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Assessment of the Hoisting Motion via Motion Analysis and Physical Perceptions

–Aiming to Reduce the Burden on the Lower Back during the Transferring Motion–

Yuma ETO*, Keiko FUKUROKU**

**School of Nursing, Faculty of Medicine, Mie University, 2-174 Edobashi, Tsu-shi, Mie 514-8507, Japan*
***Course of Nursing Science, Graduate School of Medicine, Mie University, 2-174 Edobashi, Tsu-shi, Mie 514-8507, Japan*

Abstract: The present study evaluated the burden on the lower back during the transferring motion that is commonly performed in nursing, and evaluated the association of this burden with the knee flexion angle. The aim of the present study was to verify the knee flexion angle at which the vertically upward force was maximized while the subject was performing the hoisting motion to move an object (simulating a patient). The mean maximal forces applied vertically upward to the object were significantly greater when the subject had knee flexion angles of 60° and 80° compared with a knee flexion angle of 40°. However, the mean maximal force applied vertically upward to the object with a knee flexion angle of 80° did not significantly differ from that with a knee flexion angle of 60°. This suggests that a flexion angle of the knee joint of 60° minimizes the burden on the lower back, assuming that the effect of the upper body is excluded.
Keywords: *nursing care, transfer motion, burden on the lower back, knee flexion angle, nursing physics*

1. INTRODUCTION

In recent years, there has been great interest in the physics associated with nursing science. Thus, an increasing amount of research is being published on nursing science related to physics. However, more research is needed. In particular, there are few reports about the occupational lower back pain that frequently occurs in nurses [1,2,3] from the aspect of body mechanics, and the discussion of this issue in current textbooks is vague [4,5]. Hence, we selected the situation in which nurses incur a heavy burden while transferring patients from the bed to the wheelchair, and investigated the relationship between the hoisting motion and the knee flexion angle.

2. AIM

The aim of the present study was to verify the knee flexion angle at which the vertically upward force was maximized while the subject was performing the hoisting motion to move an object (simulating the patient).

3. METHODS

3.1 Participants and study period

Sixteen adult students (6 males and 10 females) were recruited from the School of Nursing and other faculties of Mie University.

The study period was December 2018.

3.2 Research design

The study design comprised correlation studies and comparative studies that were based on the quantitative approach.

3.3. Experimental method （Figure 1, 2）

1) The grip strength of each subject was measured as an indication of the whole body muscle strength [6].
2) Reflective markers were affixed to the greater trochanter, caput fibulae, and external malleolus on the right side [7,8].
3) A 10 kg backpack was hung on the front of each subject's body. The front belt was adjusted so that it was in close contact with the subject and the object, and did not move or fall during the procedure.
4) The subjects were instructed to support the object in their arms, but not to add power to lift it.
5) Each subject moved to the position in which there were two pieces of tape labelled with their individual subject number. The space between the tapes was twice as long as each subject's anterior superior iliac spine. Each subject set one heel on each of the tapes.
6) When the subject achieved the specified base of

support, we adjusted his/her knee flexion angle, which was measured with an angle gauge.

7) After adjustment to the specified angle, the subject was instructed to lift the object with his/her legs.
8) As the subject lifted the object, the standing position did not shift, and the feet were maintained flat on the floor without lifting the heels. To eliminate the influence of the upper body, the trunk was retained in the upright position as much as possible. The end of the hoisting motion was defined as the time at which the knee joint was fully extended (knee flexion angle of 0°).
9) Steps 3 to 8 were repeated three times at each of three knee flexion angles (40°, 60°, and 80°).
10) The subjects then answered the questionnaire.

Figure 1: Experiment environment

Figure 2: State of hoisting motion

3.4. Measurement and analysis of data

We used a multi-motion analysis system (Carrot 2D/3D; Library Co., Ltd., Japan) to measure the knee flexion angles. The vertical upward force applied to the object was obtained by calculating the maximum acceleration in m/s^2 in the y-axis direction based on the movement of the reflection marker attached to the object. The maximum force (F) in N was obtained by substituting the acceleration value into the Newtonian Equation of motion (mass × acceleration = F).

The questionnaire administered after the experiment required the subjects to rate the motion as "easy to operate" or as a "feeling of burden of the lower back" using a Visual Analogue Scale (VAS) and a free description section.

The difference between the y-axis F of the three groups was analyzed by the multiple comparison method (Tukey test). In addition, the relationship between the VAS data obtained from the questionnaire and the mean y-axis F value at each knee flexion angle was assessed using Spearman's rank correlation coefficient. Statistical analyses were performed using SPSS Statistics version 25 (IBM). The significance level was set at $p < 0.05$.

4. ETHICAL CONSIDERATIONS

The following points were explained to the subjects in both oral and written forms: the study purpose and methods, that study participation was free, that subjects would not experience any adverse effects, that subjects could withdraw from the study before its completion even after agreeing to participate, and that all subjects' privacy would be strictly protected. All subjects provided written, informed consent for study participation.

The implementation of the present study was approved by the Medical Research Ethics Review Committee of Mie University Hospital in December, 2018 (approval number U2018-024).

5. RESULTS

The subjects were 22.3 ± 4.4 years old, with an average height of 163.9 ± 7.7 cm, average bodyweight of 55.2 ± 9.4 kg, and average grip force of 31.9 ± 8.8 kg.

The mean y-axis F values were significantly greater at knee flexion angles of 60° and 80° compared with 40° (P = 0.002, P = 0.000). However, there was no significant difference in the mean y-axis F value at the knee flexion angles of 60° versus 80° (Figure 3).

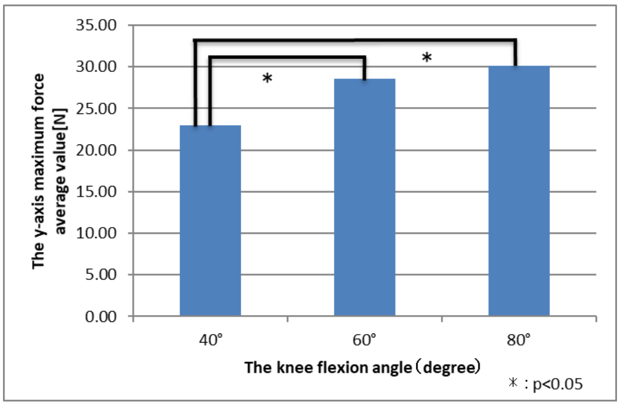

Figure 3: The mean y-axis maximum forces of the three groups (knee flexion angles of 40°, 60°, and 80°)

Spearman's rank correlation coefficient showed that there was a significant negative correlation between the mean y-axis F and the ease of operation (ρ = -0.425, P = 0.003). However, there was almost no correlation between the mean y-axis F and the feeling of burden in the lumbar region (ρ = - 0.275, P = 0.059) (Figures 4, 5).

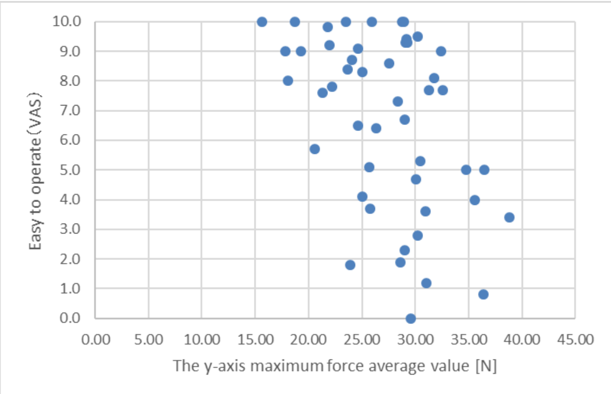

Figure 4: Correlation between the mean y-axis maximum force and the ease of operation

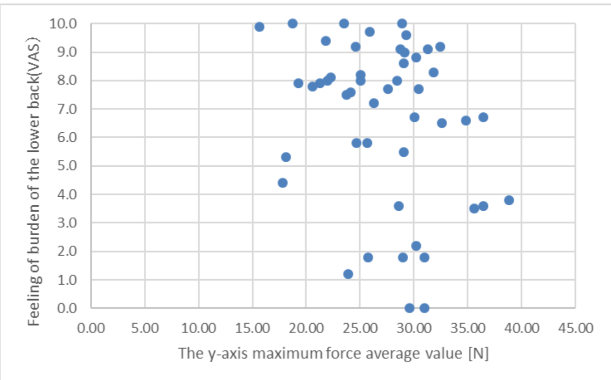

Figure 5: Correlation between the mean y-axis maximum force and the feeling of burden in the lumbar region

6. DISCUSSION

In the present study, the mean F values applied to the object in a vertical direction while the subject maintained knee flexion angles of 60° and 80° were significantly greater than that with a knee flexion angle of 40°. Mitani et al. (2013) reported that an increase in the flexion angles of the knee and hip joints increases the contribution of the lower limbs when lifting a load. In addition, Ohnishi et al. (2010) evaluated the muscle activity of the gluteus maximus, biceps femoris, rectus femoris, and medial vastus medialis during the hoisting motion, and reported that the angles of the hip and knee joints are increased by lowering the position of the baggage hand. The leg muscle group (gluteus maximus, biceps femoris, rectus femoris, and vastus medialis) is relatively large and has a strong contractile power (Marieb, 2015). Therefore, we think that increasing the flexion angle of the knee joint in the present study effectively used the gluteus maximus and the leg muscle group, which are relatively large muscles with strong contractile force. The mean F applied vertically upward to the object at the knee flexion angle of 80° was not significantly greater than that at the knee flexion angle of 60°. Fujimura et al. (2002) reported that the muscle activity of the erector spinae increases as the load becomes heavier. Furthermore, Ishida et al. (2007) reported that the muscle activity of the erector spinae, latissimus dorsi, and biceps femoris during isometric pulling exercises at trunk anteversion angles of 30°, 45°, and 60° increased as the burden increased. Therefore, in the present study, excessive flexion of the knee joint was thought to be caused by excessively increasing the activity of the gluteus maximus and the leg muscle group. In addition, we think that the muscles of the upper body could not be used efficiently during the present experiment due to the instructions to maintain an upright position.

We found a significant negative correlation between the mean y-axis F and the ease of operation. The subjects were instructed to maintain an upright position as much as possible; thus, they could not use the upper muscles efficiently, and the maneuver become a somewhat unnatural hoisting motion. As a result, we think that this motion performed in the present study produced an increased burden on the lower limbs compared with the actual hoisting motion. Hence, five of the 16 subjects reported in the free description section of the questionnaire that the burden on the knees and legs was greater at knee flexion angles of 60° or 80° than at 40°.

Although we also predicted a positive correlation between the mean y-axis F and the burden felt in the lower back, we unexpectedly found almost no correlation between the two parameters. This may have been because the upper body muscle group could not be used efficiently due to the instruction to maintain an upright position. In the free description section of the questionnaire, one subject wrote "Since the upper body was a start from the upright position, I couldn't feel the burden on the lower back so much". Therefore, we consider that the burden on the knees and legs became greater than that on the lower back, which led to the burden on the whole body.

The present study had some limitations. First, the number of subjects was small, and so it is difficult to generalize the results. Second, as the knee flexion angle setting was changed by 20° each time, detailed angle calculation could not be done. Furthermore, we could not take into account the effect of the foot angle. Third, by making the conditions of the upper body consistent, it became a somewhat artificial lifting motion. For these reasons, our findings must be confirmed with larger numbers of subjects, more detailed angular differences, and a more natural hoisting motion. These findings will be important for the consideration and investigation of preventive measures for back pain associated with nursing skills.

7. CONCLUSIONS

1) A knee flexion angle of 60° significantly increases the vertical upward force, which is important for the lifting motion.
2) We speculate that a knee flexion angle of 60° will minimize the burden on the lower back, assuming that the effect of the upper body is excluded.
3) Excessive flexion of the knee joint may increase the burden on the lower limbs and reduce the vertical upward force. Hence, we must also devise measures to use the upper body for hoist lifting procedures to lessen the burden on the lower back.

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