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Effect of Slowly Forced Expiration on Abdominal Muscle Activity During Cross Knee Curl-Up Exercise

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Abstract

Cross knee curl-up is an ideal variation of abdominal curl up exercise to strengthen abdominal musculature without excessive lumbar flexion which can increase the loads on the disc and ligaments. In addition, slowly forced expiration can facilitate the activation of the abdominal musculature. The purpose of this study was to determine the effects of slowly forced expiration on activity of abdominal muscles, such as rectus abdominis (RA), external oblique (EO), and transverse abdominis/internal oblique (TrA/IO), while cross knee curl-up. Eleven young and healthy subjects (6 males and 5 females) participated. All subjects performed the cross knee curl-up slowly forced expiration and natural breathing. Paired t-test was performed in normalized electromyogram (EMG) muscle activity of the bilateral RA, EO, and TrA/IO to compare the differences between the cross curl-up with slowly forced expiration and natural breathing. Statistical significance was set at .05. There were no significant differences in normalized EMG muscle activity of the bilateral RA, EO, and TrA/IO between the cross curl-up with slowly forced expiration and natural breathing. The finding of this study designates that slowly forced expiration does not induce increasing activity of abdominal muscle in cross knee curl-up; hence, learning step of breathing control might not be necessary to strengthen abdominal muscle in cross knee curl-up.

Key Words: Breathing; Respiration; Stabilization exercise.

Introduction

Abdominal curl-up exercise can be recommended for strengthening abdominal muscles and stabilizing lumbar area as a therapeutic exercise in rehabilitation program (Axler and McGill, 1997; McGill and Karpowicz, 2009). Also, abdominal curl-up exercise can be selected as an aerobic exercise for healthy people to strengthen abdominal muscles by health instructors in pilates, athletic and rehabilitation program (Critchley et al, 2011; Hides et al, 2011). However, the abdominal curl-up exercise also may activate the hip flexor and lumbar paraspinal muscle, a result that may not be beneficial for low back pain patient. For example, high levels activation of the hip flexor and lumbar paraspinal muscles have a tendency to rotate the pelvis anteriorly, increase lumbar lordosis and increase lumbar segmental compression, thus increasing the risk of low back pain (Ralston et al, 1990).

A previous study reported that cross knee curl-up is an ideal variation of abdominal curl up exercise to strengthen abdominal musculature without lumbar flexion which can increase the loads on the disc and ligaments (McGill, 1998; McGill, 2007). The previous researcher advocated that the cross knee curl-up can be applied to initial physical therapy for the patients with low back pain to keep neutral spine posture without pain.

Expiration is considered a passive process during quiet breathing, but with an increased breathing effort, forced expiration can facilitate the activation of

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the abdominal musculature (Simpson, 1983). The pressure of intra-abdominal is increased and the diaphragm is moved upwards for forced expiration while the abdominal musculature contracts (Campbell and Green, 1953; Woorons et al, 2007). Therefore, forced expiration can be applied to abdominal curl-up exercise and the other core stabilizing exercise (Cho et al, 2013; Kim and Lee, 2013; Lee et al, 2013). Particularly, combined task of the cross knee curl-up and forced expiration would be beneficial with increasing abdominal muscle activity while as maintaining of neural spine during core stabilizing exercise. To the best of knowledge, this is the original study to examine the effects of slowly forced expiration (Woorons et al, 2007) on activity of abdominal muscles such as rectus abdominis (RA), external oblique (EO), and transverse abdominis/internal oblique (TrA/IO). These muscles are defined as major expiratory muscles (Neumann, 2002).

Hence, the purpose of this study was to determine the effects of slowly forced expiration on activity of abdominal muscles such as RA, EO, and TrA/IO during performing of cross knee curl-up. The research hypothesis was that abdominal muscle activity will be differences of abdominal muscles activity in cross knee curl-up with slowly forced expiration compared with natural breathing.

Methods

Subjects

Eleven healthy subjects participated in this research (Table 1). Exclusion criteria were history of abdominal or lower back pain within six weeks of start of the study, past history of respiratory diseases, or inability to correctly perform the cross knee curl-up in a pain-free manner (Roussel et al, 2009; Youdas et al, 2008). In addition, The dominance of leg was determined based on asking the subject to kick a soccer ball (Jacobs et al, 2005; Sung, 2013). All participants participate in this study were right-leg dominant. All subjects provided written informed consent in agreement with the procedures of the Yonsei University Wonju Institutional Review Board.

Instrumentation

Surface electromyogram (EMG) was used to measure activity of abdominal muscles. The EMG data were collected bilaterally from the RA: electrode positioned 2 ㎝ lateral from the midline of the umbilicus, EO: electrode positioned halfway between the most inferior point of the costal margin of the ribs and the anterior superior iliac spine (ASIS) and angled toward the pubic symphysis in a parallel direction to the fibers of the EO, and TrA/IO: electrode positioned in a horizontal direction within a triangle consisting of a medial border made up of a line from the umbilicus to the pubic symphysis, an inferior border made up of a line from the ASIS to pubis symphysis, and a superior border made up of a line from ASIS to ASIS (Youdas et al, 2008). A previous study identified that the EMG signal gained from an electrode inferior to the ASIS represents the combined activity of the IO and TrA (Marshall and Murphy, 2003). Therefore, the EMG signal from TrA/IO electrode was considered as a combined activity of TrA and IO muscle. Before positioning the electrodes over each muscle, the skin of electrode sites was shaved, swabbed and sanded with alcohols-oaked cotton to decrease skin resistance. Disposable Ag/AgCl surface electrodes were located parallel to the muscle fibers with 2 ㎝ center-to-center arrangement via using the Tele-Myo 2400T EMG device with a wireless telemetry system

Table 1. General characteristics of subjects (N=11)

Parameters	Mean±SD[a]
Age (year)	24.0±1.2
Height (㎝)	160.0±7.3
Weight (㎏)	55.0±10.6
BMI[b] (kg/㎡)	21.5±2.3

[a]mean±standard deviation, [b]body mass index.

(Noraxon Inc., Scottsdale, AZ, USA).

On completing the electrode attachment, EMG data were recorded at the 1000 ㎐ sampling rate and analyzed with Myo-Research Master Edition 1.06 XP software (Noraxon Inc., Scottsdale, AZ, USA). The raw signal was filtered using a digital band-pass filter (Lancosh FIR) between 20 and 400 ㎐ to eliminate movement artifacts, and a 60 ㎐ notch filter was used to diminish electrical noise. Root-mean-square (RMS) values were considered with a moving window of 50 ㎳. For normalization, a 5-second maximal voluntary isometric contraction (MVIC) was measured 3 times per the abdominal muscles to determine a basis for EMG signal amplitude normalization.

The protocol for MVIC testing was adopted from a previous study (Escamilla et al, 2006). For the RA, the subject was positioned supine in a hook-lying position with the feet supported and the thoracolumbar spine maximally flexed (curl-up position) on the table. Then, a researcher applied manual resistance to the subject's shoulders in the direction of trunk extension. For the EO, the subject was positioned supine in a hook-lying position with feet flat on the table. The trunk was maximally flexed and rotated to the left, with applying manual resistance at the shoulders in the direction of trunk extension and right rotation. For the TrA/IO muscle, the subject was positioned supine in a hook-lying position with the trunk flexed and maximally rotated to the right. A researcher applied manual resistance at the shoulders in the direction of trunk extension and left rotation. We used central 3 seconds of collected EMG data to decide the mean amplitude of MVIC. The normalized activity of each muscle was presented as a percentage of MVIC.

Procedures

All subjects had a familiarization session to understand how to perform the cross knee curl-up. Then, the subject learned how to correctly perform the cross knee curl-up with slowly forced expiration for 7 seconds. Once the subject correctly performed the cross knee curl-up for 7 seconds, data collection session were started. At the beginning, cross knee curl-up with natural breathing were measured twice with the dominant leg straight. After 30 min of rest time, cross knee curl-up with slowly forced expiration were measured (Wojtys et al, 1996). During data collection, the researcher monitored the subject for appropriate slowly forced expiration by listening for airflow sounds and observing mouth and lip motions. If a subject was assumed of not achieving the appropriate breath condition, the data of trial were not collected.

The cross knee curl-up

McGill (1998) suggested that the cross knee curl-up would be recommended in the early stages of training or rehabilitation due to helping stabilize the pelvis and support the neutral spine. Subjects were positioned in a supine position by an investigator and how to perform the cross knee curl-up. Each subject was asked to place hands under lumbar spine to preserve a neutral lumbar spine. Right knee was straight while left knee were 90 flexed. Subjects elevated the trunk by lifting the head and shoulders such that the scapulae were lifted above the table. We installed a target bar that could be located to the chest at the point when the scapulae came off the table (Figure 1). This was to guarantee that both scapulae were constantly elevated above the ta-

Figure 1. The cross knee curl-up with dominant leg straight.

ble for each abdominal curl-up exercise. The subject was asked to touch the target bar during the cross knee curl-up. The subject was requested to hold the position isometrically for 7 seconds without hold of breathing to activate abdominal muscles. Then the subject returned to the starting position.

Slowly forced expiration and natural breathing

All subjects were supine and maintained the posture during this study. The subject was instructed to slowly inhale as deeply as possible and then to exhale as forcefully and completely with compensation movement of the trunk (Lee et al, 2013). For natural breathing, there was no specific instruction of breathing pattern to all subjects. A researcher visually observed the subjects breathing pattern during data collection to ensure the slowly forced expiration and natural breathing.

Statistical analysis

Kolmogorov-Smirnov Z-tests were performed to assess the normality of distribution. Statistical significance was set at .05. Paired t-test was performed in normalized EMG muscle activity of the bilateral RA, EO and TrA/IO muscles to compare the differences between the cross curl-up with slowly forced expiration and natural breathing. Statistical analysis was calculated with SPSS ver. 18.0 software (SPSS, Inc., Chicago, IL, USA).

Results

All of the continuous variables were found to approximate a normal distribution (Kolmogorov-Smirnov Z-test, $p>.05$). There were no significant differences in normalized EMG muscle activity (right RA: $t=1.398$, $p=.192$; left RA: $t=.978$, $p=.351$; right EO: $t=.920$, $p=.379$; left EO: $t=.472$, $p=.647$; right TrA/IO: $t=1.588$, $p=.143$; left TrA/IO: $t=1.621$, $p=.136$) between the cross curl-up with slowly forced expiration and natural breathing (Figure 2).

Discussion

The purpose of this study was to investigate the

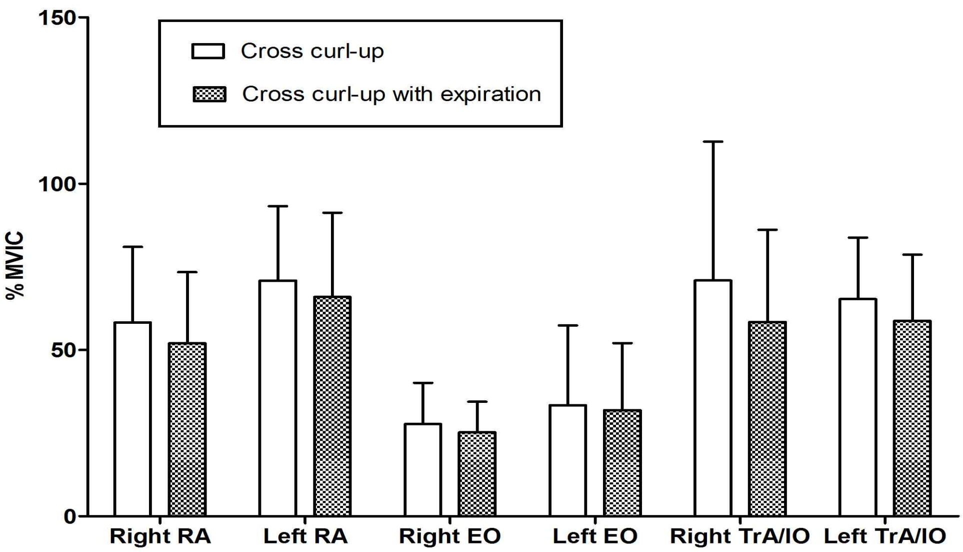

Figure 2. Normalized electromyogram muscle activity of the bilateral RA, EO, and TrA/IO muscles between the cross curl-up with slowly forced expiration and natural breathing (RA: rectus abdominis, EO: external oblique, TrA/IO: transverse abdominis/internal oblique).

effects of slowly forced expiration on muscle activity of RA, EO and TrA/IO during favorable cross knee curl-up in healthy subjects. The research hypothesis was that abdominal muscle activity will be different in cross knee curl-up with slowly forced expiration compared with natural breathing. The results of this study showed that there were no significant differences in RA, EO, and TrA/IO between cross knee curl-up with slowly forced expiration and natural breathing. Thus the findings of this study did not support research hypothesis.

There were no significant differences in RA, EO, and TrA/IO between cross knee curl-up with slowly forced expiration and natural breathing. We supposed that there could be summative effect of dual task performance (Silsupadol et al, 2009) of slowly forced expiration and cross knee curl-up. A previous study presented that slow expiration would increase the TrA/IO muscle activity (about 35%) in healthy subjects compared with those in abdominal curl up with quiet inspiration during traditional curl-up exercise (Yoon et al, 2013). However, the slowly forced expiration could not effect on abdominal muscles during one task of cross knee curl-up in our study. This result might be explained with difficulty of dual task performance due to the lack of sufficient familiarization for the participant to controlling their breathing pattern during exercise. Previous studies reported that dual task showed greater task difficulty and required more practice compared with single task (Negahban et al, 2013; Vaportzis et al, 2013; Venema et al, 2013). In breathing task, dual task did elicit significantly greater elevations in heart rate, respiratory rate, and minute ventilation than single task (Webb et al, 2010). Due to the difficulty of modifying breathing pattern in relatively short time, the abdominal muscles were more focused in the cross knee curl-up than breathing task. If we used fast forced expiration than slow forced expiration, the muscular activity of the abdominal muscles may have been different.

The other possible explanation might be that slowly forced expiration is physiological phenomena which would not counted as a single task, therefore, cross knee curl-up could combined with this physiological expiration could not generate any difference in muscle activity for the health subjects.

Although there were no significant differences in muscle activity between cross knee curl-up with slowly forced expiration and natural breathing, there were slightly decreased activation of all muscles during cross knee curl-up with slowly forced expiration. We assumed that maintaining of neutral spine by placing hand under lumbar spine would change the muscle-tension relationship and influence on activation of muscles. Maintaining of neutral spine during core stabilization exercise is important because repetitively unwanted back flexion during abdominal curl-up could load mechanical stress on lumbar disc and ligaments which might worse mechanical receptor in patients with low back pain in the phase of rehabilitation program (Panjabi, 1992). In addition, maintaining of neutral spine has shown the better co-activation of the TrA (Sapsford et al, 2010). Therefore, maintaining of neutral spine and controlling of breathing pattern during curl-up exercise should be considered for individuals with sub-acute or chronic LBP in clinic.

There are several limitations. First, healthy subject participated in this study limiting external validity for the patients with low back pain. Second, there is no data of participant's exertion scale for control slowly forced expiration during cross knee curl-up. Third, there is no clear evidence of supporting the neural spine curve by placing hands under lumbar spine. Fourth, internal intercostal muscle is other major muscle of the forced expiration, there is no data of internal intercostal activity for estimation of compensatory using instead of abdominal muscle during slowly forced expiration in this experimental exercise. The collection of activity in internal intercostal muscle and participant's exertion scale for measuring of the difficulty in performance will add internal validity of the future study.

Conclusion

This study compared the effects of slowly forced expiration and natural breathing on muscle activity of RA, EO, and TrA/IO during cross knee curl-up. The finding of this study designates that slowly forced expiration does not induce increasing activity of abdominal muscle; hence, learning step of breathing control might not be necessary to strengthen abdominal muscle in cross knee curl-up.

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