

The Correlation between the Muscle Activity and Joint Angle of the Lower Extremity According to the Changes in Stance Width during a Lifting Task

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Abstract. [Purpose] This study examined the correlation between the muscle activities and joint angle of the hip and knee according to the changes in stance width during a lifting task. [Subjects and Methods] The subjects of this study were 15 healthy students. A three-dimensional motion analyzer (SMART-E, BTS, Italy) was used to measure the joint angles of hip and knee during lifting. An 8-channel electromyograph (8-EMG) (Pocket EMG, BTS, Italy) was used to measure muscle activities of the erector spinae, gluteus maximus, rectus femoris, and tibialis anterior during lifting. The collected data were analyzed using the Pearson-test and SPSS 18.0. [Result] The muscle activity of the tibialis anterior was significantly decreased by increasing the stance width ($r = -0.285$). Muscle activity of the erector spinae was significantly decreased by increasing the knee angle ($r = -0.444$). The muscle activity of the gluteus maximus was significantly increased by increasing the muscle activity of the tibialis anterior ($r = 0.295$). [Conclusion] Efficient lifting is possible when stance width and knee flexion are increased, which results in reduced muscle activity of the tibialis anterior and the erector spinae. Lifting is facilitated when the muscle activities of the gluteus maximus and tibialis anterior are correlated.

Key words: Muscle activity, Joint angle, Lifting

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INTRODUCTION

Low back pain is a common musculoskeletal pain complaint in occupational settings¹⁾. Lifting technique can have a significant impact on spine loading during lifting²⁾. It is also recognized that lifting technique has the capacity to change the level of exposure to some risk factors for low back pain by altering trunk posture and moments generated by the external load²⁻⁴⁾.

Typically, forward bending to lift creates a lumbar moment that must be balanced and overcome by the erector spinae musculature⁵⁾. However, various calculations have shown that the erector spinae muscles alone are insufficient to raise the trunk when substantial external loads are being lifted⁶⁾. To lift heavy weights, the erector spinae must be assisted by additional musculoskeletal mechanisms to provide sufficient extensor moment⁷⁾. In a study of a squat exercise, McCaw and Melrose⁸⁾ noted a significant increase in gluteus maximus muscle activity with a heavy load under wide stance conditions as compared with a more traditional shoulder width stance. Hwang⁹⁾ reported that knee extension with prominent kinematics during squat lifting was produced by the contributions of kinetic factors from the hip and ankle joints (extensor moment and power generation) and that lumbar extension with prominent kinematics during stoop lifting could be produced by the contributions

of the knee joint kinetic factors (flexor moment, power absorption, and bi-articular muscle function). Sorensen et al.²⁾ noted that both the range of motion and peak acceleration in the sagittal plane were significantly affected by the stance width during lifting. The muscle activation levels, however, were not significantly affected by the stance width.

While there have been a number of studies that have compared the kinetic and kinematic characteristics between the stoop and squat lifting techniques¹⁰⁻¹²⁾, one characteristic of occupational lifting techniques that has not been considered is lifting stance width. Therefore, the purpose of the current study was to examine the correlation between the muscle activities and joint angles of the hip and knee according to the changes in stance width during a lifting task.

SUBJECTS AND METHODS

The subjects of this study were 15 healthy students aged 21.80 ± 1.28 years (mean \pm SD) with an average height and weight of 164.07 ± 7.44 cm and 56.20 ± 8.55 kg, respectively. None of the subjects had problems related to their musculoskeletal, nervous, or cardiovascular systems, and they were able to complete the lifting task according to the instructions given by the researcher. Before participating in this research, all the subjects were given an explanation about the content and the procedures of the experiment. They voluntarily participated in the research, and signed an informed consent form.

A three-dimensional motion analyzer (SMART-E, BTS, Italy) was used to measure the joint angles of the hip and knee during lifting. The motion analyzer has 6 infrared cameras and 2 video cameras (VIXTA 2 TVC, BTS, Italy). Circular passive markers are used for motion analysis. The kinematic data were sampled at a frequency of 120 Hz and processed using the SMART Analyzer data analysis program. The markers were attached to the anterior superior iliac spine (ASIS), greater trochanter, apex of fibular head, and lateral malleolus on the right side of the body.

An 8-channel electromyograph (8-EMG) (Pocket EMG, BTS, Italy) was used to measure muscle activities during lifting. The sampling rate of the electromyograph was set to 1,000 Hz (1,000 samples/second), and the amplified wave was band-pass filtered between 20–500 Hz. The EMG electrodes (Ag/AgCl Monitoring Electrode 2225, 3M, Korea) were attached to the erector spinae, gluteus maximus, rectus femoris, and tibialis anterior muscles on the right side of the body. The activity of each muscle was normalized to the EMG activity of maximal voluntary isometric contraction (MVIC), which was measured in manual muscle tests after linear filtering of the data for 5 seconds. The first and last second of data were discarded, and the average EMG signal of the middle 3 seconds was used as the 100% MVIC. The average root mean square (RMS) value was used to exhibit the activity of each muscle group during lifting.

Foot position was standardized with form of 11 in order to minimize measurement error. The distance between the feet was set to the appropriate stance width (10, 35, and 42 cm, respectively), according to the standard widths in Korean foot research¹³⁾. The task performed was randomized to eliminate order effects. Squat sitting was chosen for safety during lifting^{5, 14, 15)}. Sorensen et al.²⁾ reported that 10 kg is the proper weight for lifting four times consecutively over the period of one minute. Subjects performed lifting

4 times per stance width with a 10-kg box. The subjects were given 10 minutes of rest to prevent fatigue effects¹⁴⁾.

SPSS Version 18.0 for Windows was used for the data analysis in the present research. The characteristics of the data used in the analysis were confirmed to have a normal distribution with the Kolmogorov-Smirnov test (K-S test). The Pearson test was used to analyze the correlation between the muscle activities and joint angles according to changes in stance width during lifting. Statistical significance was accepted for values of $\alpha \leq 0.05$.

RESULTS

The muscle activity of the tibialis anterior was significantly decreased by increasing the stance width during lifting ($r=-0.285$, $p<0.05$). The muscle activity of the erector spinae was significantly decreased by increasing the knee flexion angle during lifting ($r=-0.444$, $p<0.01$). The muscle activity of the gluteus maximus was significantly increased by increasing the muscle activity of the tibialis anterior during lifting ($r=0.295$, $p<0.05$) (Table 1).

DISCUSSION

Cholewicki et al.¹⁶⁾ reported about stance width in heavy material lifting focused on trained power lifters. It is reported that trained power lifters show a reduction in the loading force of the lower spine (L4–5) when using a wide stance during lifting as compared with a conventional shoulder width stance; such a stance makes more efficient use of the lower muscles. Our research shows that muscle activity of the tibialis anterior decreased significantly as stance width during lifting was increased to 10, 35, and 42 cm ($p<0.05$). We thought that the loading force of the lower spine would decrease as a result of increased

Table 1. Correlation between the muscle activities and joint angles of the lower extremity according to the changes in stance width during lifting

		Stance width	Hip flexion angle	Knee flexion angle	Muscle activity			
					TA	RF	GM	ES
Stance width	r	1	0.165	-0.169	-0.285*	-0.145	0.127	-0.074
	p		0.263	0.250	0.049	0.326	0.388	0.616
Hip flexion angle	r		1	-0.018	-0.025	-0.276	0.236	0.232
	p			0.903	0.864	0.057	0.107	0.113
Knee flexion angle	r			1	0.076	-0.251	-0.242	-0.444**
	p				0.607	0.085	0.098	0.002
TA	r				1	0.077	0.295*	-0.091
	p					0.602	0.042	0.539
RF	r					1	-0.114	-0.132
	p						0.442	0.371
GM	r						1	0.205
	p							0.162
ES	r							1
	p							

r, correlation coefficient; p, probability; TA, tibialis anterior; RF, rectus femoris; GM, gluteus maximus; ES, erector spinae. * $p<0.05$; ** $p<0.01$

stance width. Also, we thought that muscle activity of the tibialis anterior would have decreased because of its large role in maintaining lower extremity position during lifting. Conversely, the muscle activity of the tibialis anterior was actually increased by decreasing the stance width. So, repeatedly lifting with a narrow stance width can result in muscle fatigue, not to mention that maintaining a proper squat position from the beginning position is more difficult than with a wide stance.

In the current study, the muscle activity of the erector spinae was significantly decreased with increasing knee flexion angle during lifting ($p < 0.01$). In previous studies, lifting 10 kg by the squat method increased the knee flexion angle and decreased the muscle activity of the erector spinae^{9, 17}. We have shown that the knee flexion angle and erector spinae are negatively correlated through analysis of statistical significance. Escamilla et al.¹⁸ reported that sumo wrestlers achieve maximum leverage by using a wide stance and increased knee flexion. Such a stance is used for powerful forces of reaction by flexion and then extension. The results of the experiment in our study reinforce the theoretical evidence for the power mechanics of sumo wrestlers.

McCaw and Melrose⁸) observed an increase in muscle activity of the gluteus maximus caused by heavy weight lifting with a wide stance during the squat exercise. In the current study, the muscle activity of the gluteus maximus was significantly increased with increasing muscle activity of the tibialis anterior during lifting ($p < 0.05$). We thought that the wide stance width associated with the hip abduction and lateral rotation would increase the muscle activity of the gluteus maximus to lift objects efficiently⁸). The finding of positive correlation between the gluteus maximus and tibialis anterior muscles can be utilized to develop an ideal strategy for lifting.

In conclusion, efficient lifting is possible when the stance width and knee flexion are increased, which results in reduced muscle activity of the tibialis anterior and the erector spinae. Lifting is facilitated when the muscle activities of the gluteus maximus and tibialis anterior are correlated. A limitation of the present research is that the experiment was conducted using only a small number of healthy students in their 20s. Thus, we cannot safely generalize our research results to any other age group. In future research, a correlation study will be conducted on the kinematics and kinetics of putting down, pushing, and pulling objects.

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