Muscle Activity of Abdominal and Back Muscles during Six Starting Positions in Untrained Individuals

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Objective: *This study aimed to investigate the electromyography (EMG) activity among five abdominal and back muscles at six starting positions in untrained individuals.*

Materials and Method: *Twenty-five healthy individuals aged 20.9±3.9 years, who were inexperienced with lumbar stabilization exercise, were recruited. They were asked to perform maximum voluntary isometric contraction (MVIC), and then six starting positions in random order. EMG data of each starting position were normalized as a percentage of MVIC. Friedman two-way analysis of variance (ANOVA) and Wilcoxon signed-ranks tests were used for data analysis.*

Results: *Significant differences in EMG activity of five abdominal and back muscles were found in all six starting positions ($p<0.001$). The highest EMG activity of the transversus abdominis/internal abdominal oblique (TrA/IO) was found in crook lying, with right leg lifted (CLR), and of multifidus (MF) in four-point kneeling with straight right leg lifted horizontally (4p-SRL).*

Conclusion: *The results suggested that CLR and sitting on a gym ball (SG) were able to facilitate TrA/IO activity with minimal activity from the rectus abdominis (RA), while CL, 4p-SRL, and SG were able to facilitate MF activity with minimal activity from erector spinae (ES).*

Keywords: *Back pain, TrA activation, Lumbar stabilization, Exercise, Position*

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Low back pain (LBP) is a major health problem[1]. The dysfunction in the neuromuscular control of the trunk muscles[2-6], by which the association between chronic LBP and poor trunk stabilization, has been reported[7,8].

Trunk stabilization exercise was able to improve strength, endurance, balance and control of trunk and pelvic muscles[9], which can be promoted by recruiting the deep abdominal muscle, the transversus abdominis (TrA)[10] together with internal abdominal oblique (IO) which run parallel to one another with a similar fiber orientation (TrA/IO). Lumbar multifidus (MF) is a local back muscle that is also concerned with trunk stabilization. Therefore, the co-contraction of TrA/IO and MF is needed in isolation from the superficial muscles such as the rectus abdominis (RA), external abdominal oblique (EO), and erector spinae (ES). One exercise that facilitates the co-contraction of these deep muscles is abdominal hollowing (AH), which can be performed in prone lying, four-point kneeling (4p)[11-13], crook lying (CL)[13], and wall-support standing[12], where the TrA/IO activity was successfully achieved with minimal activity from the RA and EO. AH is clinically used to test and retrain TrA contraction but was considered difficult to perform[14]. Therefore, it would be beneficial if some starting positions could help facilitating these local muscles. It was reported that the local abdominal and back muscles are recruited easily in some starting positions, which requires no introduction or training for abdominal hollowing, as the muscles are already activated[15,16]. Arokoski et al[16] revealed that the lumbar vertebral 5th (L5) paraspinal and abdominal muscles were activated during therapeutic exercises such as exercises with arm and/or leg lifted, or on a soft ball.

This study, therefore, aimed to determine 1) whether any significant difference was associated in electromyography (EMG) activity among these three abdominal muscles (TrA/IO, RA, and EO) and two back muscles (MF and ES) in each of the six starting

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positions, and 2) whether any significant difference was associated in the EMG activity of each muscle among the six starting positions.

Material and Method

Subjects

Twenty-five healthy individuals (8 male, 17 female) were recruited from the Physical Therapy Center, Mahidol University. They had no experience in AH or knowledge of trunk stabilization concepts. The exclusion criteria included 1) problems in lumbar spinal joint range of motion, 2) history of LBP with or without neurological disorders within six months before the study, 3) pregnancy or menstruation period, 4) obvious cardiovascular or respiratory disorders, 5) surgery, burn or previous accident related to the abdominal region, spine, pelvis, or hip, 6) spinal problems such as scoliosis, spondylolisthesis, or fracture, 7) skinfold thickness in the abdominal and supra-iliac area greater than 20 mm or, 8) other problems that decrease physical performance at the time of testing such as accidents, a vigorous exercise before testing, dining within one hour, exhaustion or fatigue.

Five muscles and six starting positions

Five muscles comprised the three abdominal muscles: the TrA/IO, RA and EO, and two back muscles: the MF and ES.

Six starting positions were as follows: 1) CL: the subjects were in supine position on a plinth with knees flexed 90° and feet flat on the plinth, 2) CL with right leg lifted (CLR): from the CL position, the subjects fully extended their right knee, 3) 4p: subjects were in the quadruped position on a plinth with hips and shoulders flexion at approximately 90°. Their hips were directly above the knees and their shoulders were above the hands. In this position, the lumbar spine was in a neutral position, 4) 4p with straight right leg lifted horizontally (4p-SRL): from the 4p position, the subjects extended their right leg parallel to the floor, kept the left hip and knee at 90° flexion placing on the ground, 5) 4p with straight left leg and right arm lifted horizontally (4p-SLL&RAL): from the 4p position, the subjects extended their left leg and right arm horizontally, kept the left hip and knee at 90° flexion placing on the ground, 6) Sitting on a gym ball (SG): the subjects sat comfortably in upright position on a gym ball. The size of a ball was selected according to their hips and knees angle flexed at approximately 90-100°, hands on their thighs, and feet on the ground. Each position was performed for 3 trials, 10 seconds each, and the smoothest EMG data were chosen.

Procedure

Subjects who were eligible received clear information about the purposes, procedures, benefits and possible risks of the study and testing procedures. Each subject signed a consent form approved by the Mahidol University Institutional Review Board (MU-IRB COA NO 2013/040.0205). The subjects were asked to wear test clothing (T-shirt and shorts). The order of six test positions was randomized. Then the subject's skin was prepared for electrode placement for EMG study. The electrodes were placed on the site according to the references from previous studies[15]. Skin preparation was required before the test including shaving hair and rubbing skin to reduce the skin impedance of less than or equal to 5 kΩ tested by a multimeter.

Surface electrode attachment

Silver/silver chloride pre-gelled surface electrodes (Noraxon, Inc. USA and AMBU-Blue sensor) were used. Two circular electrodes were placed over the right side of each muscle. The inter-electrode space was 2.2 cm from center to center[15]; TrA/IO, 2 cm inferomedial to the anterior superior iliac spine (ASIS), EO, 13-15 cm lateral to the level of umbilicus, RA, 2 cm under the umbilicus and 2 cm lateral to the midline, ES, vertically 3 cm lateral to the spine at the level of the L3 spinous process, MF, 2 cm lateral to the spine at the level of the L5 spinous process. The reference electrodes were placed on the right side of iliac crest.

Maximum voluntary isometric contraction (MVIC) testing

All subjects were asked to perform maximal efforts comprising trunk flexion and trunk flexion with right rotation in sitting, trunk side bending to the right in left side lying, and trunk extension in prone lying. Each action was performed against manual resistance with verbal encouragement provided. All subjects were informed to avoid any jerky movements to minimize the chance of injury. Each trial was held for 5 seconds with a 10-minute rest provided between trials[17]. The maximum EMG value from 10 seconds for each muscle found in any actions was selected as a reference value for normalization. Raw EMG signals from the five muscles were pre-amplified and then transmitted to the receiver (Telemyo, Noraxon, USA). The EMG signals were magnified using a general amplifier at a sampling rate of 1,000 Hz and processed by Noraxon

MyoResearch XP Master Edition/Basic Edition 1.07. The EMG data from MVIC test and each starting position were filtered between 10 and 1,000 Hz band pass and calculated using a root mean square with a window of 20 ms for each muscle during 1 second in the middle part of the duration of the static end position.

Statistical analysis

Statistical analysis was performed using SPSS for Windows, version 16.0. The Kolmogorov-Smirnov Goodness of Fit-test showed that the data were not distributed normally, so the non-parametric statistical analyses were therefore used. Friedman two-way analysis of variance (ANOVA) was used to compare the differences in EMG activity among the six starting positions or five muscles. Multiple comparisons with Wilcoxon signed-ranks tests were used to detect significant pairwise differences among the five muscles and six starting positions. The level of statistical significance was set at 95% confidence interval and *p*-value less than 0.05.

Results

The subjects aged 20.9±3.9 years and had weight 58.1±9.6 kg, height 163.6±8.9 cm, and body mass index 21.5±1.8 kg/m^2.

Table 1. Descriptive statistics of electromyography (EMG) activity of abdominal and back muscles reported as the percentage of maximum voluntary isometric contraction (MVIC) in six starting positions (n = 25)

Starting position	Muscles	EMG activity (% MVIC)	
		Mean (SD)	Range
Crook lying (CL)	TrA/IO	2.21 (4.64)	0.10-23.84
	RA	2.03 (4.54)	0.12-23.20
	EO	2.48 (1.90)	0.43-7.05
	MF	1.28 (1.49)	0.08-7.41
	ES	2.59 (3.01)	0.45-13.00
Crook lying with right leg lifted (CLR)	TrA/IO	15.13 (10.29)	5.32-43.52
	RA	7.47 (5.38)	1.73-23.98
	EO	16.62 (9.88)	4.77-42.05
	MF	14.47 (13.04)	1.15-61.66
	ES	7.22 (4.07)	2.33-18.81
Four-point kneeling (4p)	TrA/IO	4.23 (4.44)	0.39-18.72
	RA	3.72 (4.06)	0.34-12.77
	EO	6.61 (5.28)	0.85-23.69
	MF	4.15 (9.30)	0.13-47.30
	ES	3.73 (4.18)	0.78-20.25
Four-point kneeling with straight right leg lifted horizontally (4p-SRL)	TrA/IO	9.25 (8.85)	1.57-44.06
	RA	6.63 (5.79)	1.47-24.99
	EO	17.15 (9.99)	4.49-38.98
	MF	44.43 (23.93)	5.58-97.05
	ES	23.54 (17.87)	2.94-83.80
Four-point kneeling with straight left leg and right arm lifted horizontally (4p-SLL&RAL)	TrA/IO	13.98 (16.88)	2.03-89.64
	RA	11.09 (13.56)	1.52-60.34
	EO	36.53 (21.84)	5.34-97.80
	MF	38.76 (24.07)	4.44-87.94
	ES	41.69 (21.46)	10.92-91.78
Sitting on a gym ball (SG)	TrA/IO	5.56 (4.11)	0.78-20.45
	RA	3.00 (2.47)	0.67-11.26
	EO	6.84 (4.88)	0.80-18.82
	MF	4.03 (3.58)	0.21-14.23
	ES	6.89 (5.56)	1.63-23.25

TrA/IO = transversus abdominis/internal abdominal oblique; RA = rectus abdominis; EO = external abdominal oblique; MF = multifidus; ES = erector spinae

Table 1 reports means, standard deviations, and ranges of the EMG activity of the abdominal and back muscles during the six starting positions.

Comparison of the EMG activity among six starting positions

Significant differences in the EMG activity were found among the six starting positions (p<0.001) (Table 2). The results were significantly different in TrA/IO versus RA in CLR and SG, different in TrA/IO versus EO in 4p, 4p-SRL, and 4p-SLL&RAL, and different MF versus ES in CL, 4p-SRL, and SG.

Comparison of the EMG activity within the five muscles

Significant differences in the EMG activity were found among the six starting positions (p<0.001) (Table 2). The highest EMG activity of TrA/IO was found in CLR with significant differences versus other starting positions except 4p-SLL&RAL. The highest EMG activity of MF was found in 4p-SRL with significant differences versus other starting positions except 4p-SLL&RAL.

Discussion

This study aimed to investigate the electromyography (EMG) activity among five abdominal and back muscles at six starting positions among untrained individuals. The activation of TrA/IO in this study ranged from 2.21 to 15.13% in static position without AH. Therefore, the appropriate starting positions to elicit the activation of TrA/IO over RA would be CLR and SG, TrA/IO over EO consisting of 4p, 4p-SRL, and 4p-SLL&RAL. Moreover, the activation of MF ranged from 1.28 to 44.43% in static position without AH. The appropriate starting positions for deep back muscles, MF over ES, were CL, 4p-SRL, and SG.

The highest activation of TrA/IO was found in CLR. Compared with CL, CLR adds the lift of the right leg, which influences the activation of TrA/IO because of the increased lever arm. The increasing difficulty of exercise is based on the biomechanical principle, which is that the quantity of torque of the lumbar muscles increases by the mass of leg and moment arm from the center of mass of the leg to the axis of rotation[18]. The highest activation of MF was found in 4p-SRL similar to 4p-SLL&RAL, 44.43 and 38.76% MVIC, respectively. In comparison with CL, CLR, 4p, and SG, 4p-SRL and 4p-SLL&RAL had greater EMG activity of MF. The reasons are due to the addition of leg lifting either ipsilaterally or contralaterally. The position was also performed in prone kneeling; the back was oriented upwardly, which perhaps helps the back muscles to work properly compared with the supine

Table 2. Friedman two-way ANOVA for investigating the differences in EMG activity in each starting position and each muscle site (n = 25)

Differences in EMG activity of all 5 muscles in each starting position	
Starting positions	*p*-value
Crook lying (CL)	<0.001*
Crook lying with right leg lifted (CLR)	<0.001*
Four-point kneeling (4p)	<0.001*
Four-point kneeling with straight right leg lifted horizontally (4p-SRL)	<0.001*
Four-point kneeling with straight left leg and right arm lifted horizontally (4p-SLL&RAL)	<0.001*
Sitting on a gym ball (SG)	<0.001*
Differences in EMG activity of all 6 starting positions in each muscle	
Muscles	*p*-value
Transversus abdominis/internal abdominal oblique (TrA/IO)	<0.001*
Rectus abdominis (RA)	<0.001*
External abdominal oblique (EO)	<0.001*
Multifidus (MF)	<0.001*
Erector spinae (ES)	<0.001*

* Statistical significant difference at p-value<0.05

position where the back was in contact of the floor.

For clinical implications, it has been suggested that approximately 25% MVIC is needed to develop the muscle stiffness for spinal stability[6]. This study, therefore, supports only 4p-SRL and 4p-SLL&RAL for MF activation. For TrA/IO activation, all six starting positions did not exceed 25% MVIC. Therefore, the practice of AH should be added to facilitate enough TrA/IO activation[12]. Significantly, greater EMG activity was observed of TrA/IO than RA in CLR and SG, and greater than EO in 4p, 4p-SRL, and 4p-SLL&RAL. These positions might serve as starting positions for the practice of AH.

One limitation of this study was the use of surface EMG electrodes to record deep abdominal muscles (TrA and IO). However, TrA attached superficially at its insertion and both TrA and IO were aligned together. This study, therefore, recorded both TrA and IO in the combination as performed in a previous study[12] and the protocol of using EMG was strictly observed. LBP individuals are needed for further study because the individuals in this study were asymptomatic LBP.

Conclusion

The results suggested that CLR and SG were able to facilitate TrA/IO activity with minimal activity from RA, while CL, 4p-SRL, and SG were able to facilitate MF activity with minimal activity from ES. These starting positions are strongly suggested to be used for facilitating deep back or abdominal muscles with minimal activity of global muscle activation.

What is already known on this topic?

Some basic starting positions such as CL, prone lying, and 4p are commonly used for AH training. However, the practice of AH is quite difficult.

What this study adds?

Some starting positions such as 4p-SRL, 4p-SLL&RAL, CLR, and SG are strongly suggested to be used for facilitating deep back or abdominal muscles with minimal activity of global muscle activation without AH effort.

Acknowledgement

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Potential conflicts of interest

None.

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การทำงานของกล้ามเนื้อท้องและหลังขณะอยู่ในท่าเริ่มต้น 6 ท่า ในผู้ที่ไม่เคยได้รับการฝึก

ประเสริฐ สกุลศรีประเสริฐ, เพ็ญไพลิน เอกอัจฉริยา, วรรธนะ ชลายนเดชะ

วัตถุประสงค์: ศึกษาคลื่นไฟฟ้ากล้ามเนื้อในกล้ามเนื้อท้องและหลังรวม 5 มัด ในผู้ที่ไม่เคยได้รับการฝึก

วัสดุและวิธีการ: ผู้เข้าร่วมการวิจัยสุขภาพดี 25 คน อายุ 20.9±3.9 ปี ซึ่งไม่ทราบถึงการออกกำลังกาย เพื่อเพิ่มความมั่นคงของกระดูกสันหลังระดับเอว ได้รับการทดสอบแรงกล้ามเนื้อสูงสุด และได้จัดท่าอยู่ในท่าเริ่มต้น 6 ท่า แบบสุ่มลำดับ โดยทำการวัดค่าคลื่นไฟฟ้ากล้ามเนื้อในแต่ละท่าทางการเริ่มต้นโดยเทียบเป็นร้อยละ จากค่าการออกแรงกล้ามเนื้อสูงสุด สถิติที่ใช้ในการศึกษาครั้งนี้คือ Friedman two-way analysis of variance (ANOVA) และ Wilcoxon signed-ranks tests

ผลการศึกษา: พบความแตกต่างอย่างมีนัยสำคัญทางสถิติในค่าคลื่นไฟฟ้ากล้ามเนื้อท้องและหลังทั้ง 5 มัด ใน 6 ท่า เริ่มต้น ($p<0.001$) โดยพบค่าคลื่นไฟฟ้าของกล้ามเนื้อ transversus abdominis/internal abdominal oblique (TrA/IO) สูงสุดในท่า crook lying with right leg lifted (CLR) และกล้ามเนื้อ multifidus (MF) ในท่า four-point kneeling with straight right leg lifted horizontally (4p-SRL)

สรุป: การศึกษานี้พบว่าท่า CLR และ sitting on a gym ball (SG) มีส่วนส่งเสริมการทำงานของกล้ามเนื้อ TrA/IO โดยลดการทำงานของกล้ามเนื้อ rectus abdominis (RA) ในขณะที่ท่า crook lying (CL), 4p-SRL, และ SG ส่งเสริมการทำงานของกล้ามเนื้อ MF โดยลดการทำงานของกล้ามเนื้อ erector spinae (ES)