Fatigue Assessment Using Surface EMG on Lifting Motions

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***Abstract*—Caregivers experience back pain due to concentrated load on the lumbar region. It is essential to understand the correct working posture because the wrong nursing posture causes the concentrated load to the lower back. The purpose of this study is to build a framework for estimating the fatigue state from the median frequency of surface EMG to clarify the relationship between performance and fatigue due to different working postures. The tasks measured here were two movements of lifting heavy objects: Stoop, which involves lifting with the force of the waist, and Squat, which involves lifting with the force of the legs. Ten healthy adults were measured in the experiment. There was no difference in the average number of lifting movements of the subjects, 36.2 for Stoop and 35.9 for Squat. However, the number of times the subjects with shallow lumbar flexion angle in Squat was recorded much higher than the average. Single regression analysis of the intermediate frequencies of the surface EMG showed that the slope of the intermediate frequency of the Stoop movement was large, except for the right erector spinae muscle. These results suggest that that movements using leg force rather than lower back force would reduce the risk of low back pain.**

***Index Terms*—fatigue, surface EMG, posture, lower back pain, wearable sensor**

I. INTRODUCTION

Due to nursing care work, back pain among caregivers is a significant problem in an aging society. Back pain is caused by the concentrated load on the lower back during work. Since the concentrated load on the lumbar region is caused by incorrect nursing care movements, it is crucial to perform the correct movements to prevent back pain [1]. In continuous exercise, Type II fibers, which constitute the high frequency of the muscle potential and are prone to fatigue due to sustained muscle contraction, stop working. Therefore, it is known that the median frequency of the muscle potential decreases with fatigue. In addition, since performance decreases transiently, the fatigue state can also be determined by movement [2]. However, it is still a challenge to clarify the relationship between work posture and propose ways to improve the movement adapted to each individual.

Therefore, the purpose of this study is to construct a framework for estimating the fatigue state from the intermediate frequency of surface EMG through the measurement of heavy lifting motion to clarify the relationship between performance and fatigue due to differences in working posture.

II. PROPOSED METHOD

A. Participant

Ten healthy adults with no history of back pain, with a mean age of 23.0 years (range 21-24 years) and a mean weight of 64.9 kg (range 48.8-82.1 kg), agreed to participate in the study.

B. Experiment

A schematic diagram of the experiment is shown in Fig.1. A container adjusted to 20% of the subject's body weight was placed at the height of 50 cm above the ground. Each subject was requested to lift the container, rotate his or her body 90 degrees, and lower the container for two seconds each, taking a one-second break after lowering. A metronome was used to signal the time at 1-second intervals. Two lifting postures were used: Stoop (without knee bending) and Squat (with knee bending). The order of measurement was five people in each group, with the group that performed Stoop first being designated as A and the group that performed Stoop later being designated as B. There was a 30-minute break between the measurements.

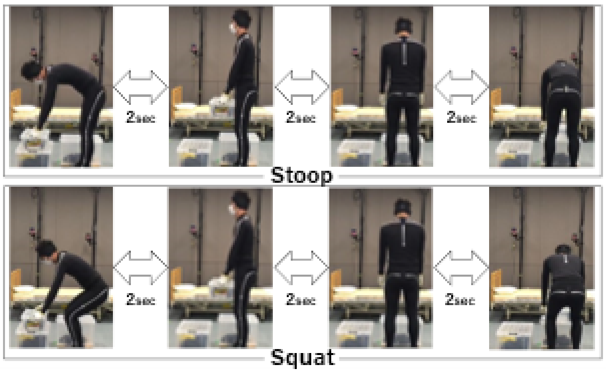

Fig. 1. Experiment flow

C. Measurement Method

EMG signals were measured using a surface EMG sensor, Delsys Trigno (Delsys Inc.). The EMG signals were measured at six locations: the right and left erector spinae, vastus lateralis, and flexor carpi radialis. An inertial motion capture system, e-Skin MEVA (Xenoma Inc.), was used to measure the working posture. The sampling rate was set at 1000 Hz for EMG and 100 Hz for motion capture.

D. Analysis Method

The measured EMG signals were subjected to spike noise removal using a Hampel filter with a window size of 199. Butterworth band-pass filters with a passband of 5 Hz and a stopband of 400 Hz were applied to remove signals that were not due to muscle activity. Frequency analysis of the filtered signals was performed for every 500 samples, and the intermediate frequencies were calculated. For motion data, the joint angle of the lumbar spine is used for evaluation. The maximum bending angle from lifting to lowering was extracted at each frequency, and the average value was calculated.

III. RESULT

The mean number of lifts and the mean maximum flexion angle of the lumbar spine for each subject are shown in Table 1. 45 Stoops were averaged in Group A, 27.4 in Group B, and 36.2 overall. 34.4 Squats were averaged in Group A, 37.4 in Group B, and 35.9 overall. The mean for Squat was 34.4 times in Group A and 37.4 times in Group B. The overall mean was 35.9 times.

TABLE I
NUMBER OF LIFTS AND AVERAGE BENDING ANGLE OF THE L-SPINE

Group	Sub No.	Stoop		Squat	
		Times	L-Spine[deg]	Times	L-Spine[deg]
A	1	58	77.13	35	81.72
	2	21	77.16	60	54.46
	3	64	60.68	40	76.22
	4	22	94.78	16	74.67
	5	60	73.01	21	79.91
B	6	36	44.72	47	45.60
	7	29	76.22	38	70.85
	8	36	46.93	52	45.64
	9	10	45.21	15	80.93
	10	26	78.62	35	68.35
Average		36.2	67.45	35.9	67.83

In the Squat movement, if we focus on subjects No.2,6,8 who had shallow lumbar flexion angle, they lifted more times than the average. On the other hand, subjects in Group A, who had a greater lumbar flexion angle in Squat, performed fewer times than Stoop. In addition to the load on the quadriceps due to the knee bending motion, the large displacement of the lumbar vertebrae also put a load on the erector spinae, which may have accelerated the accumulation of fatigue.

The results of Stoop analysis are shown in Fig. 2, and those of Squat analysis are shown in Fig. 3. The blue line is the median frequency of each subject, and the orange line is the regression line. The slopes of the obtained regression lines are shown in Table 2. The slope of the intermediate frequency was larger for Stoop except for the right erector spinae muscle.

TABLE II
SLOPE OF THE REGRESSION LINE

Name of Muscle	Stoop		Squat	
	Left	Right	Left	Right
Ercspn	-7.749	-2.992	-6.787	-7.616
Quadriceps	-19.27	-17.91	-8.021	-14.89
Radialis	-12.13	-18.20	-10.28	-5.817

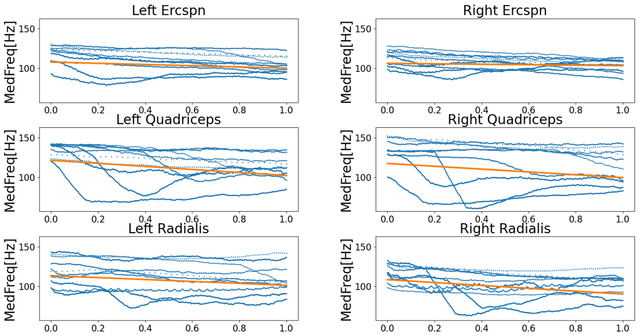

Fig. 2. Stoop

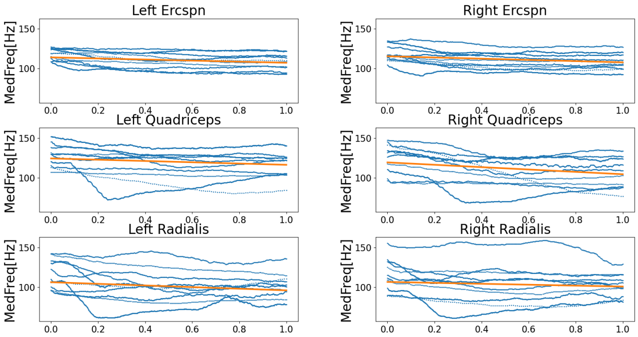

Fig. 3. Squat

IV. CONCLUTION

In this study, the lifting of heavy objects by two movements, Stoop and Squat. The average number of times the subjects lifted was 36.2 times in Stoop and 35.9 times in Squat, and the number of times the subjects lifted was higher than the average in Squat when the lumbar flexion angle was shallow. In the intermediate frequency of surface EMG, the slope of the regression line was calculated by single regression analysis, and the slope of the Stoop movement was large except for the right erector spinae muscle, suggesting that using only the power of the lumbar region to perform a movement places a heavy load on the muscles and that movements using the legs can prevent back pain.

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