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เข็มขัดช่วยพยุงหลังต่อการล้าของกล้ามเนื้อลำตัวขณะยกของ

Back belt application on trunk muscle fatigue in lifting

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บทคัดย่อ: *เพื่อศึกษาผลของการใช้เข็มขัดช่วยพยุงหลังต่อการล้าของกล้ามเนื้อลำตัวในขณะยกของ อาสาสมัครสุขภาพดี จำนวน 18 คน (หญิง 12 และ ชาย 6 คน) อายุ 27.78 ±3.54 ปี ดัชนีมวลกาย 20.48 ±1.53 กก./ตร.ม. อาสาสมัครทุกคนไม่มีประสบการณ์การใช้เข็มขัดช่วยพยุงหลังมาก่อน ทดสอบยกและวางของบนชั้นวางที่ปรับระดับได้ น้ำหนักของกล่องทดสอบคิดเป็นร้อยละ 10 ของน้ำหนักตัวของอาสาสมัคร ทำการทดสอบเป็นเวลา 12 นาที โดยที่ก่อนและทุกๆ 3 นาทีของการทดสอบ จะมีการวัดสัญญาณไฟฟ้ากล้ามเนื้อลำตัวข้างซ้าย 4 มัด ได้แก่กล้ามเนื้อมัลติฟิดัส กล้ามเนื้ออิเร็คเตอร์สไปเน่ กล้ามเนื้อทรานซ์เวอร์ซัส แอบโดมินิส/กล้ามเนื้ออินเทอร์นัลแอ็บโดมินัลอ๊อบลีก และกล้ามเนื้อเอ็กเทอร์นัลแอ็บโดมินัลอ๊อบลีก ผลการวิจัย พบว่า ณ นาทีที่ 3 กล้ามเนื้อมัลติฟิดัสในขณะใส่เข็มขัดช่วยพยุงมีการลดลงของร้อยละของความถี่มีเดียนมากกว่าไม่ใส่เข็มขัดช่วยพยุงอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) และนาทีที่ 9 และ 12 กล้ามเนื้อเอ็กเทอร์นัลแอ็บโดมินัลอ๊อบลีกในขณะใส่เข็มขัดช่วยพยุงมีการลดลงของร้อยละของความถี่มีเดียนมากกว่าไม่ใส่เข็มขัดช่วยพยุงอย่างมีนัยสำคัญทางสถิติ ($p<0.05$)เช่นกัน นอกจากนี้ยังพบผลของระยะเวลาการทำงานต่อการลดลงของร้อยละของความถี่มีเดียนอย่างมีนัยสำคัญทางสถิติในกล้ามเนื้อมัลติฟิดัส กล้ามเนื้ออิเร็คเตอร์สไปเน่กล้ามเนื้อเอ็กเทอร์นัลแอ็บโดมินัลอ๊อบลีก ($p<0.001$) และพบผลของเข็มขัดช่วยพยุงร่วมกับเวลาต่อการลดลงของร้อยละของความถี่มีเดียนในกล้ามเนื้อมัลติฟิดัส ($p<0.001$) จากการทดสอบพบว่าเข็มขัดช่วยพยุงทำให้เกิดการลดลงของร้อยละของความถี่มีเดียนมากกว่าการไม่ใส่เข็มขัดช่วยพยุงเมื่อเวลาผ่านไปโดยเฉพาะกล้ามเนื้อมัลติฟิดัสและกล้ามเนื้อเอ็กเทอร์นัลแอ็บโดมินัลอ๊อบลีก สรุปการสวมเข็มขัดช่วยพยุงหลังขณะยกของจะเพิ่มการล้าของกล้ามเนื้อลำตัวบางมัด ดังนั้นการใช้เข็มขัดช่วยพยุงหลังเพื่อวัตถุประสงค์ทางการยศาสตร์หรือสำหรับการป้องกันการบาดเจ็บควรพิจารณาอย่างรอบคอบและอยู่ภายใต้การดูแลของบุคลากรทางการแพทย์*

ABSTRACT: *To study the effects of back belt application on trunk muscle fatigue during repetitive lifting. Eighteen healthy subjects (12 females and 6 males), Age 27.78 ±3.54 years, Body Mass Index (BMI) 20.48 ±1.53 kg./m.^{2}, had no experiences wearing a back belt. The lifting task was to lift and lower a wooden box on an adjustable shelf. Lifting weight was equal to 10 % of the subjects' body weight and the test lasted for 12 min. Electromyography of four trunk muscles on the left side, multifidus (MF), erector spinae (ES), transversus abdominis/internal abdominal oblique (TrA/IO) and external abdominal oblique (EO), were recorded at the beginning and every 3-minute of each test. At min 3, the percent median frequency of MF in with back belt condition was significantly decreased with a larger reduction than without a back belt ($p<0.05$). At min 9 and 12, percent median frequency of EO in with back belt condition was significantly decreased with a larger reduction than without a back belt ($p<0.05$). For the main effect of time on percent median frequency reduction was significant in MF ($p<0.001$), ES ($p<.001$) and EO ($p<0.001$). The interaction between back belt and time on percent median frequency reduction was found significant only in MF. ($p<0.001$). Back belt application condition showed a larger reduction of percent median frequency over time than without back belt condition especially in MF and EO. In conclusion, a back belt application during lifting increases muscle fatigue in some trunk muscles, the uses of the back belt based upon ergonomic criteria should call into question the recommended prescription of the devices under the presumption of hazard control.*

คำสำคัญ: *การยก สัญญาณไฟฟ้ากล้ามเนื้อ กล้ามเนื้อล้า กล้ามเนื้อบริเวณลำตัว*
Keywords: *Lifting, Electromyography, Muscle fatigue, Trunk muscles*

1. INTRODUCTION

As a source of a low back injury, lifting has always been used in daily activities as well as in industrial tasks. Lifting is characterized by an increase of trunk flexion and trunk bending torque [1] whereas the activities that require repetitive lifting and lowering of a load are considered to be risk factors for a low back injury. There was an epidemiologic case-control study undertaken in

Connecticut showed the persons with jobs requiring lifting objects of more than 11.3 kg, more than 25 times per day had over three times of the risk for an acute low back injury as people whose jobs did not involve lifting objects of this weight [2]. During lifting, trunk muscles have to develop a sufficient force to provide adequate stability and prevent tissue failure of the spinal complex so muscle activation must be optimally timed and ordered of sufficient magnitude to protect the structures from injury during a lift [3].

A repetitive movement like repetitive lifting can induce back muscle fatigue [4]. The mechanism of back muscle fatigue is related to the development of low back pain. As the fatigued muscles are actually temporary slower. During repetitive load, the fatigue trunk muscles maybe less effective in generating the required extensor moment, forcing the passive structures, intervertebral discs, and ligaments, to hold out against relatively greater bending stress and become more susceptible to injury. Back muscle fatigue is accompanied by a diminished control of trunk movements and altered co-ordination of trunk muscle activities as well as by reductions inaccuracy when trying to generate a required force. Each of these could leave the lumbar spine more vulnerable to injury during repetitive load. There were several approaches have been used to decrease the incidence of a low back injury, for example, lifting techniques, workstation ergonomic modification and a back belt application. The use of back belts to prevent occupational low back pain, back belts are designed to provide support to the lumbar spine by reducing trunk range of motion, increasing trunk stiffness, increasing intra-abdominal pressure and decreasing the force required by the trunk muscles [5].

Even though there are many studies purposed the potential mechanisms and benefits of back belts but still, there is a lack of consistent conclusions about the benefits of back belts on muscle fatigue in particular tasks such as repetitive lifting. The main purpose of this study was to determine the effects of back belt application on trunk muscle fatigue during repetitive lifting tasks in healthy persons.

2. METHODS

2.1 Participants

Eighteen healthy adults, twelve females and six males, aged from 21 to 33 years, body mass index (BMI) was between 18.5 to 23 kg/m.^{2} (Table 1). Sample size was calculated based on a previous study [6]. None of the subjects experienced low back pain at the time of the study neither reported a history of activity limitation caused by low back pain in the last 6 months. Exclusion criteria were medical conditions that would limit subjects to complete the experimental tasks such as neuromuscular disorders, abdominal surgery, shoulder pain, cardio-respiratory or other metabolic disorders. Subjects were asked to avoid caffeine consumption for at least 12 hr. prior to the study.

Table 1: Subjects characteristics

Characteristics	Range	Mean	SD
Age (year)	21 - 33	27.78	3.54
Height (meter)	1.52 – 1.83	1.66	0.08
Weight (kilogram)	45 - 72	56.33	6.44
Body Mass Index (BMI) (kg. /m^2.)	17.4 – 22.7	20.48	1.53
Lifting load (kilogram)	4.5 – 7.2	5.64	0.65

2.2 Procedure

Full ethical approval was granted by Mahidol University research ethics committees. The written informed consent was obtained from each participant after full explanations of the experimental procedures involved also the advantages and the possible risks of the study. Subjects were interviewed about age, underlying diseases, history of injury, medical record then following with anthropometric measures: weight, height, and waist circumference. For the first test, every subject would draw lots between task A or B, task A was lifting without back belt and task B was lifting with back belt application.

2.2.1 Electromyography (EMG)

Electromyography (EMG) (Telemyo 2400T G2, 8 channels wireless, NORAXON INC. (USA)) was used to monitor left trunk muscles: erector spinae (ES), external abdominal oblique (EO), internal abdominal oblique/transversus abdominis (IO/TrA) and multifidus (MF). Bipolar surface electrodes (silver/silver chloride surface electrode, Ambu Blue sensor P, sensor area 13.2 mm^2) with the inter-electrodes distance was 2 cm in the direction of muscle fibers lines. Skin preparation for the EMG data collection, the skin was scrubbed and cleaned to keep skin resistance less than 5 kΩ. Electrode placements of ES were placed parallel to the spinous process of L3 and 2 cm. laterally from the midline. EO, were placed on the lateral side of the rectus abdominis above left anterior superior iliac spine (ASIS), between the crest and the ribs with a slightly oblique angle as their muscle fibers. IO/TrA, were placed medially to the left ASIS with a slightly oblique angle. MF, electrodes were placed 2 cm. laterally to the spinous process of L5. A reference electrode was placed on the left anterosuperior iliac crest. Each surface electrode was secured with kinesiology tape (without adding pressure or stretching the tape) to prevent slipping off of its location.

2.2.2 Lifting station

An adjustable-shelf was individually adjusted to each participant's knee height as a lifting excursion was from knee to waist level and to control the range of trunk flexion. Subjects stood on the floor at a preferred distance away from the shelf with knees fully extended, back straight, both

arms extended. The researcher marked their footprints and measured the distance from the adjustable-shelf base to the first toe to ensure the same position for two tests. A wooden box with handles, size 25 x 32 x 29 cm. with added weight equal to 10 percent of the subject's weight. [7] Elastic back belts (MEDIGRIP, Thailand), width 12 inches at the back and 6 inches at the front, there were three different sizes (small size; waist circumference 25 – 30 inches, medium size; waist circumference 30 – 34 inches and large size; waist circumference 34 - 38 inches) (Figure 1). Subjects had to do muscle stretching before and after each test and subjects were asked to indicate their rating of perceived exertion (RPE) before and after each test.



Figure 1: **Posterior view of back belt application**

2.2.3 Isometric lifting test

Median frequency (MF) measurement, the raw EMGs were recorded by having subjects performed 10-second isometric lifting at the beginning, 3, 6, 9 and 12 minutes. A starting position of the isometric test was to have subjects stood on their footprints then performed trunk forward bending and lifted the wooden box up around 2 cm. above the shelf with elbows fully extended. Subjects held in that position for 10-second before putting the wooden-box back on the shelf.

2.2.4 Repetitive lifting task

A starting position of a 3-minute repetitive lifting task was to have subjects stood on their footprints, then reached both hands forward with the elbow fully extended holding wooden box by its handles. Subjects started lifting when they heard a "beep" sound from a timer. Subjects lifted the wooden box by gradually moved their back to fully erect waiting for another "beep" sound. Then subjects lowered the wooden box back on the shelf without releasing their hands and repeated the lifting cycle. A metronome was used to control lifting pace at 15 cycles per minute. Subjects were also trained to comply with the given pace and so that the lifting and lowering phases of the task were carried out for the same time durations. Subjects performed lifting and lowering tasks continuously for 3 minutes then performed a 10-second isometric lifting then back to perform 3-minute repetitive lifting task again until the overall repetitive lifting time was 12 minutes. After the 12-minute lifting was completed, subjects took a break lying on a bed for 90 minutes which was sufficient to avoid carrying-over effect [8]. For task B, with back belt

application, subjects had to wear a back belt at the level of their waist [9] and a level of a back belt tightness was at 10 mmHg which allowed the subjects to feel comfortable [10, 11].

2.2.5 Rating of perceived exertion

The rating of perceived exertion (RPE) was used to verbally indicate the intensity of testing exercise [12]. In this study was used to compare the intensity of lifting between with and without back belt application. The scale runs from 0 (not at all) to 10 (very much, extremely exhausted). Subjects were asked to indicate their RPE prior to and after each test.

2.2.6 Data processing

The median frequency was calculated from the EMG of every 10-second isometric lifting then selected 500 msec at the middle of the EMG data manually and processed by using EMG data processing program (MyoResearch XP master Edition 1.06.64 - Master Mode – Frequency Fatigue Mode) to calculate median frequency. The median frequency at the beginning was used as a reference (100%) then the median frequencies from 3, 6, 9 and 12 minutes were calculated as percent median frequency.

2.3 Statistical analysis

Data analyses were performed using the SPSS windows. The level of statistical significance was set at a probability level less than 0.05 ($p<0.05$) for all analyses. Results were expressed in means and standard deviations. Shapiro-wilk test was performed to determine the distribution of the data. Two-way repeated measures ANOVA was used to compare the differences of the means of percent median frequency between and within two conditions. A paired t-test was used to compare the means of the rating of perceived exertion at the beginning and the end of tests.

3. RESULTS

The means of percent median frequency in four trunk muscles showed in Table 2. The results showed that between with back belt and without back belt application at first 3 minutes, multifidus muscle showed a greater reduction of median frequency in with back belt condition. At 9 and 12 minutes, external abdominis oblique showed a significant difference between two conditions. While there was no differences between two conditions in other muscles at any given point of time.

The effects of back belt application, time and interaction between them were tested by two-way Repeated Measures ANOVA (Table 3). The results indicated that the back belt application had no significant effects on the percent median frequency except external abdominal oblique. ($p<0.05$) The main effect for time was significant in multifidus ($p<0.001$), erector spinae ($p<0.001$) and external abdominal oblique muscle ($p<0.001$). For interaction between these two factors was found significant only in multifidus muscle ($p<0.001$).

Table 2: Percent median frequency on various times during 12-minutes lifting

Time	Muscles Conditions	Percent median frequency							
		MF		ES		TrA/IO		EO	
		Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
0	NB (n=18)	100	0	100	0	100	0	100	0
	WB (n=18)	100	0	100	0	100	0	100	0
3	NB (n=18)	97.10 *	9.19	93.44	12.59	98.23	15.27	100.79	23.86
	WB (n=18)	86.87 *	10.82	88.40	13.57	91.90	16.76	92.68	13.59
6	NB (n=18)	88.99	12.39	92.44	13.03	97.65	12.01	94.40	16.42
	WB (n=18)	85.03	12.60	87.31	13.59	91.80	15.79	87.37	13.23
9	NB (n=18)	87.70	16.27	89.47	13.24	89.38	14.42	93.32 *	18.33
	WB (n=18)	82.13	9.03	81.84	14.82	88.44	15.21	80.74 *	12.23
12	NB (n=18)	78.26	11.42	85.24	11.98	91.10	15.17	96.12 *	20.72
	WB (n=18)	83.38	11.33	80.19	9.04	85.57	16.23	82.30 *	13.11

* Significant (p <0.05)

Percent of median frequency was determined by static lift posture for 10 seconds every 0, 3, 6, 9 and 12 minute.

MF = Multifidus, ES = Erector spinae, TrA/IO = Transversus abdominis/Internal abdominal oblique, EO = External abdominal oblique, NB = without back belt and WB = with back belt

Table 3: The effects of back belt application and time on percent median frequency

	MF		ES		TrA/IO		EO	
	F	*p*-value	F	*p*-value	F	*p*-value	F	*p*-value
Belt	1.144	0.298	2.55	0.120	1.361	2.251	4.615	0.039
Time	17.744	<0.001*	7.898	0.000*	4.131	0.080	19.413	<0.001*
Belt*Time	8.508	<0.001*	0.223	0.841	0.490	0.675	1.487	0.228

* Significant (p <0.05)

MF = Multifidus, ES = Erector spinae, TrA/IO = Transversus abdominis/Internal abdominal oblique, EO = External abdominal oblique

The results in Table 4 showed that the back belt application significantly decreased RPE from 4.11 to 3.39 (0.72, 17.57%). 11 subjects reported a decrease of RPE between with and without back belt application and 7 subjects reported no differences.

Table 4: Rating of perceived of exertion (RPE)

No	Paired Differences	Mean difference	SD	t	df	*p*-value
1	RPE_NB vs RPE_WB	0.722	0.669	4.579	17	**<0.001***

* Significant (p <0.05)

NB = without back belt and WB = with back belt, RPE = Rating of perceived of exertion

4. DISCUSSION

Eighteen healthy subjects, twelve females and six males, were recruited. The previous study reported that gender had no effects on back muscle fatigue during the repetitive task [13]. Subjects aged from 21 to 33 years were recruited in this study because these ages are at risk of low back injury due to active lifestyles. Subjects had never had an experience with a back belt prior to the test. In order to control the other factors besides a back belt subjects were in normal body mass index range (BMI) [14]. This study was designed to investigate the back belt effects within the same person.

4.1 Effects of back belt application on median frequency of trunk muscles

The hypothesis of this study was to investigate the effects of back belt application on trunk muscle fatigue. In this study, muscle fatigue was detected by a decrease of the percent median frequency. The results of two-way repeated measures ANOVA revealed that time and the interaction between time and back belt have the effects on trunk muscle fatigue. A decrease in the percent median frequency over time is a reliable indicator of muscle fatigue [15-17] Therefore, the lifting protocol used in the current study was successful in producing trunk muscle fatigue. The muscles in this study were divided into two groups (back muscles and abdominal muscles).

The percent median frequency of back muscles, the means of percent median frequency between two conditions at minute 3, 6, 9 and 12 indicated that with back belt application showed a larger number of percent median frequency reduction, particularly for the first 3 minutes in multifidus muscle ($p<0.05$). The higher muscle fatigue may be resulted by wearing a back belt raised an intra-muscular pressure of the muscles [6] when the perfusion of skeletal muscle during exercise occurs only during the phase of muscle relaxation [18] Therefore, an increase in muscular relaxation pressure can decrease blood flow, which leads to muscle fatigue and impaired muscular function [19]. For instance, during dynamic lifting, muscles are also producing an additional pressure from repetitive muscle contraction which may lead to an increase of intra-muscular pressure along with additional pressure from back belt. These two actions may decrease blood flow and increasingly accelerate the muscle fatigue process. In static contraction, there was no changing in muscle length; the only additional pressure was caused by a back belt. The changes in percent median frequency during sustained contraction can be also resulted by many factors, for instance, changes in pH [4], temperature and blood flow [20-24].

The percent median frequency of abdominal muscles; TrA/IO and EO, at minute 3, 6, 9 and 12. The results showed that the back belt condition had a larger number of percent median frequency reduction in EO significantly at minute 9 ($p<0.05$) and 12 ($p<0.05$). The reduction at the last 6 minutes might due to the back belt design that covered along the pelvis and thoracic region of the spine, providing a greater resistance against the upper body while bending forward. To overcome the resistance from the back belt, EO has to generate more force and later on become fatigued.

Therefore, higher muscle fatigue of EO resulted from an increase of intra-muscular pressure from the back belt and muscle activities over time. In TrA/IO, the results of percent median frequency reduction were not significantly different might because, during lifting, TrA acts as a trunk stabilizer, not a prime mover. This minimal activity may not cause the percent median frequency reduction or muscle fatigue over time [25, 26].

These findings are against some previous studies which suggested that back belts may reduce trunk muscle activities via an intra-abdominal pressure mechanism [5], intra-abdominal pressure could indirectly generate an extensor moment on the lumbar spine which consequently reduces or delays muscle fatigue. Some studies found no differences between lifting with a back belt and without a back belt [6, 27-29]. This might because the study protocol used in the present study was different from previous studies such as task stimulation; lifting excursion and lifting technique, in the present study, were mainly designed to focus on trunk movement. Types of back belts are also different; the size of a back belt related to the area of trunk covered. One study of lumbar muscle fatigue used a weight-lifting belt which was smaller and rigid, during free-style heavy lifting from the floor to 72.6 cm. height. They found no differences in maximum isokinetic endurance and the slope of median frequency [29]. Another study, in 2014, investigated trunk stabilizer muscle activity during manual lifting with and without back belt condition in the experienced workers. They found that wearing a back belt significantly decreased TrA/IO activity during rest and significantly increased rectus abdominis (RA) activity during the lifting period as compared with the condition of no back belt. But this study focused in a semi-squat lifting technique and the effect of a back belt on muscle fatigue was not observed [30].

4.2 Rating of perceived exertion

The results showed that RPE range of lifting with back belt application (3.39±1.85) was lower than RPE of lifting with non-back belt (4.11±1.96); 11 subjects reported a decrease of RPE in lifting with a back belt application whereas 7 subjects reported no differences of RPE between with a back belt and without a back belt application. This might be explained by the design of the back belt, covered along thoracic to pelvis region, the use of lifting belts transferred the motion from the back to the pelvis [31]. The subject might use more pelvic tilt rotation than lumbar flexion while lifting with a back belt compared with lifting without a back belt. The redistribution of muscle forces could occur while wearing back belt. This contribution of back belt, the subjects could give a lower RPE during lifting with a back belt than without a back belt because of the different load on different muscles. Furthermore, an increase of trunk stiffness while wearing back belt, the alterations in afferent and efferent stimuli from the somatosensory system may occur. These sensations could arise from cutaneous, muscle and/or joint sensor of the trunk. The subjects may feel more secure while wearing back belt [32]. These reasons may result in a decrease of rating of perceived exertion in 11 subjects. In the psychophysical approach may not be an appropriate technique to assess the effect of back belt due to the Hawthorne effect [33, 34]. It is because the RPE is moderated by psychological factors (cognition, memory and previous

experience and understanding of the task) and situational factors (knowledge of the endpoint), duration, temporal characteristics of the task. Also, the influences of motivation for exercise can be expected to link with RPE. To decrease the variance in RPE from motivation, the recruitment of trained participants is recommended [35, 36].

5. CONCLUSION

This current study was focusing on the effects of back belt application while performing symmetrical repetitive lifting. Asymmetrical lift is more widely used in manual handling work. So the future study should be considered the effects of the back belt application on muscle fatigue in various lifting techniques. Furthermore, in terms of force production should be monitored along with EMG signals to confirm the effects of back belt on muscle fatigue. The interesting note should take into account that even though the back belts may increase person's proprioceptive awareness and sense of security that makes them feel less muscle fatigue while doing activities with more confidence. But on the other hand, wearing a back belt may make them physiological tired and muscle fatigue more easily and quickly. The lack of a strong rationale for the uses of the back belt based upon ergonomic criteria should call into question the recommended prescription of the devices under the presumption of hazard control. The decision to prescribe belts to employees in the workplace should be at the discretion of an adequately trained occupational health care provider.

REFERENCES

[1] Potvin JR, Norman RW. Quantification of erector spinae muscle fatigue during prolonged, dynamic lifting tasks. Eur J Appl Physiol Occup Physiol. 1993;67(6):554-62.

[2] Kelsey JL, Githens PB, White AA, 3rd, Holford TR, Walter SD, O'Connor T, et al. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. J Orthop Res. 1984;2(1):61-6.

[3] McGill SM, Grenier S, Kavcic N, Cholewicki J. Coordination of muscle activity to assure stability of the lumbar spine. J Electromyogry Kines. 2003;13(4):353-9.

[4] Bobick TG, Belard JL, Hsiao H, Wassell JT. Physiological effects of back belt wearing during asymmetric lifting. Appl Ergon. 2001;32(6):541-7.

[5] McGill SM, Norman RW, Sharratt MT. The effect of an abdominal belt on trunk muscle activity and intra-abdominal pressure during squat lifts. Ergonomics. 1990;33(2):147-60.

[6] Miyamoto K, Iinuma N, Maeda M, Wada E, Shimizu K. Effects of abdominal belts on intra-abdominal pressure, intra-muscular pressure in the erector spinae muscles and myoelectrical activities of trunk muscles. Clin Biomech (Bristol, Avon). 1999;14(2):79-87.

[7] Waters TR, Baron SL, Kemmlert K. Accuracy of measurements for the revised NIOSH lifting equation. National Institute for Occupational Safety and Health. Appl Ergon. 1998;29(6):433-8.

[8] Shin H-J, Kim J-Y. Measurement of trunk muscle fatigue during dynamic lifting and lowering as recovery time changes. Inter J Ind Ergon. 2007;37(6):545-51.

[9] Chen Y-L. The effect of the tightness of abdominal belts on the determination of maximal acceptable weight of lift. Inter J Ind Ergon. 2003;31(2):111-7.

[10] Cholewicki J, Reeves NP, Everding VQ, Morrisette DC. Lumbosacral orthoses reduce trunk muscle activity in a postural control task. J Biomech. 2007;40(8):1731-6.

[11] Lantz SA, Schultz AB. Lumbar spine orthosis wearing. II. Effect on trunk muscle myoelectric activity. Spine (Phila Pa 1976). 1986;11(8):838-42.

[12] Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health. 1990;16 Suppl 1:55-8.

[13] Clark BC, Manini TM, The DJ, Doldo NA, Ploutz-Snyder LL. Gender differences in skeletal muscle fatigability are related to contraction type and EMG spectral compression. J Applied Physiol (Bethesda, Md : 1985). 2003;94(6):2263-72.

[14] Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between obesity and low back pain: a meta-analysis. Am J Epidemiol. 2010;171(2):135-54.

[15] Duchene J, Goubel F. EMG spectral shift as an indicator of fatigability in an heterogeneous muscle group. Eur J Appl Physiol Occup Physiol. 1990;61(1-2):81-7.

[16] Gerdle B, Fugl-Meyer AR. Is the mean power frequency shift of the EMG a selective indicator of fatigue of the fast twitch motor units? Acta Physiol Scand. 1992;145(2):129-38.

[17] Ng JK, Richardson CA, Jull GA. Electromyographic amplitude and frequency changes in the iliocostalis lumborum and multifidus muscles during a trunk holding test. Phys Ther. 1997;77(9):954-61.

[18] Haggmark T, Thorstensson A. Fibre types in human abdominal muscles. Acta Physiol Scand. 1979;107(4):319-25.

[19] Humphreys PW, Lind AR. The blood flow through active and inactive muscles of the forearm during sustained hand-grip contractions. J Physiol. 1963;166:120-35.

[20] Arendt-Nielsen L, Mills KR. The relationship between mean power frequency of the EMG spectrum and muscle fibre conduction velocity. Electroencephalogr Clin Neurophysiol. 1985;60(2):130-4.

[21] Hakkinen K, Komi PV. Effects of fatigue and recovery on electromyographic and isometric force- and relaxation-time characteristics of human skeletal muscle. Eur J Appl Physiol Occup Physiol. 1986;55(6):588-96.

[22] Komi PV, Tesch P. EMG frequency spectrum, muscle structure, and fatigue during dynamic contractions in man. Eur J Appl Physiol Occup Physiol. 1979;42(1):41-50.

[23] Sirca A, Kostevc V. The fibre type composition of thoracic and lumbar paravertebral muscles in man. J Anat. 1985;141:131-7.

[24] Tesch PA, Komi PV, Jacobs I, Karlsson J, Viitasalo JT. Influence of lactate accumulation of EMG frequency spectrum during repeated concentric contractions. Acta Physiol Scand. 1983;119(1):61-7.

[25] Hodges PW. Is there a role for transversus abdominis in lumbo-pelvic stability? Man Ther. 1999;4(2):74-86.

[26] van Dieen JH, Kingma I, van der Bug P. Evidence for a role of antagonistic cocontraction in controlling trunk stiffness during lifting. J Biomech. 2003;36(12):1829-36.

[27] Kingma I, Faber GS, Suwarganda EK, Bruijnen TB, Peters RJ, van Dieen JH. Effect of a stiff lifting belt on spine compression during lifting. Spine (Phila Pa 1976). 2006;31(22):E833-9.

[28] Kurustein N. The comparison of "back belt and trunk muscle exercise application" for back muscle lifting load [disseratation] Mahidol University; 2002.

[29] Ciriello VM, Snook SH. The effect of back belts on lumbar muscle fatigue. Spine (Phila Pa 1976). 1995;20(11):1271-8.

[30] Kurusatien 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;97 Suppl 7:S75-9.

[31] Granata KP, Marras WS, Davis KG. Biomechanical assessment of lifting dynamics, muscle activity and spinal loads while using three different styles of lifting belt. Clin Biomech (Bristol, Avon). 1997;12(2):107-15.

[32] Grunbaum A. The placebo concept in medicine and psychiatry. Psychol Med. 1986;16(1):19-38.

[33] Ekstrom RA, Osborn RW, Hauer PL. Surface electromyographic analysis of the low back muscles during rehabilitation exercises. J Orthop Sports Phys Ther. 2008;38(12):736-45.

[34] Metzgar CR, editor Placebos, back belts, and Hawthorne effect. Proceedings of 1994 IEEE 36th Cement Industry Technical Conference; 1994 29 May-2 June 1994.

[35] Eston RG, Davies BL, Williams JG. Use of perceived effort ratings to control exercise intensity in young healthy adults. Eur J Appl Physiol Occup Physiol. 1987;56(2):222-4.

[36] Lamb KL, Eston RG, Corns D. Reliability of ratings of perceived exertion during progressive treadmill exercise. Br J Sports Med. 1999;33(5):336-9.