

Electromyographic Analysis of Thoracic and Lumbar Erector Spinae Activity Using the Abdominal Drawing-in Maneuver and Chin Tuck During Prone Thoracic Extension Exercises

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Abstract

This present study investigated the effects of the abdominal drawing-in maneuver (ADIM) and chin tuck (CT) on middle thoracic erector spinae, lower thoracic erector spinae, and lumbar erector spinae muscle activity during three prone thoracic extension (PTE) exercises. Twelve healthy subjects performed preferred PTE, ADIM PTE, and ADIM-CT PTE. Surface electromyography was used to collect data on the muscle activity of dominant middle and lower thoracic erector spinae muscles and the lumbar erector spinae. Middle and lower thoracic erector spinae muscle activity significantly increased when ADIM and CT was performed ($p < .05$). However, lumbar erector spinae muscle activity significantly decreased in ADIM PTE compared to preferred PTE ($p = .017$) and significantly increased in ADIM-CT PTE compared to ADIM PTE ($p = .004$). In conclusion, ADIM-CT PTE effectively increased middle and lower thoracic erector spinae muscle activity, and ADIM PTE decreased lumbar erector spinae muscle activity. Hence, ADIM PTE could be a recommended exercise maneuver to strengthen thoracic erector spinae without over activation of lumbar erector spinae.

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Introduction

The weakness or fatigue of trunk muscles can increase the risk of neuromuscular deficits, which, according to Panjabi's theory of the spinal stabilizing system, causes uncontrolled intervertebral movements (Granata and Gottipati, 2008; Panjabi, 1992). Thoracic extension exercise is performed to activate or strengthen weak and fatigued thoracic erector spinae

(TES). Various thoracic extension exercises are applied in the clinical setting and previous studies have reported positive results (Pfeifer et al, 2004; Sinaki, 1982; Sinaki and Lynn, 2002; Sinaki et al, 2005).

However, prone thoracic extension (PTE) can induce an undesirable compensatory deviation. Previous studies showed that lumbar extension can increase with exaggerated anterior pelvic tilt and/or cervical lordosis, leading to microtrauma and pain during

PTE (Sinaki et al, 1996). Moreover, excessive use of lumbar erector spinae (LES) is often associated with chronic low back pain (Holmström et al, 1992). Furthermore, repetitive lumbar extension and anterior pelvic tilt may contribute to over activation of LES and less activation of TES. Hence, prescribing PTE alone may also increase cervical and/or lumbar lordosis (Kuramoto et al, 2011), which is not desirable for individuals with lumbar extension syndrome.

Several modes of exercise have been developed for improving the muscular function of the back (Menacho et al, 2010). Hongo et al (2007) found that modified PTE is required for preventing unwanted effects in order to increase the strength of TES and the quality of life of patients with osteoporosis (Hongo et al, 2007). Another previous study advocated internal or external stabilization for the application of TES without increasing lumbar lordosis (Kisner and Colby, 2007).

Abdominal drawing-in maneuver (ADIM) was advocated to stabilize lumbopelvis and to reduce unwanted compensation in various previous studies (Cynn et al, 2006; Oh et al, 2007; Park et al, 2011). The pressure biofeedback unit was utilized in different body position to educate and confirm the lumbopelvic stabilization (Richardson et al, 2004).

The chin tuck (CT) exercise has been recommended to provide craniocervical stability and to activate deep cervical stabilizers, such as rectus capitis anterior, rectus capitis lateralis, longus capitis, and longus colli. In particular, weakness of deep cervical stabilizers and over activation of global muscles (e.g., sternocleidomastoid and scalenus muscles) were noticed in patients with cervical pain. CT has been practiced in the clinical interventions for patients with chronic cervical pain to correct the forward head posture. In the previous study, there was no significant differences in improvement of craniocervical flexor performance in the fifty female patients with chronic mild neck pain (O'Leary et al, 2007).

However, no previous study was performed to investigate whether ADIM can alter the muscle activ-

ity of TES and LES during PTE. In particular, the role of CT exercises in craniocervical stability has not been evaluated in the literature. Thus, this study aimed at determining the effect of ADIM and CT on the muscle activity of the middle and lower TES and LES during three different PTEs in healthy subjects. The research hypothesis is that during PTE, ADIM and CT increase the muscle activity of middle and lower TES and decrease the muscle activity of LES.

Methods

Subjects

A power analysis was performed to calculate the sample size in this study. From the data of a pilot study of 5 subjects, the necessary sample size of 12 subjects was to achieve the effect size of .4 (calculated by partial η^2 of .14) with an alpha level of .05, and the power of .8. Twelve healthy subjects were recruited to accommodate the calculated sample size. The characteristics of the subjects are shown in Table 1. The inclusion criteria for the subjects were as follows: 1) no current pain at neck, thoracic, and lumbar pain. 2) not participating in any regular flexibility or strengthening exercise programs. 3) no history of surgery at neck, thoracic, or lumbar spine. The exclusion criteria for the subjects were as follows: 1) previous pain at neck, thoracic, or lumbar spine within six months of entering this study; 2) taking any muscle relaxant or steroid injection re-

Table 1. General characteristics for this subjects (N=12)

Variables	Male (n ₁ =7)	Female (n ₂ =5)
Age (yrs)	33.7±9.8 ^b	26.2±9.8
Height (m)	1.78±0	1.62±.1
Weight (kg)	74.1±9.3	61.0±9.8
BMI ^a	23.3±3.7	23.2±3.1
Dominant side (right/left)	(6/1)	(4/1)

^abody mass index, ^bmean±standard deviation.

lated to pain in neck, thoracic, or lumbar spine. This study was approved by the Human Studies Committee of Yonsei University Wonju Campus. All participants provided written informed consent before the data collection began.

Instruments

Surface EMG¹⁾ was used to collect data on the muscle activity of middle and lower TES and LES. EMG data were collected at the sampling rate of 1024 Hz and analyzed with MYOLAB (BTS Company, Italy) software. A bandpass filter (20–450 Hz) and notch filter (60 Hz) were used, and the data were processed to produce the root mean square (RMS) (Cynn et al, 2006). Data were collected from the dominant side of the trunk. Electrode placement sites were shaved and then swabbed with alcohol to decrease skin resistance. Disposable Ag/AgCl surface electrodes were placed over each erector spinae muscle on the belly, approximately 2 cm lateral to the spinous process of T7 or T8 for middle thoracic erector spinae muscle, T12 for lower thoracic erector spinae, and L3 for lumbar erector spinae (Cram et al, 1998). The raw data were processed to produce RMS with a window of 50 milliseconds. For normalization, the mean RMS of three trials of 3-second maximal voluntary contraction was calculated for the three erector spinae. Maximal voluntary isometric contractions (MVIC) were collected during prone back extension with maximal resistance for 5 seconds. The manual muscle testing position was used, as described by Kendall et al (2005). The muscle activity was expressed as a percentage of the calculated

root mean square of MVIC (%MVIC).

Procedures

The primary investigator demonstrated PTE and instructed each subject with consistent verbal and tactile cues. All subjects were pain free and comfortable after the familiarization period. The target bar for PTE was placed at a height of 10 cm from the occiput of each prone subject. Figure 1 shows each prone thoracic extension exercise.

For familiarization with ADIM, the pressure bio-feedback unit was placed between the pad on the physical treatment table and the subject's lower abdomen and was then inflated to 70 mmHg. The subject was asked to perform ADIM and decrease the pressure from 70 mmHg to 60 mmHg. The subject was given verbal feedback from a secondary investigator to maintain around 60 mmHg during PTE (Oh et al, 2007).

For familiarization with the CT exercise, the primary examiner taught the subjects the correct method of performing the CT exercise in the sitting posture. To standardize the CT, the subjects were positioned in the sitting posture with the forehead and chin positioned vertically. An imaginary line parallel to the plinth extended from the tragus of the ear, bisecting the neck longitudinally. This CT method was modified from the test position of craniocervical flexion (Kelly et al, 2012). Subjects performed the CT and received verbal and tactile feedback from the secondary examiner during the familiarization session.

For familiarization for ADIM PTE, subjects performed thoracic extension to contact occiput with the



Figure 1. The prone thoracic extension exercises (a: preferred prone thoracic extension (PTE), b: abdominal drawing-in maneuver (ADIM) PTE, c: ADIM-CT (chin tuck) PTE).

1) BTS FREEEMG 300, BTS Company, MI, Italy.

target bar and ADIM, consecutively. Subjects received information from the secondary examiner about the pressure biofeedback unit during ADIM PTE for 5 seconds. This familiarization period was finished after the pressure had been stabilized in three consecutive trials.

For familiarization with ADIM PTE with chin tuck, subjects performed thoracic extension to attain contact of the occiput with the target bar and ADIM-CT, consecutively. Subjects received information from the secondary examiner about the pressure biofeedback unit during ADIM PTE for 5 seconds. This familiarization period was finished after the pressure had been stabilized in three consecutive trials.

Data collection

Data on the muscle activity of the TES and LES was collected in the preferred PTE. Following the preferred PTE, ADIM with the pressure biofeedback unit was familiarized. Subjects performed ADIM PTE followed by a 5-second isometric contraction. A metronome was used to control the time and speed of movement. The starting signal was provided by a beeper sound cue in the MYOLAB software. The data collection was repeated in ADIM-PTE. Finally, ADIM with chin tuck PTE was performed in ADIM-CT PTE. Subjects were instructed to perform ADIM PTE and then were asked to tuck their chins gently. The principal investigator placed the tip of the index finger to the subject's chin to maintain and confirm the chin tuck maneuver. The same procedure for data collection procedure was repeated in ADIM-CT PTE. PTE was performed at a comfortable speed and consisted of a concentric phase, isometric phase, and eccentric phase. EMG data were collected within 5 seconds in the isometric phase. Subjects performed three trials of each PTE condition with 1 minute rests. The mean value was used for the data analysis.

Statistical Analysis

SPSS ver. 12.0 software was used for the statistical analyses. One-way analysis of variance (ANOVA) with repeated measures was employed for comparing the three different exercise conditions (preferred, ADIM, ADIM-CT). In the case of significant differences between exercise conditions, Bonferroni's post hoc test was performed. In all analyses, the level of statistical significance was set at $\alpha=.05$.

Results

For middle TES muscle activity, there was a significant difference in three conditions ($F=21.848$, $p<.001$). The post hoc test revealed significant differences in all comparisons (preferred PTE vs. ADIM PTE, $p=.031$; preferred PTE vs. ADIM-CT PTE, $p=.001$; ADIM PTE vs. ADIM-CT PTE, $p=.002$). The means of %MVIC in three conditions increased as follows: preferred PTE (30.4 ± 14.7) < ADIM PTE (36.3 ± 18.5) < ADIM-CT PTE (44.6 ± 20.9). For lower TES muscle activity, there was a significant difference in three conditions ($F=12.836$, $p=.002$). The post hoc test revealed significant differences in all comparisons (preferred PTE vs. ADIM PTE, $p=.005$; preferred PTE vs. ADIM-CT PTE, $p=.001$; ADIM PTE vs. ADIM-CT PTE, $p=.003$). The means of %MVIC in three conditions were increased as follows: preferred PTE (40.9 ± 18.5) < ADIM PTE (46.8 ± 18.3) < ADIM-CT PTE (58.5 ± 20.6). For LES, there was a significant difference in three conditions ($F=9.149$, $p=.001$). The post hoc test demonstrated significantly lower differences in the ADIM PTE condition compared to the preferred PTE ($p=.017$) and ADIM-CT PTE conditions ($p=.004$). However, no significant difference was observed between preferred PTE and ADIM-CT PTE ($p=1.000$). The means of %MVIC in the three conditions were as follows: preferred PTE= 46.9 ± 16.5 , ADIM PTE= 32.6 ± 18.3 , and ADIM-CT PTE= 46.8 ± 20.7 .

Discussion

The aim of this study was to investigate the effects of ADIM and CT on the muscle activity of TES and LES during three different PTEs. The results showed that ADIM-CT PTE increased the muscle activity of middle and lower TES and ADIM PTE decreased that of LES. Thus, the findings of this study partially supported the research hypothesis.

The %MVIC in three prone thoracic extension exercises was described in Table 2. The greatest middle and lower TES muscle activity was found in ADIM-CT PTE among three different PTE. These results are consistent with previous studies, which reported that ADIM can successfully stabilize the lumbopelvic area and facilitate target muscles during functional activity (Cynn et al, 2006; Oh et al, 2007; Park et al, 2011). Furthermore, the combination of ADIM and CT further activated middle and lower TES. This combined effect of ADIM-CT may have provided the lumbopelvic area and craniocervical stability was obtained. This result proves the combined effect of craniocervical stabilization on lumbopelvic stabilization during PTE by facilitating the middle and lower TES for thoracic extension in the prone position.

LET muscle activity was significantly lower in the ADIM PTE condition compared to preferred PTE. This finding is in line with previous studies, which reported that ADIM reduced over activity of LES during active prone knee flexion (Park et al, 2011). However, adding the chin tuck to ADIM failed to decrease lumbar ES muscle activity during PTE. No

significant difference was noted between preferred PTE and ADIM-CT PTE, indicating that lumbar ES muscle activity in ADIM-CT PTE was comparable to that in preferred PTE. This result can be explained by the concept of lever arm. In ADIM-CT PTE, maintaining CT increased the lever arm of the trunk, neck, and head from the lumbar spine. Thus, increased extension torque was required by the rigid longer lever arm, producing increased lumbar ES muscle activity. Moreover, the muscle activity of the sternocleidomastoid and the scalenus could have increased to maintain PTE, because deep cervical flexion was not familiarized with the biofeedback unit in this study. The expected effect of CT was to improve craniocervical stability during PTE, so that excessive craniocervical movement or deviation could have been avoided. Therefore, the exact role of CT versus the activation of deep cervical flexion should be further examined during PTE following familiarization with the biofeedback unit.

Many studies have shown that patients with low back pain have impairments in muscular strength and endurance (Mälkiä and Ljunggren, 1996). However, performing physical tests involves not only the physical capacity of back pain patients but also the psychological effects of confidence, pain, avoidance/fear of pain, or forms of abnormal behavior (Hirsch et al, 1991). The result of this study could be a guideline for a favorable combination with ADIM during PTE to strengthen TES without unwanted compensatory effects. The ideal application of ADIM should be considered in accordance with the targeted muscles and the client's condition during PTE in the clinical setting.

Table 2. Three prone thoracic extension exercises

(Unit: %MVIC)

Muscles	Conditions		
	Preferred	ADIM ^c	ADIM-CT ^d
Middle TES ^a	30.4±14.7 ^e	36.3±18.5	44.6±20.9
Lower TES	40.9±18.5	46.8±18.3	58.5±20.6
LES ^b	46.9±16.5	32.6±18.3	46.8±20.7

^athoracic erector spinae, ^blumbar erector spinae, ^cabdominal drawing-in maneuver, ^dabdominal drawing-in maneuver and chin tuck, ^emean±standard deviation.

This study has several limitations. First, because healthy young subjects performed PTE in three conditions, generalizability is limited. Second, kinematic data while performing PTE was not obtained. Thus, the amount of thoracic and lumbar extension cannot be quantified. Third, although abdominal muscle stiffness or shortness and degree of thoracic kyphosis can affect thoracic extension, these data were not collected for each subject. Further study with a kinematic analysis of a patient population is warranted in order to generalize the findings of this study.

Conclusion

This study examined the muscle activity of middle and lower TES and LES during three different PTEs. Middle and lower TES muscle activity significantly increased when ADIM and CT were added. Lower TES muscle activity significantly decreased when ADIM was added; however, added CT to ADIM increased lower ES muscle activity. Therefore, ADIM PTE can favorably increase middle and lower TES muscle activity while reducing LES activity during PTE. CT should be carefully applied because LES muscle activity may be increased during PTE.

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