

What is a Suitable Pressure for the Abdominal Drawing-in Maneuver in the Supine Position Using a Pressure Biofeedback Unit?

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Abstract. [Purpose] The aim of this study was to determine the appropriate pressure variation for performing a successful abdominal drawing-in maneuver (ADIM). The abdominal muscle thickness variations and contraction ratios were examined in relation to pressure variations using a Pressure Biofeedback Unit (PBU) during an ADIM in the supine position. [Methods] The PBU was placed identically between the lumbar lordosis of 20 healthy subjects (12 males and 8 females) and the pressure of the PBU was maintained at 40 mmHg. Then, while the subjects performed ADIM at four random pressure variations (0, 2, 4, or 6 mmHg), the thicknesses of the transversus abdominis (TrA), the internal oblique abdominal muscle (IO), and the external oblique abdominal muscle (EO) were measured using ultrasonography. [Results] Pressure increases of 0–2 mmHg resulted in significant decreases in IO and EO thicknesses compared to pressure increases of 6 mmHg. Increases of 0–2 mmHg also resulted in significant decreases in IO+EO and EO contraction ratios compared to pressure increases of 6 mmHg, while the preferential activation ratio of the TrA was significantly increased. [Conclusion] Compared to the other pressure increases, an increase of 0–2 mmHg effectively regulated the thicknesses and contraction ratios of superficial muscles such as IO and EO, rather than the thickness and contraction ratio of the TrA, showing high and indirect preferential activation ratios for TrA. Therefore, for successful ADIM, rather than using large PBU pressure increases, exercises that promote slight increases of around 0–2 mmHg from a baseline of 40 mmHg are desirable.

Key words: Pressure biofeedback unit, Abdominal drawing-in maneuver, Pressure variation

(This article was submitted Sep. 27, 2012, and was accepted Oct. 26, 2012)

INTRODUCTION

Stabilization exercise is an effective intervention method for relieving the pain and dysfunction associated with low back pain and for decreasing its recurrence. Stabilization exercise programs typically include the motor control training of abdominal muscle. Among the abdominal muscles, the transversus abdominis (TrA) is of particular interest to physical therapists as a spinal stabilizer because of its anatomical characteristics¹⁾. This is because the upper fibers of TrA provide stability to the thorax, the middle fibers increase the tension of the thoracolumbar fascia (TLF) for controlling the spine, and the lower fibers provide compression for decreasing the laxity of the sacroiliac joint and supporting the internal organs of the abdomen²⁾.

Independent contraction of TrA is achievable through the abdominal drawing-in maneuver (ADIM)³⁾. The ADIM re-educates the functions of this muscle and is therefore effective at relieving lumbopelvic pain and dysfunction⁴⁾. For this reason, the ADIM is frequently used as a basic element in stabilization exercise programs. However, learning and teaching an accurate ADIM can be time consuming and

difficult⁵⁾. For this reason, feedback tools such as the Pressure Biofeedback Unit (PBU), Electromyography (EMG), and Real-time Ultrasound imaging (RUSI) are often used.

Surface EMG is a non-invasive method, but it is limited in its ability to detect fine activities of the deeply located TrA. Fine-wire EMG can be used to observe these fine activities, but this is an invasive method and can cause pain and inflammation. On the other hand, RUSI is a non-invasive method that enables observation of the fine activities, but its high cost is prohibitive. In contrast, a PBU is a non-invasive method that is more economical than either of these other feedback tools, and it can be easily used anywhere since it is portable.

PBUs are used for clinical evaluation of the abdominal and cervical muscles, but it can also provide feedback to subjects who are receiving motor control training⁶⁾. In the case of ADIM, the prone and supine positions can be employed when using a PBU. In the prone position, the PBU is placed between the navel and the anterior superior iliac supine and air is infused into the bulb to create a pressure of 70 mmHg. A decrease of 4 mmHg in pressure in performance of the ADIM is believed to indicate a successful result of the exercise⁷⁾, whereas a 4–10 mmHg pressure decrease indicates independent contraction of the TrA⁸⁾. Obese patients, patients with respiratory diseases, and preg-

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nant women must avoid prone positions and perform ADIM in the supine or other positions⁸⁾.

In the supine position, the PBU is placed below the lumbar lordosis and air is infused into the bulb to create a pressure of 40 mmHg. However, unlike the prone position, no validated pressure variation values have been published for the performance of ADIM in the supine position. Rather, slight pressure increase or maintaining the pressure of 40 mmHg has been recommended for the performance of ADIM⁸⁾. This lack of definitive information has led to the use of diverse levels of pressure when using a PBU, depending on the researchers' intentions⁹⁻¹²⁾. For this reason, the aim of the present study was to determine the appropriate pressure variation for performing a successful ADIM, by measuring thickness variations in the abdominal muscles and their contraction ratios in response to pressure variations of a PBU during performance of ADIM in the supine position.

SUBJECTS AND METHODS

The subjects of the present study were 14 healthy males and 9 healthy females who were given an explanation of the purpose and method of the study, and who voluntarily agreed to participate in the study. Subjects who had experienced low back pain within the last six months, who had pain while performing ADIM, who showed deformation such as scoliosis, who had received a surgical intervention, who had neurological disease, or who had previous experience of ADIM training using a PBU were excluded. Three participants (2 males, 1 female) could not perform ADIM at any of the four pressure variations and were excluded from the analysis of the present study. Therefore, the final study subjects were 20 persons (12 males, 8 females) and their mean age, height, weight and BMI were 23.60±3.72 years, 169.15±8.49 cm, 60.30±11.85 kg, and 20.91±2.80, respectively.

A PBU (Chattanooga Group Inc. Hixson, TN37343, USA) was placed between the lumbar lordosis and the ground, with subjects in the supine position with knees bent at 90° before performing ADIM. The bulb was then inflated to 40 mmHg of pressure and maintained while the subject performed the ADIM. The subject used an ADIM method in which the pelvic floor muscles were also contracted in order to increase the contraction of the TrA, as described by Critchley¹³⁾. All of the subjects were taught to pull the lower abdomen in slowly, without moving the spine, ribs, or pelvis, while simultaneously contracting the pelvic floor muscles. The subjects performed ADIM in the supine position targeting randomized pressure increase of 0, 2, 4, or 6 mmHg from the initially maintained 40 mmHg. Pressure variations were achieved by the subjects watching the PBU while performing ADIM. Variations in TrA and the thicknesses of the internal oblique abdominal muscle (IO) and the external oblique abdominal muscle (EO) were measured using ultrasonography. To verify the accuracy of the PBU, a weight of 4.54 kg was placed on each PBU and the PBUs were observed for 24 hours¹⁴⁾. The units that showed decreases of 0.5 mmHg or less were used in the study.

A Sonoace X4 (Medison, Korea) was used for ultrasonography. The effects of breathing were controlled by collecting all data at the end-point of expiration¹⁵⁾ using a 7.5 MHz linear transducer. Abdominal muscle thicknesses were measured by placing the transducer transversely on the middle abdominal region between the border of the 11th costal cartilage and the iliac crest¹⁶⁾. The abdominal muscle thicknesses were first measured at rest, and were subsequently measured every time the pressure changed, while the subjects were performing ADIM. Muscle contraction ratios were calculated using equations presented in previous studies¹⁶⁻¹⁸⁾.

TrA contraction ratio =
TrA thickness in contraction/TrA thickness at rest

EO contraction ratio =
EO thickness in contraction/EO thickness at rest

IO + EO contraction ratio =
IO + EO thickness in contraction/IO + EO thickness at rest

TrA preferential activation ratio =
(TrA in contraction/TrA + IO + EO in contraction) -
(TrA at rest/TrA + IO + OE at rest)

Differences in abdominal muscle thickness variations in relation to pressure variations and the contraction ratios of individual muscles were compared using one-way ANOVA. *Posthoc* analyses were conducted using Tukey's multiple comparison and analysis. Statistical processing was conducted using SPSS 12.0 for Windows, and the significance level, α , was chosen as 0.05.

RESULTS

The effects of pressure variations on abdominal muscle thicknesses at rest and during ADIM are shown in Table 1. Significant differences were found in muscle thickness between the resting and ADIM conditions for the IO and the EO. Thickness variations in the IO showed significant differences between pressure increases of 0 and 6 mmHg, and between 2 and 6 mmHg. Thickness variations in the EO also showed significant differences between pressure increases of 0 and 6 mmHg, and between 2 and 6 mmHg.

Variations in abdominal muscle contraction ratios in relation to pressure variations showed significant differences among the IO+EO contraction ratios, the EO contraction ratios, and the TrA selective contraction ratios (Table 2). The IO+EO contraction ratios showed significant differences between 0 and 4 mmHg, 0 and 6 mmHg, and 2 and 6 mmHg. The EO contraction ratios showed significant differences between 0 and 6 mmHg. The TrA selective contraction ratios showed significant differences between 0 and 6 mmHg, and 2 and 6 mmHg.

The reliability within the measurers of the measurements of the thicknesses of each muscle was tested using ICC (3,1). The reliability values for TrA, IO, and EO were 0.96, 0.96, and 0.97, respectively.

Table 1. Comparison of muscle thickness changes between rest and ADIM in the supine position at pressure variations (N=20)

		0 mmHg	2 mmHg	4 mmHg	6 mmHg
TrA	Rest	3.06±0.62	3.03±0.58	3.10±0.84	3.15±0.61
	ADIM	4.73±0.92	4.92±1.41	4.90±1.26	4.92±1.02
	Change in thickness	1.67±0.64	1.90±1.08	1.80±0.84	1.76±0.76
IO	Rest	6.72±1.79	6.72±1.92	6.63±1.90	6.62±1.67
	ADIM	7.36±2.01	7.78±2.37	8.22±2.57	8.81±2.48
	Change in thickness*	0.65±0.72 ^a	1.06±1.00 ^a	1.60±1.28 ^{ab}	2.19±1.56 ^b
EO	Rest	5.04±1.43	5.10±1.38	5.14±1.39	5.15±1.33
	ADIM	4.92±1.51	5.13±1.35	5.40±1.67	5.68±1.48
	Change in thickness*	-0.13±0.49 ^a	0.02±0.57 ^a	0.27±0.75 ^{ab}	0.53±0.60 ^b

Unit: mm; *Significant difference ($p < 0.05$); ^{a, b} values with different superscripts within the same columns are significantly different at $p < 0.05$.

Table 2. Abdominal muscle contraction ratios in response to pressure variations (N=20)

	0 mmHg	2 mmHg	4 mmHg	6 mmHg	p value
TrA CR	1.56±0.22	1.62±0.32	1.60±0.32	1.56±0.26	0.851
IO + EO CR	1.05±0.07 ^a	1.10±0.09 ^{ab}	1.16±0.12 ^{bc}	1.22±0.11 ^c	0.009
EO CR	0.97±0.10 ^a	1.01±0.13 ^{ab}	1.05±0.14 ^{ab}	1.11±0.11 ^b	0.000
TrA PCR	0.08±0.03 ^a	0.07±0.04 ^a	0.05±0.04 ^{ab}	0.04±0.02 ^b	0.007

Values: Mean±Standard Deviation; CR: contraction ratio; PCR: preferential contraction ratio; ^{a, b, c} values with different superscripts within the same columns are significantly different at $p < 0.05$.

DISCUSSION

The present study was conducted to determine the appropriate pressure variation for performing successful ADIM in the supine position, using a PBU. Increases in pressure of 0–2 mmHg resulted in significant decreases in the thicknesses of both the IO and the EO compared to the changes seen following increases of 6 mmHg. In this study, 0–2 mmHg increases showed respective decreases of 1.13–1.54 mm, and 0.51–0.66 mm in IO and EO thicknesses compared to 6 mmHg. Additionally, although the 4 mmHg increase was resulted in IO and EO thicknesses that were not significantly different from the 0–2 mmHg increase, the 0–2 mmHg increase showed respective decreases of 0.54–0.95 mm, and 0.25–0.40 mm in IO and EO thicknesses from their values at 4 mmHg increase. Increases in pressure of 0–2 mmHg may be more effective for decreasing the thicknesses of both IO and the EO compared to other pressure variations. Increases of 4–6 mmHg resulted in increased IO and EO thicknesses similar to those reported in a previous study¹⁹) in which no PBU was used, and this means that ADIM was not performed successfully.

In the present study, the TrA contraction ratio showed no significant differences in relation to pressure variations, but the TrA preferential activation ratios between 0–2 mmHg and 6 mmHg pressure increases showed significant differences. This is because there was a significant difference between the IO+EO contraction ratio and the EO contraction ratio. Successful performance of ADIM is determined by the selective activity of TrA rather than the more superficially located abdominal muscles, such as the

rectus abdominis (RA), IO, and EO²⁰). In particular, unlike the case for RA, activity cannot be easily suppressed in EO while ADIM is being performed because of the anatomical characteristics of EO²¹). In this study, 0–2 mmHg increases resulted in significant decreases in the EO contraction ratio compared to the 6 mmHg increase. The variation in EO contraction ratio resulting from 0–2 mmHg increases was similar to results reported in previous studies^{17, 18}) in which ADIM was performed in the supine position using a feedback tool. However, the 0–2 mmHg increase resulted in an EO thickness that was 0.35–0.50 mm lower than that reported in a previous study¹⁹), in which ADIM was performed using the same method as in the present study, but without a PBU.

Pressure increases of 0–2 mmHg also resulted in significant decreases in the IO+EO contraction ratio compared to the 6 mmHg pressure increase and a significant increase in the TrA preferential activation ratio. In the present study, while variations in TrA thickness and the response of the TrA contraction ratio to pressure variations did not show any significant differences between the resting state and ADIM, the variations in the TrA preferential activation ratio showed significant differences between pressure increases of 0–2 mmHg and 6 mmHg. Given these results, pressure variations appear to regulate the thicknesses and contraction ratios of superficial muscles, such as IO and EO, rather than those of TrA, causing an indirect increase in the preferential activation ratio of TrA.

For 0–2 mmHg increases, the TrA preferential activation ratio was higher than previously reported in studies using a feedback tool^{17, 18}) and those shown by other pres-

sure variations in the present study. Therefore, 0–2 mmHg increases are appropriate pressures for successful performance of ADIM. Among the subjects of the present study, 3 participants could not perform the exercise following a 6 mmHg increase and they were excluded from the final tests. Among the final subjects, only 5 participants (3 males, 2 females) succeeded in performing the exercise after an 8 mmHg increase. The other subjects had difficulty in performing ADIM after an 8 mmHg increase, since the movements of the pelvis and other joints were affected. In addition, almost all of the participants in the present study used many other movement strategies to perform ADIM when pressure was increased by up to 10 mmHg from 40 mmHg^{10–12}). Therefore, for successful ADIM, we recommend performing the exercise at a slightly increased pressure of about 0–2 mmHg.

Since different movement strategies can be adopted at the same PBU pressure, the quantification of TrA contraction using PBUs has limitations¹¹). To solve this problem, all of the subjects in the present study performed the exercise in the same order and used the same method of contraction. However, since abnormal movement strategies were visually observed, we consider the lack of kinematic information for objective control of movement strategies is a limitation of the present study. We hope that future studies will account for these limitations and that diverse study tools will be applied to the investigation of abdominal muscle contraction ratios in relation to pressure variations for ADIM performance in the supine position.

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