ORIGINAL ARTICLE

IJPHY

Changes in Trunk Muscle Activity When Holding an Object in Place — Focusing on the Distance Between Object and Body —

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ABSTRACT

Background: Sports events that involve heavy lifting include weightlifting and judo. Low back pain has been reported not only in these sports activities but also in jobs that require heavy weightlifting. This study focused on the posture used when holding an object in place since posture forms the basis of motion when lifting or carrying an object. The purpose of the study was to clarify the changes in muscle activity of the trunk based on the distance between the object and the body by surface electromyography (EMG).

Methods: EMG of the trunk muscles was measured in a resting standing position in which the subjects felt comfortable and in a standing position while holding an object. Dumbbells of two weights, 5 kg and 10 kg, were used as the weighted objects. The distances between the dumbbell and the body were set at 10 cm, 20 cm, and 30 cm, and the EMG of the trunk muscles was recorded. The relative values of integrated electromyography and the median power frequency were calculated.

Results: The results of this study indicate that control by the sacrospinal complex increases with the distance between the body and the object ($p < 0.01$).

Conclusion: This suggests that the level of activity required of the rectus abdominis remains the same at rest as when holding the object and that the activity of the sacrospinal complex should be adjusted considering the distance between the object and the body.

Keywords: Muscle activity, Electromyography, Holding, Trunk, Low back.

Received 28th August 2024, accepted 23rd November 2024, published 09th December 2024

www.ijphy.com

10.15621/ijphy/2024/v11i4/1527

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INTRODUCTION

Sports events that require heavy lifting include weightlifting and judo. Weightlifters lift heavy barbells from the floor to above their heads. Judo athletes repeat the motions of lifting, pulling, throwing, and pushing from various positions, even for opponents who are larger than themselves. Repeating these motions applies a load to the lower back and can cause lower back pain [1,2]. In judo athletes, the lumbar intervertebral disc degeneration rate has been reported to be higher in the heavyweight class than in the lightweight class [3]. Low back pain can also occur in these other sports, and low back pain limits sports activity.

Low back pain is also reported in jobs requiring heavy weightlifting [4-6]. Workers diagnosed with work-related lower back pain are most commonly engaged in the transportation and construction industries. It is well known that these industries require more frequent lifting and carrying of heavy weights than other industries. Physiotherapists and nurses are also at higher risk of low back pain [7,8]. Healthcare workers tend to experience low back pain in the context of their work. In daily work, they must assist patients and lift and carry them. These tasks load the lower back [9]. When they cannot use support aids during these tasks, more load is applied to the lower back. Low back pain affects work productivity, and the quality of medical care decreases [7,10].

Additionally, it can lead to absenteeism and poor performance by healthcare workers, decreased job satisfaction, and increased healthcare costs[11]. More broadly, lifting and holding objects such as luggage requires combined spinal column movements in daily life, exposing the lumbar region to chronic strain. Even if an object is light and small, repeating such motions may factor in lower back pain. It is, therefore, necessary to clarify the load on the lower back in motions that involve lifting and holding objects.

Causes of low back pain include lifting heavy weights and work environments that require repetition and combined postures of lateral bending and rotation [12]. In particular, work requiring lifting heavy weights usually involves repeated postures such as lateral bending and rotation, which is closely related to the occurrence of injury. Many studies have examined trunk muscle activity while lifting heavy weights [13-16]. However, most of them examined the differences in muscle activity depending on the weight being lifted or the lifting posture in flexion-extension motions. Since posture is the basis of the movement when lifting or carrying an object, paying attention to the posture when holding the object is also important. In a previous study that focused on the posture when holding an object, the position of the weight was changed, and trunk muscle activity was examined. It was shown that when handling the same magnitude of external loading, a more medially distributed load configuration would result in higher levels of trunk muscle contraction compared to a more laterally distributed load configuration [17]. In addition, another study that calculated the moment reported that holding an object close to the body reduces the bending moment of the spine [18]. However, in the study, the weight was the same, but the object's size was different. Therefore, the comparison was made under different shoulder joint flexion angle conditions. The weight of the upper limbs could not be taken into consideration. The height of an object also differs depending on the shoulder joint flexion angle. It is necessary to consider these and compare them under the same conditions. From the above, the purpose of this study was to clarify the changes in muscle activity of the trunk according to the distance between the object and body by surface electromyography, keeping the size of the object and the height at which it is held constant.

METHODS

The participants were nine healthy males (age: 23.6 ± 1.8 (21 - 26) years, height: 172.9 ± 6.1 (165.0 - 183.0) cm, weight 66.6 ± 4.7 (60.0 - 75.0) kg) who did not show any abnormality of neurological function or the musculoskeletal system. The participants were healthy with no previous history of spinal surgery, scoliosis, spinal fracture or spondylolisthesis, or low back pain in the last 12 months. All study tasks were carried out following the Declaration of Helsinki. Before the experiment, all participants were informed of the purpose of the study and agreed to participate. The study was approved by the Ethical Review Committee of the participants' hospital.

Surface electromyography (EMG) of the trunk muscles was performed in a resting standing position in which the subject felt comfortable (unloaded) and in a standing position while holding an object (loaded). These positions were held for 10 seconds. In the resting standing position, the upper limbs were kept at the side of the body. In the loaded standing position, the elbow joints were flexed 90 degrees from the resting position, and the forearms were in a supinated position parallel to the floor. Dumbbells of two weights, 5 kg and 10 kg, were used as weighted objects. The distance between the dumbbell and the body was defined as the shortest distance between a perpendicular line passing through the acromion and the center of the dumbbell, and three conditions were set: 10 cm, 20 cm, and 30 cm (Figure 1). Six patterns combining the conditions of dumbbell type and distance between dumbbell and body were performed randomly.

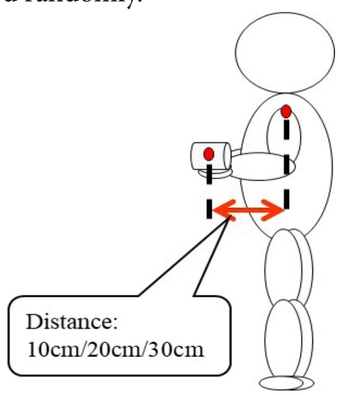

Figure 1. The distance between the dumbbell and the body

During the tasks, EMG of the trunk muscles was recorded using a MyoSystem 1400 (Noraxon, USA). The muscles tested were the rectus abdominis (upper and lower parts) and the sacrospinal complex (thoracic and lumbar spinal columns). The skin was meticulously prepared for analysis using EMG by abrasion with gel and alcohol before electrode placement. Then, electrodes were placed using the anatomical landmarks as indicators (Figure 2). In the rectus abdominis, the navel was used as the index for dividing the upper and lower parts. In the sacrospinal complex, the level of the twelfth thoracic (Th12) was used as the index for the thoracic spinal column, and the level of the third lumbar (L3) was used as the index for the lumbar spinal column. The EMG data underwent band-pass filtering (10 - 500 Hz) before being sampled at 1 kHz. The data used were the middle 5 seconds within 10 seconds of measurement time, excluding 2.5 seconds each at the start and end. The integrated EMG (IEMG) of each muscle in the loaded standing position (while holding the dumbbell) was divided by the IEMG of the resting standing position of the same muscle, and the relative values of IEMG were calculated. The median power frequency (MdPF) was also calculated.

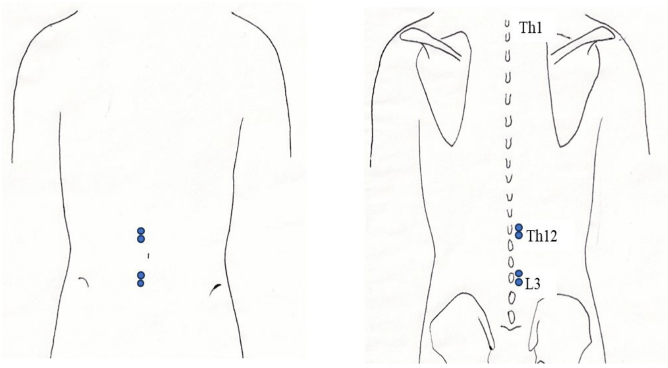

Figure 2. The electrode location

The normality of the distribution of the obtained data was evaluated using the Shapiro-Wilk test. Subsequently, comparisons among the IEMG and MdPF under different conditions (5cm, 10cm, and 15cm) were conducted using the Friedman test, followed by post hoc Bonferroni correction to identify significant differences. There was a repeated measures component. Statistical analyses were performed using SPSS (version 28.0 for Windows; IBM SPSS Japan, Tokyo, Japan), with the significance level set at $p < 0.05$.

RESULTS

The results of each measurement parameter are shown in Tables 1 and 2.

In comparing the relative values of IEMG, the thoracic spinal column of the sacrospinal complex in 5kg and 10kg were significantly higher in 20cm and 30cm than in 10cm ($p < 0.01$). The thoracic spinal column of the sacrospinal complex in 10kg was also significantly higher in 30cm than in 10cm ($p < 0.01$). In addition, the lumbar spinal column of the sacrospinal complex in 5kg was significantly higher in 30cm than in 10cm ($p < 0.01$). The lumbar spinal column of a sacrospinal complex in 10kg was also significantly higher in 20cm and 30cm than in 10cm ($p < 0.01$). However, no significant differences were observed between conditions in the upper parts of the rectus abdominis in 5kg ($p = 0.169$) and 10kg ($p = 0.169$). No significant differences were observed between conditions in the lower parts of the rectus abdominis in 5kg ($p = 0.196$) and 10kg ($p = 0.236$).

In comparing the MdPF, the lumbar spinal column of the sacrospinal complex in 5kg and 10kg was significantly higher in 30cm than in 10cm ($p < 0.05$). However, no significant differences were observed between conditions in the upper parts of the rectus abdominis in 5kg ($p = 0.462$) and 10kg ($p = 0.264$), and in the lower parts of the rectus abdominis in 5kg ($p = 0.819$) and 10kg ($p = 0.895$). No significant differences were observed between conditions in the thoracic spinal column of a sacrospinal complex in 5kg ($p = 0.169$) and 10kg ($p = 0.236$).

Table 1: Comparison of the relative values of IEMG under three experimental conditions (N = 9)

		10cm	20cm		30cm		df	χ^2	p
Upper parts of the rectus abdominis	5kg	1.07 ± 0.18	0.92 ± 0.19		0.97 ± 0.18		2	3.556	0.169
	10kg	1.07 ± 0.23	1.05 ± 0.19		1.08 ± 0.26		2	3.556	0.169
Lower parts of the rectus abdominis	5kg	1.22 ± 0.17	1.03 ± 0.16		1.12 ± 0.20		2	3.257	0.196
	10kg	1.05 ± 0.20	1.10 ± 0.18		1.13 ± 0.32		2	2.889	0.236
Thoracic spinal column of sacrospinal complex	5kg	2.10 ± 0.87	2.85 ± 1.10	a	3.57 ± 1.44	a	2	11.556	0.003
	10kg	2.62 ± 0.86	4.05 ± 1.50	a	5.79 ± 2.48	ab	2	18.000	<0.001
Lumbar spinal column of sacrospinal complex	5kg	1.52 ± 0.37	2.16 ± 1.06		0.27 ± 0.13	a	2	9.556	0.008
	10kg	0.18 ± 0.12	0.27 ± 0.14	a	0.37 ± 0.11	a	2	14.889	<0.001

Mean ± SD.

a: $p < 0.01$ vs. 10cm, b: $p < 0.01$ vs. 20cm.

IEMG under different conditions (10cm, 20cm, and 30cm) was compared using the Friedman, followed by post hoc Bonferroni correction to identify significant differences.

Table 2: Comparison of MdPF under three experimental conditions (N = 9)

		10cm	20cm	30cm	df	χ^2	p
Upper parts of the rectus abdominis	5kg	23.10 ± 14.81	20.89 ± 9.73	20.09 ± 9.32	2	1.543	0.462
	10kg	18.96 ± 7.90	16.81 ± 8.85	21.57 ± 9.56	2	2.667	0.264
Lower parts of the rectus abdominis	5kg	87.02 ± 55.80	98.40 ± 54.53	85.81 ± 46.10	2	0.400	0.819
	10kg	88.73 ± 68.23	79.27 ± 46.82	96.68 ± 60.32	2	0.222	0.895
Thoracic spinal column of sacrospinal complex	5kg	57.88 ± 18.72	61.80 ± 13.05	64.37 ± 10.26	2	3.556	0.169
	10kg	62.26 ± 11.38	68.36 ± 16.04	67.98 ± 10.61	2	2.889	0.236
Lumbar spinal column of sacrospinal complex	5kg	58.17 ± 27.18	65.33 ± 30.83	74.00 ± 28.65 a	2	6.889	0.032
	10kg	52.92 ± 33.80	74.11 ± 27.89	91.04 ± 22.57 a	2	8.971	0.011

Mean ± SD.

a: $p < 0.01$ vs. 10cm.

MdPF under different conditions (10cm, 20cm, and 30cm) was compared using the Friedman, followed by post hoc Bonferroni correction to identify significant differences.

DISCUSSION

This study focused on the loaded standing position (holding an object) and examined the changes in trunk muscle activity at different distances between the object and the body.

In the upper and lower parts of the rectus abdominis, there were no significant differences in the relative values of IEMG at different distances between object and body at both 5 kg and 10 kg, and the muscle activity was similar to that in the resting standing position. This indicates that an object of about 10 kg can be held without changing the muscle activity of the rectus abdominis. In addition, there was no significant difference in the MdPF among distances at 5 and 10 kg. From these results, the number of motor units participating in muscle activity and the firing rates of the motor units do not change when the participant holds an object up to 30 cm away at 10 kg.

In contrast, in the thoracic spinal column and lumbar spinal column of the sacrospinal complex, the relative values of IEMG at 20 cm and 30 cm were higher than at 10 cm when holding a 5 kg and 10 kg object. In addition, the MdPF at 30 cm was higher than at 10 cm. Previous studies reported that the closer the object is to the body during weight-holding tasks, the less the spinal flexion moment [18]. Therefore, it shows that the farther the object is from the body, the more the spinal flexion moment is controlled and the more active the lower back muscles. Therefore, the results of this study support previous studies.

Since the condition of this task was that the forearms be parallel to the floor, the object was level with the lumbar region. The L3 has a well-developed vertebral arch and is a relay point for the latissimus dorsi, the longissimus thoracis, and the multifidus [19]. Thus, the L3 experiences additional traction load from the muscle group originating from the sacrum and ilium even though the L3 is located at the top of lordosis in the lumbar spine. Because the L3 is mobile, it has a role in bridging the pelvis and the spinal column. From above, the rotation axis of the trunk flexion is considered to be at the level of the L3, and we can consider that this part of the trunk controls the moment of flexion caused by holding the object. As a result, the relative values of IEMG and the MdPF were increased in the sacrospinal complex. This indicates that the flexion moment of the trunk that occurs while holding the object in front of the body in the standing position needs to be controlled by the sacrospinal complex. The results also clarified that this moment became more pronounced at a distance of approximately 30 cm, weighing about 10 kg. This confirmed that the muscle activity of the sacrospinal complex increases depending on distance, even for the same weight.

Furthermore, it was found that the muscle activity of the sacrospinal complex may increase when the object's weight increases, even at a distance of about 30 cm when the upper arm is near vertical. Since we focused on the muscle activity of the trunk, we did not examine external forces or stresses on bones and ligaments. In the future, we would like to investigate these factors to gain further insights.

The results of this study indicate that control by the sacrospinal complex increases when the distance between the body (center of mass) and the object is far; the activity required of the rectus abdominis does not change between resting and holding the object, while the activity required of the sacrospinal complex depends on the distance between the object and the body.

In this study, we examined the load on the lower back while holding an object from the viewpoint of muscle activity. In the loaded standing position (while holding the weighted object), a distance of about 30 cm between the object and body can be judged to be 'far'. It can be used as a guideline based on our observation that muscle activity of the sacrospinal complex is increased at 30 cm for a 10 kg weight. As for the weight of an object that would affect muscle activity of the sacrospinal complex, 10 kg can be used as a reference value. However, it is necessary to consider the muscle strength of the trunk when instructing others because it differs among individuals.

The results of this study can be used to instruct low back pain patients on safe motion, such as focusing on sacrospinal complex activity rather than the rectus abdominis activity when holding an object of 10 kg or moving the object as close to the body as possible.

Clinical Relevance

The clinical relevance of the study outlined in the passage lies in its implications for understanding and managing low back pain, particularly in individuals engaged in activities that involve heavy lifting or holding objects at various distances from the body.

- Insights into Low Back Pain Mechanisms: The study sheds light on the role of trunk muscle activity, specifically the rectus abdominis and the sacrospinal complex, in maintaining stability and controlling movements while holding objects. Understanding how different muscles are recruited and how muscle activity changes based on factors like object weight and distance from the body provides valuable insights into low back pain mechanisms.

- Guidelines for Safe Lifting Practices: By identifying that muscle activity of the sacrospinal complex increases when holding an object at a distance of about 30 cm, especially with a weight of approximately 10 kg, the study offers practical guidelines for safe lifting practices. This information can be utilized in occupational settings, such as construction or healthcare, to help workers minimize the risk of low back injuries while performing tasks that involve lifting or holding objects.

- Clinical Recommendations for Low Back Pain Patients: The findings can inform clinical recommendations for individuals with low back pain, guiding safer lifting techniques and object manipulation strategies. Specifically, emphasizing the importance of sacrospinal complex activity over rectus abdominis activity when handling heavier objects or moving them away from the body could help reduce the risk of exacerbating low back pain symptoms during daily activities.

- Customized Rehabilitation Strategies: Understanding how different trunk muscles respond to varying loads and distances can aid in developing tailored rehabilitation strategies for patients with low back pain. Therapeutic interventions targeting specific muscle groups based on the findings of this study could improve treatment outcomes and facilitate the safe return to functional activities.

- Preventive Measures in Sports and Occupational Settings: Sports coaches, athletes, and occupational health professionals can use the study findings to implement preventive measures to reduce the incidence of low back pain related to heavy lifting or holding objects. This may include optimizing lifting techniques, incorporating strength and conditioning programs targeting relevant trunk muscles, and promoting ergonomic practices in the workplace.

Overall, the study contributes to our understanding of the biomechanics of low back pain and provides practical implications for injury prevention and rehabilitation strategies in various contexts, ranging from sports to occupational settings and clinical rehabilitation.

Limitations of the Study:

- Small Sample Size: With only nine male participants, the study's findings may lack generalizability to broader populations, especially to females or older individuals.

- Limited Weight and Distance Variations: The study used only two weights (5 kg and 10 kg) and tested three distances (10 cm, 20 cm, and 30 cm). It did not explore the effects of heavier weights or greater distances, which may be relevant in real-world settings.

- Narrow Scope of Muscle Activity: The focus was on muscle activity, but other factors, such as ligament or joint stress and external forces on bones, were not assessed. These aspects could also contribute to low back pain.

- Healthy Participants Only: The study was conducted on healthy individuals without musculoskeletal or neurological abnormalities, limiting its applicability to individuals with low back pain or other physical conditions.

CONCLUSIONS

The study found that while holding an object, particularly at heavier weights (10 kg), the relative muscle activity of the sacrospinal complex's thoracic and lumbar spinal columns increased significantly when the object was held at a distance of 30 cm compared to 10 cm. This indicates that the distance between the body and the object plays a crucial role in determining the level of muscle activation in the sacrospinal complex. In addition, the findings have implications for instructing low back pain patients on safe motion techniques. Specifically, the study suggests that focusing on sacrospinal complex activity, rather than rectus abdominis activity, may be more beneficial when holding objects weighing approximately 10 kg. Additionally, it recommends moving objects as close to the body as possible to minimize the strain on the lower back.

Acknowledgments

The authors of this study are grateful to the volunteer participants.

Funding Source Declarations: This research did not receive any specific grant from public, commercial, or not-for-profit funding agencies.

Conflict of Interest Statements: The authors have no conflict of interest to declare.

Disclaimer: The views expressed in the article are ours and not those of funders/institutions.

Credit Authorship Statement

Yumi Okayama: Methodology, Validation, Conceptualization, Resources, Data curation, Formal analysis, Writing - original draft.

Shinich Daikuya: Supervision, Project administration.

REFERENCE

[1] Pococco E, Ruedl G, Stankovic N, Sterkowicz S, Vecchio FBD, Gutiérrez-García C et al. Injuries in judo: a systematic literature review including suggestions for prevention. Br J Sports Med. 2013; 47: 1139-43.

[2] Yabe Y, Hagiwara Y, Sekiguchi T, Momma H, Tsuchiya M, Kanazawa K et al. Low Back Pain in School-Aged Martial Arts Athletes in Japan: A Comparison among

Judo, Kendo, and Karate. Tohoku J Exp Med. 2020; 251: 295-301.
[3] Okada T, Nakazato K, Iwai K, Tanabe M, Irie K, Nakajima H. Body mass, nonspecific low back pain, and anatomical changes in the lumbar spine in judo athletes. J Orthop Sports Phys Ther. 2007; 37(11): 688-93.
[4] Walsh K, Varnes N, Osmond C, Styles R, Coggon D. Occupational causes of low-back pain. Scand J Work Environ Health. 1989; 15(1): 54-9.
[5] Xu Y, Bach E, Orhede E. Work environment and low back pain: the influence of occupational activities. Occup Environ Med. 1997; 54: 741-5.
[6] Riihimaki H. Low-back pain, its origin and risk indicators. Scand J Work Environ Health. 1991; 17(2): 81-90.
[7] Holder NL, Clark HA, DiBlasio JM, Hughes CL, Scherpf JW, Harding L et al. Cause, prevalence, and response to occupational musculoskeletal injuries reported by physical therapists and physical therapist assistants. Phys Ther. 2009; 79(7): 45-52.
[8] Kasa AS, Workineh Y, Ayalew E, Temesgen WA. Low back pain among nurses working in clinical settings of Africa: systematic review and meta-analysis of 19 years of studies. BMC Musculoskelet Disord. 2020; 21(310): 1-11.
[9] Farooq MA, Awwal LM, Musa HA, Mustapha GA. Work-related risk factors for lower Back pain among nurses in Ahmadu Bello University teaching hospital (ABUTH), Zaria-Nigeria. IOSR J Nurs Heal Sci. 2015; 4(3): 20-5.
[10] Punnett L, Wegman D. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol. 2004; 14:13-23.
[11] Asadi P, Kasmaei VM, Ziabari SMZ, Zohrevandi B. The prevalence of low back pain among nurses working in Poursina hospital in Rasht, Iran. J Emerg Practice and Trauma. 2016; 2(1): 11-5.
[12] Adam MA, Hutton WC. The effect of posture on the lumbar spine. J Bone Joint Surg. 1985; 67B (4): 625-9.
[13] Delitto RS, Rose SJ. An electromyographic analysis of two techniques for squat lifting and lowering. Phys Ther. 1992; 72(6): 438-48.
[14] Chen WJ, Chiou WK, Lee YH, Lee MY, Chen ML. Myo-electric behavior of the trunk muscles during static load holding in healthy subjects and low back pain patients. Clin Biomech. 1998; 13(1): 9-15.
[15] MacKenzie JF, Grimshaw PN, Jones CDS, Thoirs K, Petkov J. Muscle activity during lifting: Examining the effect of core conditioning of multifidus and transversus abdominis. Work. 2014; 47(4): 453-62.
[16] Boocock MG, Taylor S, Mawston GA. The influence of age on spinal and lower limb muscle activity during repetitive lifting. J Electromyogr Kinesiol. 2020; 55: 1-8.
[17] Medinei S, Ning X. Effects of the weight configuration of hand load on trunk musculature during static weight holding. Ergonomics. 2018; 61(6): 831-8.
[18] Nordin M, Frankel VH. Basic Biomechanics of the Musculoskeletal System. Fourth Edition, Williams & Wilkins, 2012.
[19] Neuman DA. Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation. Third Edition, Elsevier, 2017.