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Original Article

Relationship between surface electromyography of the spinae erector muscles and subjectively adjusted step length in the supporting standing-up motion

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Abstract. [Purpose] Caregivers experience low back pain owing to frequent patient handling motions such as supporting the body while standing up. To prevent low back pain in caregivers, low load posture while engaging in patient handling motions is required. We determined the relationship between surface electromyography of the erector spinae muscles and subjective step length as “long” and “short” during the supporting standing-up motions of caregivers. [Participants and Methods] Ten young male participants were asked to perform supporting standing-up motion 10 times using two-step lengths comprised of subjective long and short steps. During supporting standing-up motion, we measured surface electromyograms of the erector spinae muscles and calculated the integral electromyographic values. [Results] The subjective long/short-step length normalized by body height did not differ across the participants. In addition, the subjective long-step length was longer than the subjective short-step length in all the participants. Integral electromyographic values for both the left and right erector spinae muscles in the short-step length were significantly lower than those in the long-step length when the data obtained from all the participants were used. [Conclusion] We considered that the load of the erector spinae muscle will be reduced if the short-step instead of the long-step instruction is given. In the future, instructions based on the subjective step-length variation in caregivers must be considered.
Key words: Supporting standing-up, Subjective step-length, Low back pain

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INTRODUCTION

There is a possibility that many of the health and welfare workers with low back pain are contributing to the injury unconsciously, due to improper posture and environment[1)]. Especially, caregivers experience low back pain associated with patient handling motions[2)], and motions often associated with patient handling are considered a risk factor for low back pain because they are strongly related to heavy lifting, frequent bending, and twisting[2)].

There are lifting devices and sliding sheets that support patient handling motions[3)]. However, these devices are not frequently used because they are inefficient, costly, and associated with workspace complications[3)]. Therefore, it is necessary to consider how to reduce low back pain associated with patient handling motions without the use of these assistive devices.

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The use of body mechanics has been considered a possible means to reduce the low back load without the use of assistive devices[4–6].

Body mechanics consider movements and postures during common activities, such as lifting, pushing, and pulling[4], and help to remedy and prevent low back problems[4]. In a previous body mechanic investigation, it was found that low back load is prevented when reducing forward trunk bending and using lower limb muscles in patient handling motions[5]. Movements of the trunk have been studied, but the effectiveness of some parameters, such as foot position for reducing low back loads based on body mechanics, has not been clarified.

In this study, we focused on the foot position of the caregiver as one of the subjective, adjustable parameters. According to the body mechanics, lowering the center of gravity and closing the distance to the patient[6] are recommended to reduce low back load. It is considered that a caregiver needs a long step-length to lower the center of gravity. However, a short step-length is required to close the distance to the patient. Thus, body mechanics do not show which step-length is effective to reduce low back load. Therefore, it is necessary to study the relationship between step-length and low back load of the caregiver during patient handling motion. In addition, it is necessary to clarify whether abstract and intuitive instructions, such as long/short step-length, are rational when adjusting step-length of the caregiver.

Therefore, the purpose of this investigation was to assess the relationship between surface electromyography (EMG) of the erector spinae muscles as a means to evaluate low back load and subjectively adjust step-length, such as long and short step-lengths during the supporting standing-up motion and see if this reduces low back load.

PARTICIPANTS AND METHODS

Total 10 healthy male volunteers participated in this investigation. Table 1 shows participant characteristics. All procedures were approved by the Ethics Committee for Human Research of Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology (approval number: 17-05). All participants received a description of this research and signed a written, informed consent form before participating.

Figure 1 shows the supporting standing-up motion in this experiment. In this study, to remove the effects of many factors of patient's motion on lumbar load of caregivers, a doll made of plastic bottles filled with water was used, instead of a patient as a basic study for patient handling motion. In order to prevent accumulation of lumbar load on the participant as caregivers, weight of the doll is 10 kg lighter than actual human. Participants were asked to lift the doll with two different step-lengths, ten times. In addition, each participant was asked to subjectively adjust step-length for long and short step-lengths. These two step-lengths were adjusted before measurement and fixed during measurement. The left foot was considered as the front foot and fixed under the footrest of the wheelchair, and the right foot was considered the rear foot and changed by two step-lengths (long and short step-lengths). The lateral width between the feet was fixed to the shoulder width of each participant. The step-length was measured by a tape, and normalized step-length [%height] was calculated by dividing by the height of each participant.

Surface EMG of the right and left erector spinae muscles were measured while supporting the standing-up motion. Surface EMG was measured using Blue Sensor P (Ambu, Ballerup, Denmark) as electrodes and the EMG Logger LP-WS1402-W (Logical Product Inc., Fukuoka, Japan). The skin of the participants was shaved before mounting of the electrodes. Electrode locations for the trunk muscles were determined as per McGill[7]. The cables were fixed with tape to ensure durability and to minimize the potential inconvenience for participants. The sampling frequencies of all devices were set at 1,000 Hz. Data

Table 1. Characteristics of the participants

	Mean ± SD
Age (years)	24.1 ± 1.3
Height (cm)	173.5 ± 5.5
Weight (kg)	67.6 ± 8.8

(n=10)

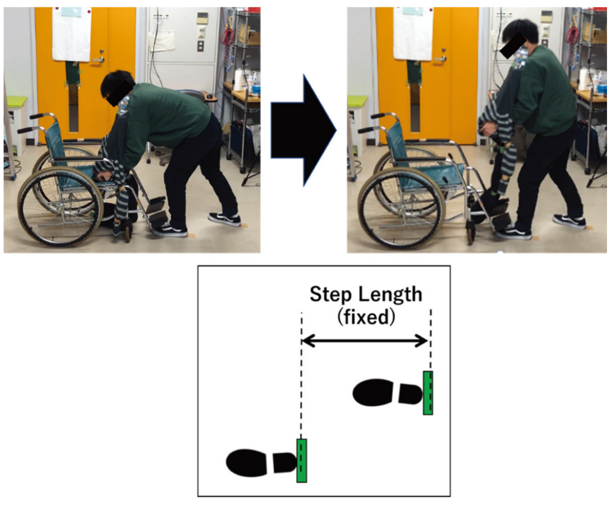

Fig. 1. Supporting standing-up motion.

were then processed into integrated values (IEMG) from the rectified signal of surface EMG, and the data was compared between the two step-lengths in each participant. These IEMG values were time-normalized by dividing each by total motion time. All calculations and signal processing were performed using MATLAB R2018 (Mathworks Inc., Natick, MA, USA). The differences in IEMG values between long- and short-step were evaluated using the Wilcoxon signed rank test for each participant and all participants. These statistical analyses were performed using EZR[8)] with a p-value of <0.05 considered significant.

RESULTS

Table 2 shows two normalized subjective step-lengths of each participant. The long step-length are longer than the short step-length in all participants. The lengths of long- and short-step were adjusted by the participants height 43.0 ± 5.5 (%height) and 28.9 ± 6.1 (%height), respectively. In addition, a difference in the step-length between long- and short-step was 14.1 ± 4.1 (%height).

Table 3 shows the IEMG values of the erector spinae muscles in two step-lengths. IEMG values for both the left and right erector spinae muscles in the short step-length were significantly lower than in the long step-length when data was obtained from all participants. In addition, IEMG values for either the left or right erector spinae muscles in the short step-length were significantly lower than in the long step-length for seven participants (A, B, C, E, F, G, and H). Furthermore, IEMG values of short step-length were significantly smaller in the left erector spinae muscles in three participants (B, F, and H) and in the right erector spinae muscles for five participants (A, B, C, E, and G).

DISCUSSION

The standard deviations (SD) in the subjectively adjusted step-lengths of long- and short-step and the difference in the two step-lengths were 5.5 (%height), 6.1 (%height), and 4.1 (%height), respectively. These SDs were shorter than foot size which is approximately 15% of the body height[9)]. Thus, commands, such as long and short step-lengths, would be useful for intuitive and rough instruction of patient handling motions.

Table 2. Step lengths of each participant

Participants	Normalized step length (%Height)		
	Long-step	Short-step	Difference (Long–Short)
A	50.3	38.0	12.3
B	46.8	35.3	11.5
C	46.1	33.2	12.6
D	39.4	29.3	10.1
E	45.6	34.3	11.6
F	31.6	17.9	13.3
G	39.3	23.4	15.9
H	50.1	26.6	23.4
I	39.4	28.5	10.9
J	41.4	22.1	19.5
Mean ± SD	43.0 ± 5.5	28.9 ± 6.1	14.1 ± 4.1

Table 3. Integrated electromyographic values of erector spinae muscles in two foot placements

Participants	IEMG of erector spinae muscles (μV)			
	Left		Right	
	Long-step Median (IQR)	Short-step Median (IQR)	Long-step Median (IQR)	Short-step Median (IQR)
A	191.2 (4.3)	191.9 (2.0)	204.1 (2.4)	201.0 (4.4)*
B	136.5 (20.0)	92.6 (13.0)*	142.9 (23.7)	114.0 (17.2)*
C	196.1 (10.2)	192.9 (3.3)	240.4 (18.4)	221.8 (9.4)*
D	189.8 (2.2)	189.4 (4.7)	197.8 (6.6)	200.1 (7.9)
E	189.4 (1.8)	188.0 (2.2)	233.6 (18.3)	225.8 (16.9)*
F	207.9 (36.7)	192.4 (1.1)*	199.2 (0.8)	199.3 (2.2)
G	190.8 (2.7)	191.5 (5.2)	204.2 (199.8)	199.8 (4.6)*
H	216.0 (6.7)	209.9 (13.3)*	240.9 (12.6)	232.9 (15.4)
I	194.9 (10.5)	194.1 (4.9)	200.3 (3.7)	205.4 (3.8)
J	195.5 (6.2)	194.3 (10.1)	201.5 (5.8)	197.6 (3.7)
All	192.6 (11.8)	184.2 (5.9)*	207.1 (30.4)	200.4 (17.9)*

IQR: Interquartile range. *Significant difference (p<0.05).

Because IEMG values for both the left and right erector spinae muscles in the short step-length were significantly lower than in the long step-length when data was obtained from all participants, it is likely that the short step-length was more effective in reducing low back loads during supporting standing-up motion. This is likely because the short step-length was initiated close to the center of gravity of the caregiver and patient, so the moment arm and required force for lifting were shorter and smaller. Shortening the moment arm is recommended by body mechanics to close the distance to the patient[6]. Furthermore, it is considered that lowering the center of gravity recommended by body mechanics[6] is initiated by flexion/extension of the knee and ankle joints at the short step-length. The long step-length was effective in lowering the center of gravity. However, it may have also caused twisting trunk related to lumbar loading. Twisting of the trunk may be a risk factor for low back pain in caregivers who frequently handle patients[10].

Because there were half of the participants with significant different IEMG values in the right spinae muscles, the differences between the step-lengths affect the load of the right erector muscles in the rear lower limbs that are involved in the supporting standing-up motion. In the present investigation, step-length was adjusted by changing the position of the rear foot. Therefore, it is likely that the eccentric contraction of elector spinal muscles related to the movement of the rear lower limb is affected by changing the step-length.

One potential limitation of this investigation was that only two step-lengths were considered. It is necessary to investigate more detailed step-lengths and lateral width of the feet. Furthermore, if a quantitative step-length is required for low load patient handling motions, it is necessary to consider an intuitive instruction that can be easily understood by the caregiver. Examples of this include the number of feet and other specifics. Moreover, this research evaluated the lumbar load using only surface EMG of the erector spinal muscles. Previous studies have shown that surface EMG is useful for evaluating lumbar load[11]. However, low back pain is associated with stress of the lumbar vertebra[10, 12] and muscle cross-sectional areas[13, 14]. We evaluated the patient handling motions to the doll to fix several factors. In future research, it is necessary to evaluate the relationship between the proposed patient handling motions and lumbar loads in actual patients for long term.

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Conflict of interest

None.

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