Verification Experiments on the Lower Back Burden caused by Posture and Environment during Lifting Operations

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Abstract

One of the measures to prevent back pain is the use of appropriate posture corrections. In generally, the Squat method (method of keeping the knees bent and the waist as straight as possible) is recommended over the Stoop method (method of keeping the knees straight and the waist bent). The results of previous studies using acceleration and muscle potentials have shown that the lifting with knees in a kneeling position reduces the amount of load born by the lower back. However, few studies discuss the case where there is an obstacle between the subject and the object to be lifted and further, the scenarios where the object is away from the body's center of gravity. Therefore, this research focus on analyzing three types of movements using the AnyBody musculoskeletal mechanics analysis software, the Yo-bukun back pain prevention application, and the Delsys surface EMG and verifying the amount of lower back burden when there is an obstacle between the lifting object and the subject. This paper presents the verification results.

Keywords: Lower back burden, Posture correction, EMG, The body's center of gravity

1. Introduction

Frequent lifting activities in the construction and nursing care industries place a heavy burden on the lower back and can easily lead to lower back pain. One of the measures that can be taken by individuals to prevent back pain is to improve posture. There are two main types of lifting movements: the Stoop method (keeping the knees straight and the hips flexed) and the Squat method (keeping the knees flexed and the hips as straight as possible). The Japanese Ministry of Health, Labour and Welfare's "Guidelines for Prevention of Back Pain in the Workplace" recommends the knee-bend lifting method. The results of the previous study and the analysis using the "Yo-bukun" application for measuring back strain showed that the lifting method with the knees bent reduced the amount of back strain compared to the lifting method without knees bent [1], [2], [3]. In addition, the previous study showed that the lifting method with the knees bent was associated with a lower EMG burden when the lifting object was located close to the body's center of gravity [4], [5].

However, few previous studies have discussed the case where there is an obstacle between the lifting object and the subject and also when the object is far from the body's center of gravity. Therefore, the purpose of this paper is to analyze three types of movements using the AnyBody musculoskeletal mechanics analysis software, Yo-bukun back pain prevention application, and the Delsys surface electromyograph, in order to verify the amount of back burden when there is an obstacle between the lifting object and the subject.

2. Methodology

In this paper, lumbar burden was measured using AnyBody, Yo-bukun applications, and Delsys EMG.

2.1. Measuring equipments

AnyBody is a musculoskeletal mechanics analysis software from Terrabyte Co. Basically, it calculates the forces acting on each part of the human body, such as muscle activity, muscle force, and joint moments, when a movement is applied to a musculoskeletal model using inverse dynamics analysis.

Yo-bukun is an application developed by the University of Miyazaki in collaboration with DENSAN Corporation for the prevention of back pain for the iPhone. It is calibrated when the user stands upright, and calculates the amount of lumbar burden based on the tilt of the iPhone.

Delsys is the generic name for Trigno EMG system incorporated with some additional sensors developed by Delsys. In addition to EMG, IMU sensors (accelerometer, gyroscope, and magnetometer) are built in to collect kinematic data (angles) at the same time.

2.2. Measurement method

A video camera footage was used as the method of measurement for the analysis by AnyBody application. Under Yo-bukun approach, subjects were asked to keep their iPhones installed with Yo-bukun application, in their chest pockets for the measurement. EMG based approach employs two EMG sensors placed on the subject's erector spinae. The positioning of the lumbar EMG sensors is shown in the Fig. 1. The left side sensor is considered as the first channel and the right side sensor is the second channel.

The subjects were all healthy adult males, 174±3 cm tall and 22±1 years old. Subject identifiers are A, B, and C respectively. The movement to be measured was the lifting and lowering of an object while kneeling on one knee. The dimensions of the object (a box), are 35(W)×23.5(D)×31(H)cm and the weight is 1 kg. Three types of movements were measured to examine the effects of the presence of an obstacle and the distance between the centers of gravity. The size of the obstacle was 51(W)×10(D)×51(H)cm. The subject's center of gravity was set at the pelvis. The experimental apparatus is shown in the Fig. 2.

The initial measurement was a subject lifting the object as close as possible to its body's center of gravity without placing any obstacles. The step wise process involves a subject lifting the object and remaining for 5 seconds, before lowering it. The distance between the center of gravity of the object and the subject's center of gravity was 10 cm. In the second measurement, the obstacle is in place, and the subject lowers the object to behind the obstacle starting from an apparatus configuration as in Fig. 2, subsequently returns it to the top of the obstacle. Upon lowering the object behind the obstacle, the subject stood upright and maintained the position for a duration of 5 seconds.

Fig.1 . EMG sensor placements

Fig.2 . Experimental apparatus (includes the lifting object and the obstacle)

Fig.3 Posture in which the center of gravity of both the subject and the object 10 cm

Fig.4 . Posture in which the center of gravity of both the subject and the object 30 cm

Then, the subject knelt down once more and raised the object back over the obstacle. The distance between the object's center of gravity and the subject's center of gravity was 30 cm. The third measurement closely resembled the second, with the distance between the center of gravity of the object and that of the subject being 45 cm. The postures observed during such measurements at the distance between the center of gravity of the object and that of the subject being 10 cm and 30 cm are depicted in Fig 3 and Fig. 4.

After that the transition of the amount of burden applied on the lower back during such movements were calculated using AnyBody and Yo-bukun. Later, the analysis incorporates the maximum and average values of the amount of burden observed here. The Delsys measured the EMG potentials of the lower back during movements. To reduce the influence of noise, the rate of increase was calculated by dividing the difference between the mean value of the EMG during movement and the mean value of the EMG at rest by the mean value of the EMG at rest. The resting EMG potentials refer to the potentials recorded when the subject is at rest for a 5-second interval between lifting and lowering movements.

3. Results

This chapter outlines the measurement outcomes for the three equipment types and provides a comparison between them. The movements are individually analyzed for lifting and lowering at center-of-gravity distances of 10 cm, 30 cm, and 45 cm, respectively.

3.1. Similarity between AnyBody and Yo-bukun

To validate the reliability of Yo-bukun, the similarity between AnyBody and Yo-bukun was assessed. Verification utilized the measurement data of subject B, analyzable with A. The coefficients of determination for each center-of-gravity distance are presented in Table 1. A somewhat stronger correlation was evident in the data at a center-of-gravity distance of 10 cm, while robust correlations were observed at center-of-gravity distances of 30 cm and 45 cm.

Table 1. Correlation between AnyBody and Yo-bukun (Subject B)

Center of gravity distance (cm)	R^2
10	0.5582
30	0.9289
45	0.9812

Table 2. The rates of increase in Yo-bukun measurements

Subject Identity	Center of gravity distance (cm)	Raising movement (Up) %	Lowering movement (Down) %
A	10	97.39	107.02
	30	110.71	104.21
	45	120.70	105.34
B	10	90.68	108.78
	30	140.64	132.38
	45	172.14	163.56
C	10	137.98	157.31
	30	197.84	193.90
	45	196.63	162.03

3.2. Analysis results using Yo-bukun

The rate of increase was also determined for the Yo-bukun in comparison with myoelectric potentials. The rate of increase in the Yo-bukun measurements for the three movements is shown in Table 2. The comparisons for the raising and lowering movements are shown in Fig. 5 and 6, respectively. The average rate of increase was obtained by excluding the rate of increase at 10 cm. The average rate of increase was 156.44% for the lifting motion and 143.57% for the lowering motion.

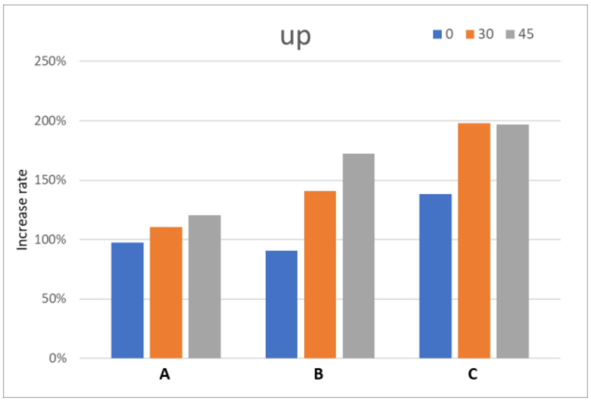

Fig.5. Yo-bukun Increase rate (up)

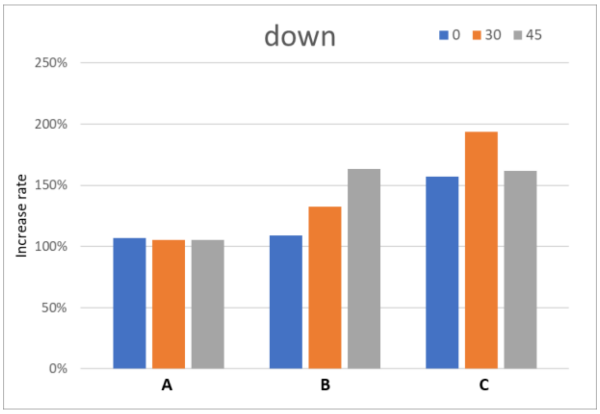

Fig.6. Yo-bukun Increase rate (down)

3.3. Analysis results using Delsys device

The rates of increase in lumbar EMG potentials during the three movements are shown in Table 3, and comparisons for raising (up) and lowering (down) movements are shown in Fig. 7 and Fig. 8, respectively. In all cases, the rate of increase was lowest when the center of gravity distance was 10 cm for each subject. For Subjects A and C, the rate of increase was higher when the center of gravity was 45 cm than when the center of gravity was 30 cm, for both lifting and lowering. For subject B, the rate of increase was higher when the center of gravity was 30 cm than when the center of gravity was 45 cm. The average rate of increase was obtained by excluding the rate of increase at 10 cm. The average rate of increase was 404.43% for the lifting motion and 394.71% for the lowering motion. The average increase was 2.59 and 2.75 times that of Yo-bukun for each operation.

Table 2. The rates of increase in lumbar EMG potentials

Subject Identity	Center of gravity distance (cm)	Raising movement (Up) %	Lowering movement (Down) %
A	10	30.43	5.73
	30	230.24	239.78
	45	339.78	296.69
B	10	59.08	68.08
	30	352.31	357.99
	45	247.76	284.30
C	10	16.20	16.48
	30	518.76	534.77
	45	737.72	654.72

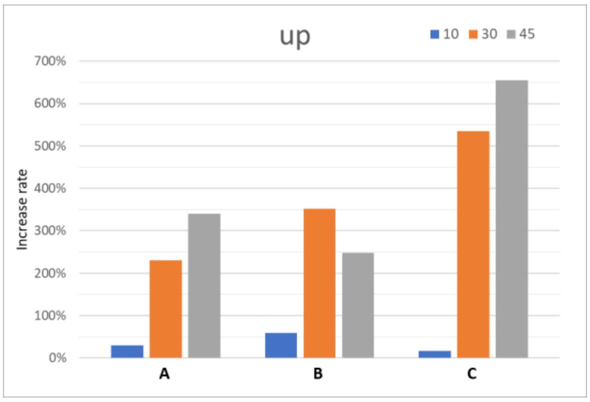

Fig.7. EMG Increase rate (up)

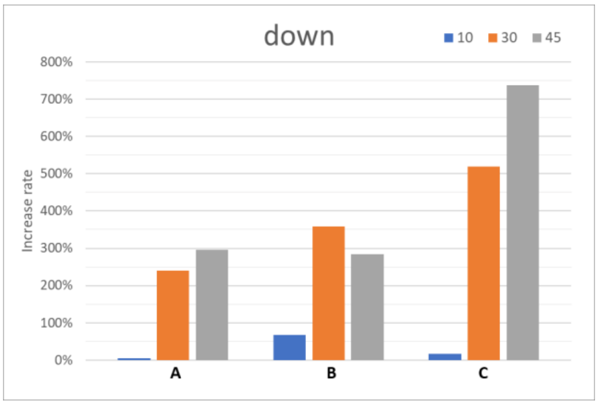

Fig.8. EMG Increase rate (down)

Fig.9 . Posture (Left: Subject B, Right: Subject C)

4. Conclusion

The rate of increase of EMG potentials during the movement was different in Subject B than in the other subjects. The possible reason for this is the difference in posture. The most notable difference is the curvature of the back. A comparison of the posture of Subject B and Subject C at a center of gravity distance of 45 cm is shown in the Fig. 9. The yellow circle at the pelvis position is the center of gravity. The white line is a simplified representation of the back. It can be seen that subject B has a straighter back than subject C. This indicates that subject B has a straighter back than subject C. This suggests that Subject B had less muscle stretch than Subject C, and that the rate of increase in myopotential was less pronounced in Subject B than in the other subjects.

In this paper, we analyzed movements using three types of measurement devices and verified the amount of lumbar burden in a situation where there is an obstacle between the subject and the lifting object. The analysis results shows that the change in the amount of lumbar burden due to the difference in the center of gravity distances was more pronounced in the electromyograms than in the measurements from the posture-based devices, such as the Anybody and the Yo-bukun. Therefore, it is possible that even in the one-kneeling lifting method, a significant distance between the object and the operator's center of gravity might not result in a reduction of electromyographic back burden.

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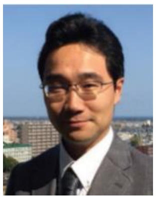

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