

# Effects of performing an abdominal hollowing exercise on trunk muscle activity during curl-up exercise on an unstable surface

MOON-HWAN KIM, PT, MSc<sup>1)</sup>, JAE-SEOP OH, PT, PhD<sup>2)\*</sup>

<sup>1)</sup> Department of Physical Therapy, Graduate School, Yonsei University, Republic of Korea

<sup>2)</sup> Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University: 607 Obang-dong, Gimhae-si, Gyeongsangnam-do 621-749, Republic of Korea

**Abstract.** [Purpose] The purpose of this study was to investigate the effects of the abdominal hollowing exercise on trunk muscle activity during the curl-up exercise on an unstable surface by measuring electromyography (EMG) activity. [Subjects] Fourteen young healthy adults (nine male, five female) voluntarily participated in this study. [Methods] Each subject was asked to perform a curl-up exercise on two supporting surfaces (stable and unstable surfaces) combined with the abdominal hollowing exercise on an unstable surface. The muscle activities of the rectus abdominis (RA), external oblique (EO), internal oblique (IO), and transverse abdominis (TrA) were measured using surface EMG during performance of the curl-up exercise. [Results] The EMG activity of the RA and EO was significantly higher on an unstable surface than on a stable surface during the curl-up exercise. The EMG activities of the TrA and IO were greater in combination with the abdominal hollowing exercise on an unstable surface than during the curl-up exercise on both a stable and unstable surface. [Conclusion] These findings suggest that the local trunk muscle activity during the curl-up exercise is more strongly affected by combination with the abdominal hollowing exercise than by performance on an unstable supporting surface.

**Key words:** Abdominal hollowing exercise, Curl-up exercise, Unstable surface

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## INTRODUCTION

Abdominal muscle strengthening exercises are frequently used during rehabilitation of low back pain<sup>1)</sup>. Recent work has demonstrated the importance of the abdominal muscles in ensuring sufficient spine stability to prevent buckling and enhance function<sup>2, 3)</sup>. The curl-up, performed as an abdominal exercise, has been shown to produce reasonable levels of activity in the rectus abdominis (RA) muscle while minimizing the resultant spine load and has been incorporated into several low back fitness programs<sup>4)</sup>.

The use of unstable surfaces underneath the subject for stability training of the injured low back is becoming more popular<sup>4)</sup>. Swiss balls have been incorporated into strength-training regimens and can reportedly be used to more effectively train the musculoskeletal system. Performing strength exercises on Swiss balls has been advocated based on the belief that a labile surface will provide a greater challenge to the trunk musculature, increase the dynamic balance of the user, and possibly train users to stabilize their spines to

prevent and treat injury<sup>5)</sup>. Studies have been conducted to document the loads imposed on the spine during various abdominal exercises<sup>6)</sup>, but the effect of unstable surfaces has not been examined. We believe that there is a clinical need to understand the effects of using unstable surfaces to challenge the muscular system during the curl-up exercise.

Recent evidence regarding the conservative management of low back pain suggests that the restoration of neuromuscular control in the transverse abdominis (TrA), together with minimal contraction of other superficial oblique, internal, and external abdominal muscles, is essential for effective treatment during the early stages of rehabilitation<sup>7, 8)</sup>. Previous studies have demonstrated that performance of the abdominal hollowing exercise in particular is far more effective than performance of general core-stabilizing techniques in improving the cross-sectional area of the TrA<sup>9, 10)</sup>. The abdominal hollowing exercise is designed to emphasize deep local muscle activity while minimizing the activity of the more superficial global muscles. Although many studies on the effect of the abdominal hollowing exercise in rehabilitation programs have been performed, none have examined the combined effect of the abdominal hollowing exercise and curl-up exercise on an unstable surface.

Therefore, the purpose of this study was to investigate the effects of the abdominal hollowing exercise on trunk muscle activity during the curl-up exercise on an unstable surface by measuring electromyography (EMG) activity.

\*Corresponding author. Jae-Seop Oh (E-mail: ysrehab@inje.ac.kr)

## SUBJECTS AND METHODS

Fourteen healthy subjects (nine males, five females) volunteered to participate in this study (Table 1). All subjects were in good health and reported no history of neurological and/or respiratory diseases. None of them had undergone institutional care for any pathological back conditions during the preceding year. All participants gave their written informed consent to participate in the study. This work was approved by the Inje University Institutional Research Review Committee.

EMG data were collected using a Biopac MP150WSW data acquisition system (BIOPAC Systems, Inc., CA, USA). Surface electrode pairs were oriented along the line of action of the underlying muscle fibers on the right side: RA, centered 2 cm lateral and caudal to the umbilicus; TrA, centered 2 cm cephalad to the pubic bone, just lateral to the midline, and parallel to the superior pubic ramus; external oblique (EO), centered over the tip of the eighth rib diagonally; and internal oblique (IO), centered 2 cm proximal to the midpoint from the anterior superior iliac spine (ASIS) to the symphysis pubis diagonally<sup>11</sup>. A common reference electrode was placed over the right ASIS. The maximum voluntary isometric contraction (MVIC) of each muscle was measured using the maneuver suggested by Kendall et al.<sup>12</sup> for normalization.

The subjects were instructed on how to perform the curl-up and abdominal hollowing exercises by the investigator. All subjects were instructed to place their hands on their abdomen for tactile feedback during both exercises. For the abdominal hollowing, the subjects were instructed to draw the lower part of the abdomen up and in toward the spine

without moving the trunk or pelvis. A pressure biofeedback unit (Chattanooga Group, Inc., TN, USA) was used to ensure that the subjects were performing the exercises correctly. A pressure cuff unit was placed under their lumbar spine and inflated to 40 mmHg before the exercises were performed<sup>13</sup>. When the subject performed the hollowing correctly, the pressure either stayed at 40 mmHg or decreased, and the subjects felt their abdomen hollow. The subjects held the trunk and pelvis in that position for 5 s while continuing to breathe normally<sup>1</sup>.

All subjects were requested to perform three different curl-up exercises. The first task was to perform a traditional curl-up exercise on a flat floor with the hips and knees flexed to 90° and legs supported on a platform. The subject's hands were placed by the sides of their body, and only the head and shoulders were elevated from the flat floor. The next two tasks varied based on the type of unstable surface. For the second task, the subjects assumed the supine position on a flat floor with the hips and knees flexed to 90° and legs supported on a gym ball. Ball inflation was checked between subjects to ensure that the diameter remained at 70 cm prior to each test. For the third task, the subjects assumed the supine position on a flat floor with the hips and knees flexed to 90° and legs supported on a gym ball. Only the head and shoulders were then elevated from the flat floor with performance of the abdominal hollowing exercise during the curl-up exercise. The subjects held each contraction for 5 s and then returned to the resting position. Each subject had 1 min of rest between each trial and 5 min of rest between the tasks. The exercises were executed in a random sequence.

The data are expressed as means  $\pm$  SD. Repeated-measures ANOVA with post hoc Bonferroni correction was used to determine the trunk muscle activation during the three exercises ( $p < 0.05$ ). All analyses were performed using the SPSS ver. 17.0 statistical software.

## RESULTS

The mean EMG amplitudes of the abdominal muscles during the three curl-up exercises are presented in Table 2. The EMG activities of the RA and EO trunk muscles during the curl-up exercise were significantly higher on an unstable surface than on a stable surface. The EMG activity of the RA was lower when combined with the abdominal hollowing exercise on an unstable surface than that when performing the curl-up exercise on both a stable and unstable surface. The EMG activities of the TrA and IO were higher when

**Table 1.** Summary of anthropometric characteristics and neck disability index of the study participants

Characteristic	Control group (n = 13)	MNP group (n = 14)
Gender (n, male)	6	6
Age (years), mean (SD)	20.6 $\pm$ 1.6	20.6 $\pm$ 1.5
Height (cm), mean (SD)	167. $\pm$ 6.9	168.0 $\pm$ 8.0
Weight (kg), mean (SD)	60.7 $\pm$ 10.7	61.0 $\pm$ 12.4
Neck disability index (NDI) (%), mean (SD)	3.3 $\pm$ 2.6	16.9 $\pm$ 7.1*

MNP: mild neck pain; SD: standard deviation. \*significant difference between the two groups ( $p < 0.05$ )

**Table 2.** Mean relative muscle activity (% MVIC) and standard deviation of the various abdominal muscles during three different curl-up exercises

Muscles	Stable surface	Unstable surface	Unstable surface with abdominal hollowing exercise
Rectus abdominis*	41.6 $\pm$ 14.6	49.3 $\pm$ 15.0	26.2 $\pm$ 10.5
External oblique	43.6 $\pm$ 18.6	48.2 $\pm$ 12.8	49.8 $\pm$ 19.8
Internal oblique*	42.1 $\pm$ 18.0	47.2 $\pm$ 16.6	62.6 $\pm$ 21.2
Transverse abdominis*	19.2 $\pm$ 7.4	38.4 $\pm$ 13.5	56.5 $\pm$ 20.4

\* $p < 0.05$

combined with the abdominal hollowing exercise on an unstable surface than those during the curl-up exercise on both a stable and unstable surface.

## DISCUSSION

The present study showed that the combination of the abdominal hollowing exercise and curl-up exercise on an unstable surface was associated with higher EMG activities of the TrA and IO and lower EMG activity of the RA than during the curl-up exercise on both stable and unstable surfaces. The EMG activities of the RA and EO were significantly higher on an unstable surface than on a stable surface during the curl-up exercise.

Several studies have suggested that the Swiss ball may be helpful in increasing trunk muscle activity for stabilization of the lumbar spine during rehabilitation exercises<sup>5</sup>). During the curl-up exercise on the Swiss ball, the RA and EO activity may undergo more physical demand, as evidenced by the fact that the Swiss ball created more perturbations in our study. Contraction of superficial trunk muscles such as the RA and EO without local muscle contraction may lead to compressive loading and shearing forces during the curl-up exercise, which may induce stress on the inner tissues during the entire range of motion and serve as a major source of spinal pain. Although the curl-up exercise on an unstable surface induced higher EMG activities of the RA and EO, a reverse effect may be seen in individuals with spinal instability. Thus, clinicians who apply an unstable surface to increase the trunk muscle activity must consider the provocation that patients endure.

In this study, the EMG activities of the TrA and IO were higher during the combination of the abdominal hollowing exercise and curl-up exercise on an unstable surface. Conversely, the EMG activity of the RA decreased during the combination of the abdominal hollowing exercise and curl-up exercise on an unstable surface. The abdominal hollowing exercise was developed for neuromuscular retraining and kinesthetic awareness of the TrA<sup>14</sup>). Our results showed that abdominal hollowing exercise resulted in higher EMG activity of local muscles than of global muscles. The local muscle system involves the TrA and IO, which provide dynamic stability to each spinal segment<sup>15</sup>). The findings of the present study suggest that the abdominal hollowing exercise as a therapeutic option may be used to preferentially load certain local muscle groups during the curl-up exercise on an unstable surface, and that these effects may be favorably produced in individuals with low back pain.

There were several limitations to this study. First, our results cannot be generalized to other populations because all the subjects who participated in the study were healthy young individuals. Second, surface EMG was used to monitor muscle activity, leaving the possibility of crosstalk from

adjacent muscles.

This study provides empirical evidence that the curl-up exercise in combination with the abdominal hollowing exercise is more useful for enhancing abdominal muscle activity than is the curl-up exercise on an unstable surface. This finding offers clinical insight into the additive effect of the abdominal hollowing exercise in selectively stimulating local muscles and suggests that it may be used as an alternative core stabilization technique for the management of patients with low back pain. These findings should be considered when selecting rehabilitation exercises for neuromuscular retraining of the abdominal muscles.

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