibility of developing the lumbago.

Definite number which develop the lumbago has been unclear, but it could be concluded that motion before learning is likely to induce the lumbago. This is why a small difference make a big difference in the case of repetitive motion such as nursing motion. In addition, from this result, our extracted skills were appropriate because the lumbar burden decreased after skill learning.

However, in this experiment, three skill points were transferred to the participant at the same time, and the most important skill to decrease the lumbar burden was not clarified. For the future education service, it is necessary to elucidate the most important skill to decrease the lumbar burden and the risk of developing lumbago in order to prioritize teaching skills.

4.2 Proficiency

Based on extracted skill points, proficiency on each skill point was evaluated. Figure 8 (a)-(b) shows the standard deviation of elbow and shoulder angle during one draw sheet motion respectively. Each angle was calculated with measured joint trajectory data. As shown in Table 1, expert keep the 0° position of shoulder flex angle and put close arm and trunk. Thus, expert fix their flex arm near trunk and decrease variance of elbow, shoulder angle. As shown in Fig. 8 (a, b), motion after learning decrease variance of elbow, shoulder angle compared to motion before learning. The participant moved and utilized arm largely before learning. Dependence of arm in draw sheet motion is high before learning.

Figure 8 (c) shows the standard deviation of trunk joint angle during draw sheet motion. As with the elbow and

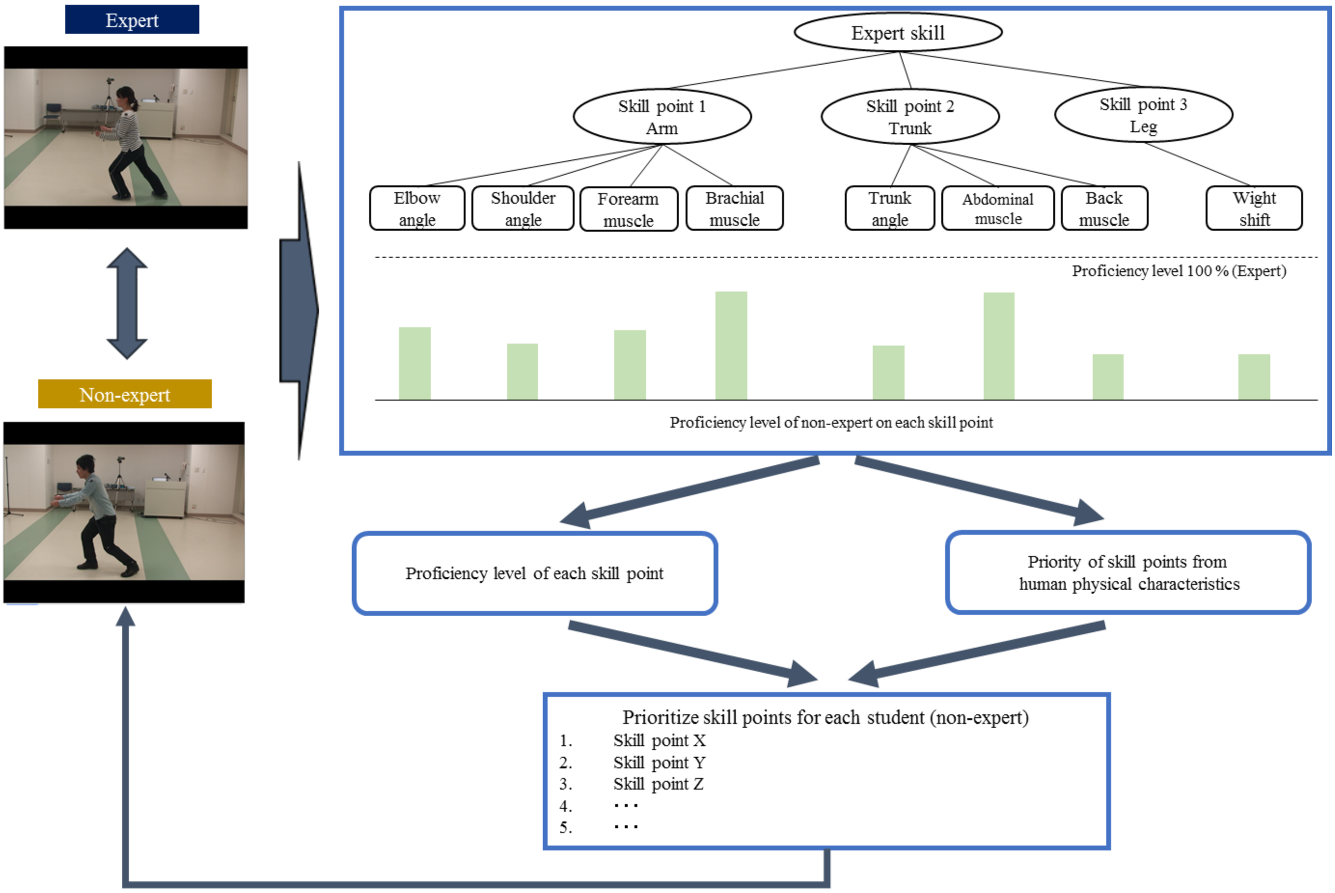

Fig. 9 Our future service concept for skill education. In this service, based on proficiency level of each skill point and priority of skill points from human physical characteristics, skill points prioritize for each non-expert student in order to develop the most effective skill education service.

shoulder angle, trunk angle during motion after leaning were kept vertically. On the other hand, during motion before learning, trunk angle were changed remarkably and the trunk was bent forward. This results leads to the increase of hip flex moment.

Figure 8 (d)-(e) show the vertical reaction force from left foot and from right foot during motion respectively. As shown in these figures, motion after learning induced weight shift compared with motion before learning. Therefore it is implied that, in motion after learning, weight shift is utilized without relying on arm movement and hip flex moment is reduced.

In this experiment, motion after learning was able to achieve three skill points of bed care motion which was extracted from interview and video analysis. Before learning, the participant draw sheet using arm power without weight shift, and move upper body largely. On the other hand, the participant after learning draw using weight shift without relying on arm power.

Especially it was defined that trunk movement has important function for posture and balance in the previous research [10]. In a first step of skill education service for non-expert student, it may be important to teach trunk movement of expert.

5 CONCLUSION

Nursing skill was extracted from interview and video analysis. Three skill points were extracted focusing on arm, trunk and leg. Based on these extracted skills, we analysed draw sheet motion with slide sheet. Our analysis results show that motion after skill learning reduces the lumbar burden compared to motion before skill learning. This is why hip flex moment and erector spinae muscle activation, which is related to lumbago, was reduced in motion after learning. From this result, our extracted skill points were appropriate.

However, if motion after learning were not to achieve the acquisition of skills, we could not conclude this result. In order to confirm that our skill education was conducted in an appropriate way, proficiency on each skill point was evaluated after learning based on these skill points which was extracted from interview and video analysis. Our analysis suggested that motion after learning was able to achieve these three skill points.

In this study, the experiment was conducted in the improvised condition. Thus, we will conduct future experiment in a condition which is close to a real nursing scene using hospital bed, real slide sheet, and another participant as a patient.

Figure 9 shows our future service concept for skill education. In our future work, based on proficiency level of each skill point and priority of skill points from human physical characteristics, skill points will be prioritized for each non-expert student in order to develop the most effective skill education service. On this account, we will need to investigate the priority of skill points in terms of human physical characteristics.

It is necessary to design the education service of nursing skill for not only nurses but also patients. Therefore we should take the burden reduction of patients into consideration for more practical education service of nursing skill.

ACKNOWLEDGEMENT

This work was in part supported by JST RISTEX Service Science, Solutions and Foundation Integrated Research Program, the MEXT KAKENHI, Gtant-in-Aid for Scientific Research (B) 24300198.

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