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Correlation of exercise level and electromyography of trunk stabilizer muscles during manual lifting among experienced back belt users

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Abstract

Background: The exercise level of the trunk stabilizer muscles (ELLS) is known to be associated with the ability to control back stability with the transversus abdominis (TrA) muscle. An important role of the TrA is feedforward activity necessary for preventing lower back injury (LBI). Therefore, it can be postulated that lifting workers who always wear a back belt for certain periods of time are at risk for decreasing activity in the TrA or other trunk muscles during lifting with or without a back belt.
Objective: This study evaluates the correlation between the ELLS and electromyography (EMG) of selected trunk muscles during manual lifting with and without a back belt in experienced back belt users.
Materials and Methods: Sixteen participants from a warehouse in Thailand, aged 22 to 44 years, were assessed for ELLS, which was indicated by values ranging from level 1 (weakest) to level 6 (strongest), and the EMG of selected trunk stabilizer muscles, including the rectus abdominis (RA), external abdominal oblique (EO), TrA/internal oblique (IO), erector spinae (ES), and multifidus (MF). The EMG data were recorded during manual lifting in a dynamic semisquat posture for conditions of lifting with and without a back belt.
Results: The results of the Pearson correlation coefficient between the ELLS and normalized EMG (NEMG) of the selected trunk muscles showed a positive significant correlation between the ELLS and TrA/IO activity only during lifting without a back belt (r_p = 0.537, p = 0.032). However, there was no correlation between the ELLS and other selected muscles during lifting with or without back belt.
Conclusion: This study demonstrates that ELLS indicates the importance of workers using the TrA during lifting without a belt. Therefore, a specific exercise program to improve the strength of the TrA is necessary for back belt users.

Keywords: Transversus abdominis; abdominal support; material handling; ergonomics; lumbarstabilization; MVC

1. Introduction

The exercise level of lumbar stabilizers muscles (ELLS) is measured in a series of six exercises ranging from easy (level 1) to most difficult (level 6) on the basis of the ability to maintain the spine in a static position while increasing lower extremity loading [1]. This ELLS was modified from the series of seven exercises created by Hagins [2] and was improved to be more reliable and more appropriate for Thai people [3]. The ELLS is known to be associated with the ability to control back stability with the transversus abdominis (TrA) muscle [2]. Therefore, the highest level of ELLS indicated the strongest TrA, which can consequently help prevent back injury.

A previous study found an increasing back injury rate among lifting workers when they were not wearing a belt following a period of wearing a belt [4]. It was believed that the belt decreases back muscle activity by increasing intra-abdominal pressure. This effect helps a lifting worker feel safe in lifting significantly more weight. However, it was not recommended for healthy workers to wear a back belt as a protective device [5]. In spite of this, a belt is still commonly used by manual laborers. Thus, manual lifting workers who still need to wear a belt should know more about their ability to control back stability, especially with the TrA, to prevent back injuries. However, there have been no studies concerned with the level of ELLS and the relationship between the level of ELLS and EMG of back stabilizers muscles among experienced back belt users during manual lifting. The results of this study will help produce recommendations for back belt users to further exercise the TrA as an important trunk stabilizer muscle.

The purpose of this study was to clarify the correlation between the ELLS and EMG of selected trunk muscles during manual lifting with and without a back belt among experienced back belt users.

2. Methods

2.1. Study design

The study had a quasi-experimental design. The subjects performed a lifting task three times with two belt conditions, with and without a belt, and performed an ELLS test.

2.2. Subjects

Sixteen male subjects with no previous history of back or abdominal surgery that may have affected the experiment participated in this study. All of the subjects were workers from one section of a warehouse and distribution center in Thailand, and their work involved only repetitive manual lifting tasks. They had been wearing back belts for at least six months. All subjects provided written informed consent before participating in the study. The protocol for the study was approved by the Mahidol University Institutional Review Board.

2.3 Instruments

- Back belt: The back belt used in this study was a typical industrial elastic belt with four semirigid bars aligned on the back with anterior fastening with Velcro. The belt had a posterior height of 20 cm and an anterior height of 12 cm.
- Work simulator and EMG: A Primus RS system (BTE Technologies, Inc. USA) was used to simulate lifting work tasks. A lifting box was created from wood with dimensions of 25 × 32 × 29 cm^3 (W × L × H) and was placed on a wooden stand 24 cm high. The base of the box was attached to the cable system of the Primus RS. The two parameters of the lifting task, torque (T) and velocity (V), were synchronized with an EMG unit (Telemyo 2400 G2, Noraxon, USA, Inc) using the Noraxon Program on an EMG monitor.
- Pressure biofeedback unit (PBU): This unit, called the Stabilizer (Chattanooga, manufactured in Australia), which was used to test for the level of lumbar stabilization, consisted of a three-connected-chamber air-filled bag. The air-filled bag was inflated to fill the space between the target body area and a firm surface. The pressure gauge was marked in increments of 2 mmHg from 0 to 200 mmHg to indicate the pressure in the bag for feedback on position.

2.4. Experimental procedure

All of the experimental procedures related to EMG electrode placement, the MVC test, and the lifting task test have already been described in a previous study by the authors [6]. The EMG electrode was placed on the right trunk muscles, including the TrA/internal abdominal oblique (IO), rectus abdominis (RA), external abdominal oblique (EO), erector spinae (ES), and multifidus (MF) [7]. The lifting task test (see Fig. 1) involved dynamic semisquat lifting from the middle of the shank to knuckle height with and without a back belt. Subjects were instructed to lift three times with 20 s of rest between each lift. The lifting condition order was randomized with 5 min of rest between conditions. Lifting speed was controlled by a metronome preset at a frequency of 48 beats/min.

The EMG signals were recorded at a sampling rate of 2 kHz and processed using MyoResearch XP EMG Application Protocols v. 1.06.54 (Noraxon Inc., USA) to reduce the electrocardiogram (ECG) signal and smooth data using the root mean square (RMS) while moving the processing window every 20 ms. Only the position of the start of the lift of the box was calculated to determine the percentage of the MVC (%MVC) in order to normalize all EMG values (NEMG) [6].

Figure 1 Position of EMG recording in the position of start lifting

The ELLS test in this study followed the guidelines from Thongjunjua 2005 [8]. To start testing, the examiner aligned the PBU bag under the L1-S2 back level of the subject and inflated the bag to a pressure of 40 mmHg. Then, all subjects had to complete the tests in the order stated below. In each test, the subject was instructed to hollow the abdominals and maintain a pressure of 40 mmHg ($\pm$4 mmHg) for three breathing cycles. The degrees of difficulty of the test exercise were as follows [8]:

Figure 2. Starting position of ELLS test

- **Level 1: Abdominal hollowing**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor (Fig. 1) and performed static abdominal hollowing for three breathing cycles.
- **Level 2: Unilateral abduction**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor. Then, the right leg was abducted to approximately 45° from the floor with the left knee held steady.
- **Level 3: Unilateral knee extension**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor. The right knee joint was extended to 0° while controlling the hip to remain at a constant angle.

- **Level 4: Unilateral knee raise**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor. The right knee was raised toward the chest until it just passed a hip flexion of approximately 90° and then was allowed to flex naturally.
- **Level 5: Bilateral knee raise**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor. The right knee was raised toward the chest until it just passed a hip flexion of approximately 90° with the knee in a flexed position and held. This was followed by raising the left knee in the same manner and holding both knees together and finished by placing the right leg in the starting position. The procedure was then repeated with the left leg.
- **Level 6: Bilateral knee raise**. Participant assumed bent lying position with the hips at 70° and feet flat on the floor. Both knees were raised toward the chest until they just passed a hip flexion of approximately 90° with natural knee flexion. Both legs were placed in the starting position to finish the movement.

The outcome of ELLS test for each subject was the last level of ELLS that the subject could completely perform three times.

2.5. Statistical analysis

The Pearson correlation coefficient was used to determine the association between the NEMG of trunk muscles and ELLS.

3. Results

There were a total of 16 experienced manual lifting workers in the study. They had no musculoskeletal disorders or other disorders that might have affected participation in the study. Their mean age, height, weight, and body mass index (BMI) were 30.17 ± 6.15 yrs, 170.5 ± 6.05 cm, 62.08 ± 8.4 kg, and 21.29 ± 2.02 kg/m^2, respectively. Most of them had experience in lifting tasks in the range of 1–7 years and had regularly worn a back belt for more than 8 h per day. They took the belts off only during resting periods**.**

Table 1 presents the ELLS test results among all 16 subjects in this study. A higher level indicates a greater ability of the TrA to stabilize the lumbar spine (Table 1). That is, level 1 represents the least control using the TrA muscle, and level 6, which is highest level in this test, represents the greatest ability of the TrA muscle to stabilize the lumbar spine. The results showed that half of the subjects in this study had an ELLS at level 4 (50%).

Table 1. The exercise level of the lumbar stabilization of subjects

Level of ELLS	Number of subjects (n = 16)	Percentage
Level 1	1	6.2%
Level 2	3	18.8%
Level 3	2	12.5%
Level 4	8	50.0%
Level 5	2	12.5%

Table 2 presents the statistical analysis results of the Pearson correlation coefficient between the level of ELLS and NEMG (%MVC) of five trunk muscles during manual lifting with and without a belt. The results showed a significant positive correlation between ELLS and TrA/IO activity during lifting without a back belt ($r_p = 0.537$, $p = 0.032$). A higher level of ELLS corresponds to more EMG activity of the TrA muscle during lifting without a belt among belt users.

Table 2. Correlations between level of trunk stabilization and %MVC of RA, TrA/IO, EO, ES, and MF during lifting without and with back belt (n = 16)

Independent variables	Correlation coefficient with %MVC of trunk muscle activities during lifting **without** a back belt				
	TrA	RA	EO	ES	MF
Exercise level of lumbar stabilization (1–6)	r_p = 0.537* p = 0.032	r_p = 0.039 p = 0.887	r_p = -0.343 p = 0.194	r_p = -0.185 p = 0.493	r_p = 0.026 p = 0.924
Independent variables	**Correlation coefficient with %MVC of trunk muscle activities during lifting with a back belt**				
	TrA	RA	EO	ES	MF
Exercise level of lumbar stabilization (1–6)	r_p = 0.303 p = 0.254	r_p = 0.106 p = 0.697	r_p = -0.386 p = 0.139	r_p = -0.070 p = 0.796	r_p = 0.177 p = 0.511

Note: * = Significant difference at $p < 0.05$

r_p = Pearson correlation coefficient

4. Discussion

The hypothesis of this study was that wearing a back belt may reduce the activity of the TrA because the effect of the belt may help stabilize the spine. Thus, long-term use may decrease the role of this stabilizer. However, the results of the current study showed that more than half of the subjects had adequate levels of trunk stabilization control, and half of them (50%) had an ELLS of level 4, which meant that they had good control of the TrA muscle.

In the statistical study between the ELLS test and NEMG, it was found that NEMG of the TrA during lifting without a belt was significantly correlated with exercise level (Table 2). This means that during lifting without a back belt, the activity of the TrA/IO increased in subjects who had a high level of ELLS and decreased in subjects who had a low level of ELLS. Thus, without a belt, workers performing lifting tasks should be encouraged to exercise the TrA muscle, as it can improve ELLS, which can help prevent back injury from lifting tasks. On the other hand, inadequate support indicated that the belt decreased ELLS among belt users, as most of them had high levels of ELLS.

5. Conclusion

This study reports that more than half of experienced lifting workers who wore a back belt for more than 1 yr had adequate levels of trunk stabilization control (level 4). A positive significant correlation between ELLS with TrA/IO activity during lifting without a back belt was found; thus, a specific exercise program to improve the strength of the TrA is necessary for back belt users.

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References

[1] Thongjunjuea S, Wongprasertgan M. Reference values of exercise level attained for lumbar stabilization exercises in young adults. *Thai J Phy Ther*. 2011;**34**(1):37–44.

[2] Hagins M, Adler K, Cash M, Daugherty J, Mitrani G. Effects of practice on the ability to perform lumbar stabilization exercises. *J Orthop Sports Phys Ther* 1999;**29**(9):546–55.

[3] Thongjunjua S. Effects of lumbar stabilization exercises on exercise level attained in heathy subjects. *Thai J Phy Ther*. 2006;**29**(1):1–13.

[4] Reddell CR, Congleton JJ, Dale Huchingson R, Montgomery JF. An evaluation of a weightlifting belt and back injury prevention training class for airline baggage handlers. *Appl Ergon* 1992;**23**(5):319–29.

[5] McGill SM. Should industrial workers wear abdominal belts? Prescription based on the recent literature. *Int J Ind Ergonom* 1999;**23**:633–6.

[6] Kurustien N, Mekhora K, Jalayondeja W, Nanthavanij S. Trunk stabilizer muscle activity during manual lifting with and without back belt use in experienced workers. *J Med Assoc Thai* 2014;Suppl(**97**):s75–9.

[7] Marshall P, Murphy B. The validity and reliability of surface EMG to assess the neuromuscular response of the abdominal muscles to rapid limb movement. *J Electromyogr Kines:* 2003;**13**(5):477–89.

[8] Thongjunjua S. Effects of lumbar stabilization exercises on exercise level attained in healthy subjects. [Thesis (M.Sc.(Physiotherapy)]. Bangkok: Mahidol University; 2005.