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Original Research

Comparison of Changes in Abdominal Muscle Thickness According to Arm Position and Application of Elastic Band Resistance during Crunch Exercises

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Abstract

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This study aimed to compare changes in the thickness of specific abdominal muscles according to arm position and the application of tubing band resistance during crunch exercises. Thirty healthy participants (15 males, 15 females) performed three types of crunch exercises: traditional crunch, shoulder extension resistance crunch, and shoulder horizontal abduction resistance crunch using a medium-resistance tubing band. The thicknesses of the upper and lower rectus abdominis, external oblique, internal oblique, and transversus abdominis muscles were measured at rest and during exercise using B-mode ultrasonography. Data were analyzed using one-way repeated-measures analysis of variance (ANOVA), followed by Bonferroni post hoc tests. The upper and lower rectus abdominis, external oblique, and internal oblique muscles showed significantly greater increases in thickness during both shoulder extension and shoulder horizontal abduction resistance crunch exercises compared to the traditional crunch exercise ($p < 0.05$). Compared with the traditional crunch exercise, the shoulder extension resistance crunch produced increases of 19.2%, 15.7%, 14.1%, and 15.8% in the upper rectus abdominis, lower rectus abdominis, external oblique, and internal oblique muscles, respectively (Cohen's d = 0.53–1.02). Similarly, the shoulder horizontal abduction resistance crunch produced increases of 14.7%, 11.4%, 24.9%, and 11.9%, respectively (Cohen's d = 0.50–0.94). In particular, the external oblique exhibited a 10.8% greater increase in thickness during the shoulder horizontal abduction resistance condition than during the shoulder extension resistance condition (Cohen's d = 0.36, $p < 0.05$). No significant differences were observed in transversus abdominis muscle thickness among the three exercise conditions. These findings suggest that incorporating arm resistance into traditional crunch exercises may influence abdominal muscle thickness responses depending on the direction of upper-extremity resistance. In particular, the shoulder horizontal abduction resistance may be useful for increasing external oblique thickness responses during crunch exercise.

Keywords: Abdominal muscles, core stabilization, elastic band resistance, shoulder extension resistance crunch, shoulder horizontal abduction resistance crunch, ultrasonography

Introduction

The abdominal muscles are located in close proximity to the spine, where they protect the spine by dispersing the pressure applied to it and provide structural stability.[1] These muscles assist in the movement of both the upper and lower limbs[2] and play a crucial role in enhancing physical performance during daily activities and sports.[3] Weakness of the abdominal muscles can reduce spinal stability and increase the risk of low back pain,[4-6] leading to inefficient movement patterns and an overall decline in physical performance.[7]

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One of the most common methods for strengthening the abdominal muscles is the crunch exercise, which involves trunk flexion in the sagittal plane to effectively contract the abdominal musculature.[8-10] The crunch exercise requires only a limited range of motion in which the upper body is slightly lifted, thereby minimizing excessive load on the lumbar spine,[11] and it can be performed anywhere without the need for special equipment or large space, making it highly accessible and practical.[12] However, because the abdominal muscles can easily adapt to repetitive and identical stimuli, continuing training at the same intensity may limit further muscle development.[13,14] Therefore, to more effectively strengthen the abdominal muscles, strategies that diversify exercise intensity and the direction of applied stimuli are required.

Previous studies have shown that resistance applied to the arms during crunch exercises increases abdominal muscle thickness, and that adding isometric resistance to both the arms and legs significantly increases the thickness of abdominal muscles, including the external oblique.[15,16] Rutkowska et al. (2010) also reported that changes in the load applied to the upper body during curl-up exercises influence abdominal muscle recruitment patterns.[17] Similarly, in a study of patients with post-stroke hemiplegia, shoulder extension and horizontal abduction movements using elastic bands in a sitting position significantly increased the activation of the rectus abdominis, external oblique, and internal oblique muscles compared to shoulder flexion. Notably, horizontal abduction produced a greater increase in external oblique activation than shoulder extension.[18] These findings suggest that upper limb movements using elastic bands can reflexively activate the abdominal muscles and induce feedforward postural adjustments, thereby enhancing trunk stability.[19-21] Moreover, the fact that the response patterns of the abdominal muscles differed according to the type of upper limb movement indicates the need for targeted interventions based on the functional characteristics of each muscle.

Anatomically, the abdominal muscles consist of superficial layers, including the rectus abdominis and external oblique, and deeper layers, including the internal oblique and transversus abdominis, which contribute to maintaining balance.[22] The rectus abdominis runs vertically along the abdomen, bringing the pelvis and rib cage closer together to facilitate trunk flexion[23] and is involved in increasing intra-abdominal pressure and maintaining trunk stability.[24] The internal oblique rotates the trunk in the same direction, whereas the external oblique rotates it in the opposite direction.[25] The internal oblique and transversus abdominis also protect the inguinal region and maintain postural stability,[26] with the transversus abdominis being the first muscle to activate before upper or lower limb movement, playing a key role in lumbar stabilization.[27] Given that abdominal muscles respond differently to movement depending on their anatomical structure and functional characteristics, exercise programs designed to strengthen them effectively should be based on these functional roles.

Therefore, the present study aimed to compare changes in the thickness of the rectus abdominis, external oblique, internal oblique, and transversus abdominis muscles according to arm position and the use of tubing bands during crunch exercises, providing foundational data for the development of function-specific abdominal muscle strengthening strategies. Three exercise conditions were implemented: (1) traditional crunch with the arms extended forward, (2) crunch with shoulder extension against tubing band resistance, and (3) crunch with shoulder horizontal abduction against tubing band resistance. The study hypotheses were as follows: (1) tubing band resistance (shoulder extension or shoulder horizontal abduction) would produce greater increases in abdominal muscle thickness than the traditional crunch, and (2) shoulder horizontal abduction with tubing band resistance would produce greater increases in external oblique thickness than shoulder extension.

Methods

Participants

This study recruited 30 healthy adult men and women. All participants were provided written informed consent after receiving a comprehensive explanation of the study's purpose and procedures. A total of 30 individuals completed the study. The required minimum sample size was calculated using G*Power software (version 3.1.9.6; Heinrich Heine University, Düsseldorf, Germany). With the significance level (α) set at 0.05 and statistical power ($1-\beta$) at 0.80, a minimum of 22 participants was deemed necessary.

The inclusion criteria were as follows: adults aged 18 years or older, cognitively capable of understanding and following the investigator's instructions, no participation in similar studies within the previous year, and no participation in regular resistance training or structured core exercise programs within the previous six months. The exclusion criteria included: voluntary withdrawal during the study period; unstable cardiovascular conditions such as hypertension, arrhythmia, or angina; a history of thoracic or abdominal surgery; orthopedic impairments; visual field defects that could interfere with the study; congenital thoracic deformities; rib fractures; and diagnosed pulmonary, renal, endocrine, orthopedic, or rheumatic disorders. Participants with skin hypersensitivity or intolerance to vibration stimuli were also excluded.

All participants' privacy rights were strictly protected, and no personally identifiable information was collected or disclosed without explicit informed consent. Experiments involving human participants were conducted in accordance with the ethical standards of the Declaration of Helsinki. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science.[28] The study protocol was approved by the Institutional Review Board (IRB) of B University (IRB No. BUIRB-202506-HR-52).

Procedure

Participants were informed of the purpose and procedures of the study and provided written informed consent prior to participation. All experiments were performed under consistent environmental conditions with controlled temperature and lighting. Height and body mass were measured before testing.

To measure resting muscle thickness, participants lay in a supine position and remained relaxed while the upper rectus abdominis, lower rectus abdominis, external oblique, internal oblique, and transversus abdominis muscles were assessed using B-mode ultrasonography. Following these measurements, exercise order was randomized to minimize potential carryover effects and fatigue. Randomization was performed by having participants draw one of three numbered slips (1, 2, or 3) from an opaque container. Exercise conditions were as follows: (1) traditional crunch, (2) shoulder extension resistance crunch, and (3) shoulder horizontal abduction resistance crunch. Each exercise was conducted by maintaining the crunch position for 8 seconds, followed by a 30-second rest, and repeated three times.[16] A 3-minute rest interval was provided between exercise types to prevent fatigue and maintain consistent performance. During each exercise condition, muscle thickness measurements were obtained for the upper rectus abdominis, lower rectus abdominis, external oblique, internal oblique, and transversus abdominis muscles in the same order as in the pre-test. Muscle thickness values were obtained during the middle 3 seconds of each 8-second contraction, and the average value across the three trials was used for analysis.

Measurements

A LOGIQ P6 PRO B-mode ultrasound system (GE Inc., New Jersey, USA) with a linear transducer was used to measure morphological changes in the abdominal muscles. All measurements were performed by the same experienced examiner to ensure consistency. Measurements were obtained for the dominant side (defined as the side of the hand used for writing) in the following order: upper rectus abdominis, lower rectus abdominis, external oblique, internal oblique, and transversus abdominis. Measurement sites were marked with a water-soluble pen to ensure consistency. The upper rectus abdominis was measured 3 cm lateral and 3 cm superior to the lateral edge of the umbilicus (Figure 1A). The lower rectus abdominis was measured 3 cm lateral and 3 cm inferior to the lateral edge of the umbilicus, with the transducer placed transversely along the abdominal wall (Figure 1B). The external oblique, internal oblique, and transversus abdominis were measured at a point between the 12th rib and the iliac crest, approximately 2.5 cm anterior to the mid-axillary line, with the transducer placed transversely (Figure 1C).[29-30]

In ultrasound images, the external oblique appears as the most superficial layer, followed by the internal oblique, and finally the transversus abdominis adjacent to the peritoneal cavity. Each muscle layer appears as a hypoechoic (dark) band, with boundaries defined by hyperechoic (bright) fascial borders (Figure 2B).[31] Muscle thickness was measured along the fascial borders, excluding the superficial and deepest fascia. For each muscle, the central portion of the image was used for thickness measurement, as it generally represented the thickest region.[30]

Muscle thickness values obtained during the middle 3 seconds of each 8-second contraction across all three trials were averaged and used for statistical analysis to minimize potential measurement error and performance variability and to obtain more stable and reliable representative values. The percentage change in muscle thickness was calculated as follows: (average thickness during exercise / thickness at rest) × 100.[16] The reliability of ultrasound measurements for abdominal muscle thickness is reported to be excellent, with an intraclass correlation coefficient (ICC) of 0.989.[32]

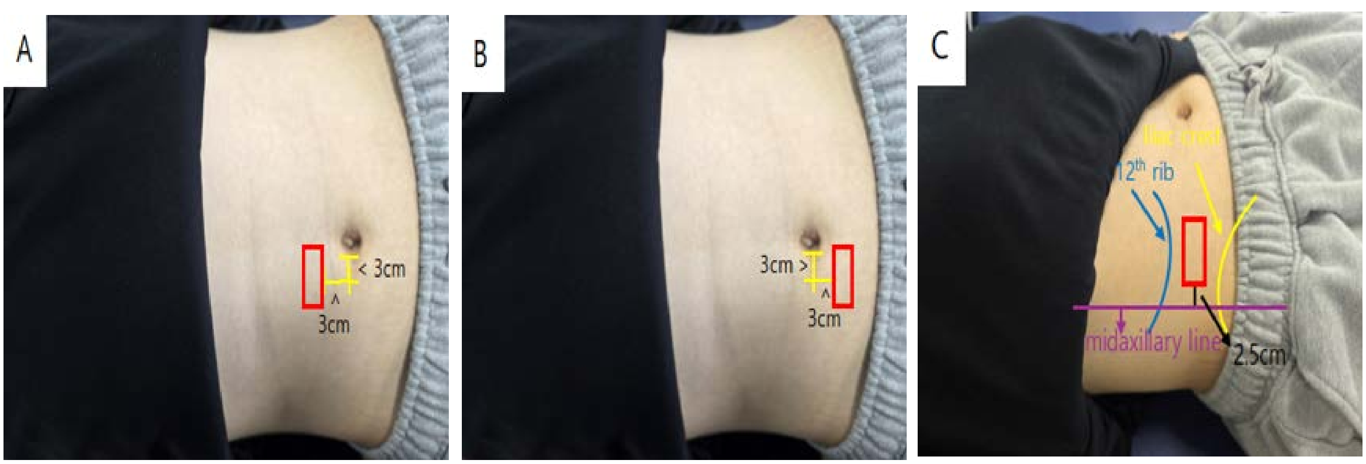

Figure 1. Probe locations for measuring abdominal muscles. (A) upper rectus abdominis; (B) lower rectus abdominis; (C) external oblique, internal oblique, and transversus abdominis.

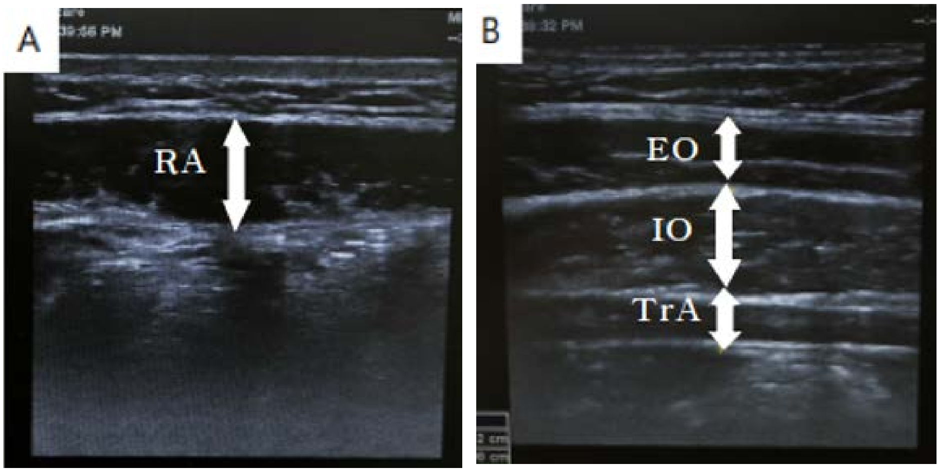

Figure 2. Ultrasonographic images of abdominal muscles. (A) rectus abdominis (RA); (B) external oblique (EO), internal oblique (IO), and transversus abdominis (TrA).

Interventions

This study implemented three intervention conditions: traditional crunch exercise, shoulder extension resistance crunch exercise, and shoulder horizontal abduction resistance crunch exercise (Figure 3). Different directions of upper-extremity resistance were applied to investigate whether direction-specific loading strategies would produce different abdominal muscle thickness responses during crunch exercise. The traditional crunch exercise was performed following protocols from previous studies.[15,16] A digital goniometer (Baseline Digital Goniometer, HiRes™, USA) was used to ensure precise maintenance of trunk flexion range and shoulder flexion, extension, and horizontal abduction angles during exercise. All resistance and exercise conditions were performed using the dominant arm, while the non-dominant arm was maintained at 90° shoulder flexion with the elbow, wrist, and fingers extended. Prior to testing, all participants received standardized verbal instructions and demonstrations regarding exercise performance. During each exercise condition, the examiner provided consistent verbal cues, including "maintain the trunk position," "avoid compensatory movements," and "hold the position steadily," to ensure uniform performance across participants. The examiner continuously monitored participants during each exercise to prevent compensatory movements. For the resistance crunch exercises (shoulder extension and shoulder horizontal abduction), a medium-resistance green tubing band (Thera-Band, Hygenic Corporation, USA) was used.[18] This band has been reported to provide appropriate upper limb resistance for both males and females.[18] In the present study, participants held the band at a position 80 cm from the fixed anchor point to maintain consistent resistance during exercise.[18] The exercise protocols for each intervention condition are summarized in Table 1.

Traditional Crunch Exercise

Participants lay in a supine position with the hip joints flexed to 45° and the knee joints flexed to 90°. The knees were shoulder-width apart, and the feet were placed flat on the floor. At the start of the exercise, the chin was tucked, and the shoulder joints were flexed to 90° with both arms extended forward. Participants flexed the trunk approximately 30°, lifting the head and shoulders off the floor. This position was held for 8 seconds, followed by 30 seconds of rest, and repeated three times (Figure 3A).

Shoulder Extension Resistance Crunch Exercise

The starting position was identical to that of the traditional crunch exercise. The non-dominant arm was flexed to 90° at the shoulder and held forward, while the dominant hand grasped the tubing band positioned 80 cm from the fixed anchor point. During the exercise, the trunk was flexed approximately 30°, lifting the head and shoulders off the floor while simultaneously extending the dominant shoulder to 40°. This position was maintained for 8 seconds, followed by 30 seconds of rest, and repeated three times (Figure 3B).

Shoulder Horizontal Abduction Resistance Crunch Exercise

The starting position was identical to that of the traditional crunch exercise. The non-dominant arm was flexed to 90° at the shoulder and held forward, while the dominant hand grasped the tubing band positioned 80 cm from the fixed anchor point. During the exercise, the trunk was flexed approximately 30°, lifting the head and shoulders off the floor while simultaneously performing 90° horizontal abduction of the dominant shoulder. This position was maintained for 8 seconds, followed by 30 seconds of rest, and repeated three times (Figure 3C).

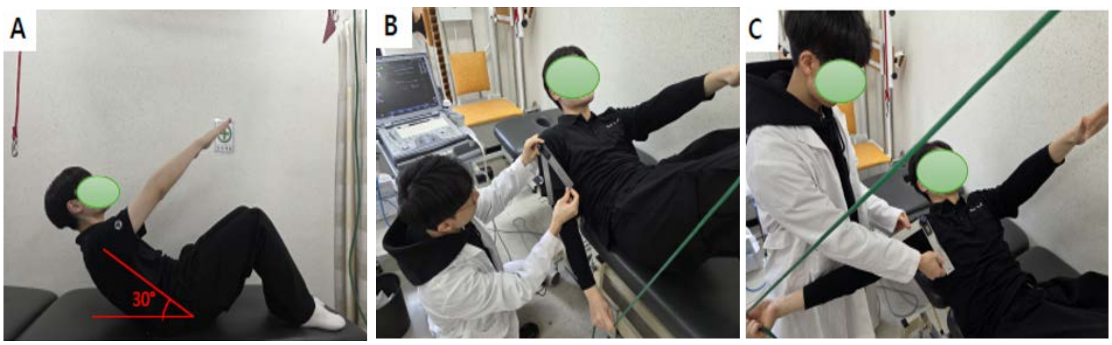

Figure 3. Three crunch exercises: (A) traditional crunch exercise, (B) shoulder extension resistance crunch exercise, (C) shoulder horizontal abduction resistance crunch exercise.

Table 1. Summary of exercise protocols.

Exercise condition	Hold duration	Rest between repetitions	Repetitions	Rest between conditions	Resistance
Traditional crunch exercise	8 s	30 s	3	3 min	None
Shoulder extension resistance crunch exercise	8 s	30 s	3	3 min	Medium-resistance green tubing band
Shoulder horizontal abduction resistance crunch exercise	8 s	30 s	3	3 min	Medium-resistance green tubing band

Statistical analysis

All data were analyzed using PASW Statistics version 18.0 for Windows (SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test was performed to assess the normality of the general characteristics of the participants, and normal distribution was confirmed. Parametric statistical methods were therefore applied Five separate 1 × 3 repeated-measures analyses of variance (ANOVAs) were conducted to compare the percentage changes in muscle thickness across the three exercise conditions (traditional crunch exercise, shoulder extension resistance crunch exercise, and shoulder horizontal abduction resistance crunch exercise) for each abdominal muscle measurement site: upper rectus abdominis, lower rectus abdominis, external oblique, internal oblique, and transversus abdominis. When significant main effects were identified, Bonferroni post hoc tests were performed for pairwise comparisons. The level of statistical significance was set at $\alpha = 0.05$. Effect sizes (Cohen's d) were calculated for pairwise comparisons using the mean difference divided by the pooled standard deviation[30] According to Cohen's guidelines, effect sizes were interpreted as small (0.2), moderate (0.5), and large (0.8).[30]

Results

Participant Characteristics

The general characteristics of the participants are presented in Table 2.

Table 2. Demographics of the participant.

	(N=30)	
Variables	Male (n = 15)	Female (n = 15)
Age (yrs)	24.20±1.97	22.27±1.28
Height (cm)	175.33±5.67	161.73±5.39
Weight (kg)	77.67±7.72	54.07±7.13

Note: Results are presented as mean ± SD.

Percentage Increase in Abdominal Muscle Thickness Among the Three Crunch Exercises

A comparison of the three crunch exercise conditions revealed significant differences in the percentage increase in muscle thickness of the upper rectus abdominis, lower rectus abdominis, external oblique, and internal oblique ($p < 0.05$, Table 3).

For both the upper and lower rectus abdominis, the percentage increase in muscle thickness was significantly greater during the shoulder extension resistance crunch and shoulder horizontal abduction resistance crunch compared to the traditional crunch ($p < 0.05$; Table 4, Figure 4). However, no significant difference was observed between the shoulder extension resistance and shoulder horizontal abduction resistance conditions ($p > 0.05$, Table 4, Figure 4).

For the external oblique, the percentage increase in muscle thickness was significantly greater during both the shoulder extension resistance crunch and the shoulder horizontal abduction resistance crunch compared to the traditional crunch ($p < 0.05$, Table 4, Figure 4), and was significantly greater during the shoulder horizontal abduction resistance crunch than during the shoulder extension resistance crunch ($p < 0.05$, Table 4, Figure 4).

For the internal oblique, the percentage increase in muscle thickness was significantly greater during both the shoulder extension resistance crunch and the shoulder horizontal abduction resistance crunch compared to the traditional crunch ($p < 0.05$, Table 4, Figure 4). However, no significant difference was found between the two resistance conditions ($p > 0.05$, Table 4, Figure 4).

No statistically significant differences in the percentage increase in muscle thickness were observed for the transversus abdominis among the three exercise conditions ($p > 0.05$, Table 3, Figure 4).

Table 3. Percentage increase in abdominal muscle thickness during three different crunch exercise conditions (N=30)

	TC	EC	HC	F	P
URA (%)	126.44±21.25[a]	150.77±26.12	145.08±31.50	15.104	$< 0.001^{***}$
LRA (%)	127.93±25.87	147.99±23.64	142.56±28.66	12.066	$< 0.001^{***}$
EO (%)	116.05±23.19	132.42±33.83	144.96±36.64	16.448	$< 0.001^{***}$
IO (%)	122.01±30.18	141.25±41.61	136.58±31.03	5.684	$< 0.01^{**}$
TrA (%)	128.41±35.96	126.15±30.82	127.66±34.67	.106	NS.

Note: Results are presented as mean ± SD; TC, traditional crunch exercise; EC, shoulder extension resistance crunch exercise; HC, shoulder horizontal abduction resistance crunch exercise; URA, upper rectus abdominis; LRA, lower rectus abdominis; EO, external oblique; IO, internal oblique; TrA, transversus abdominis. % = (thickness during exercise / thickness at rest) × 100. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. NS = not significant ($p > 0.05$).

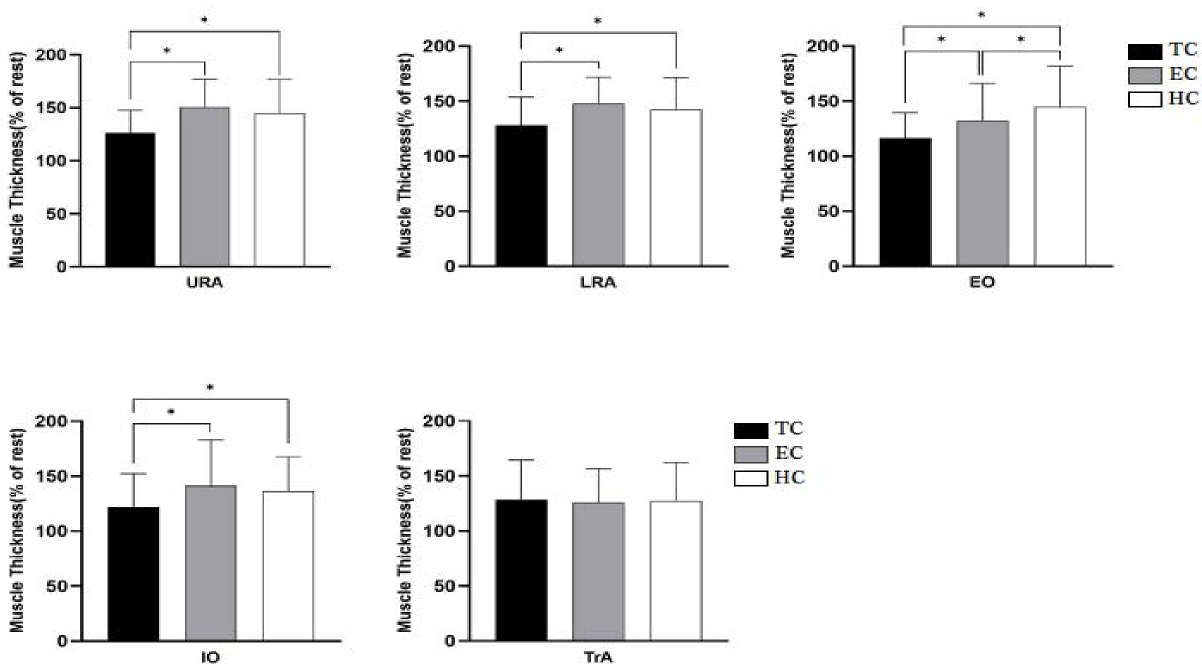

Figure 4. Multiple comparisons of the percentage increase in abdominal muscle thickness across three different crunch exercise conditions.

Note: Results are presented as mean ± SD; TC, traditional crunch exercise; EC, shoulder extension resistance crunch exercise; HC, shoulder horizontal abduction resistance crunch exercise; URA, upper rectus abdominis; LRA, lower rectus abdominis; EO, external oblique; IO, internal oblique; TrA, transversus abdominis. Y-axis values represent muscle thickness during exercise expressed as a percentage of resting thickness (rest = 100%). $^{*}p < 0.05$.

Table 4. Pairwise effect sizes (Cohen's d) from Bonferroni post-hoc comparisons.

(N = 30)

Comparison	URA	LRA	EO	IO	TrA
	Δ% / d	Δ% / d	Δ% / d	Δ% / d	Δ% / d
TC vs EC	$+19.2^{*}$ / 1.02	$+15.7^{*}$ / 0.81	$+14.1^{*}$ / 0.57	$+15.8^{*}$ / 0.53	-1.8 / 0.07
TC vs HC	$+14.7^{*}$ / 0.71	$+11.4^{*}$ / 0.56	$+24.9^{*}$ / 0.94	$+11.9^{*}$ / 0.50	-0.6 / 0.02
EC vs HC	−3.8 / 0.20	−3.7 / 0.21	$+10.8^{*}$ / 0.36	−3.3/ 0.13	+1.2 / 0.05

Note. Δ% = mean difference in muscle thickness percentage between conditions, Positive Δ% indicated greater thickness increase in the latter condition, negative values in the former; d = Cohen's d effect size. TC = traditional crunch; EC = shoulder extension resistance crunch; HC = shoulder horizontal abduction resistance crunch; URA = upper rectus abdominis; LRA = lower rectus abdominis; EO = external oblique; IO = internal oblique; TrA = transversus abdominis. $^{*}p < .05$ (Bonferroni post-hoc).

Discussion

This study compared changes in the thickness of the upper and lower rectus abdominis, external oblique, internal oblique, and transversus abdominis muscles during crunch exercises performed with different arm positions and the application of elastic band resistance. The findings revealed that the upper and lower rectus abdominis, external oblique, and internal oblique showed significantly greater increases in muscle thickness during both the shoulder extension resistance crunch and shoulder horizontal abduction resistance crunch compared to the traditional crunch. In the resistance conditions, the application of elastic band resistance and changes in upper-extremity position may have increased external torque and mechanical loading on the trunk around the lumbopelvic axis of rotation during trunk flexion, particularly in the posterior pelvic region near the sacrum and coccyx. Consequently, greater contractile demands may have been placed on the abdominal muscles to maintain trunk stability during the crunch exercise, resulting in greater muscle thickness changes. In particular, the shoulder horizontal abduction position may have increased the moment arm of the upper extremity and shifted the center of mass laterally, thereby increasing rotational and lateral stabilization demands on the trunk. These biomechanical characteristics may partially explain the greater increase in external oblique thickness observed during the shoulder horizontal abduction resistance crunch exercise. In contrast, no significant differences in transversus abdominis thickness were observed among the three exercise conditions. This may be because the transversus abdominis primarily functions as a deep stabilizing muscle involved in feedforward postural control and local stabilization rather than large-amplitude trunk flexion movements. In addition, because the crunch exercises used in the present study represented dynamic tasks with relatively greater contractile demands on the rectus abdominis and oblique muscles, the relative contribution of the transversus abdominis may have been limited. Furthermore, because this study evaluated immediate changes in muscle thickness during short-duration contractions, these findings should not be interpreted as indicating an absence of transversus abdominis activation or functional contribution. The findings for each dependent variable are discussed below in comparison with previous studies.

For the upper rectus abdominis, muscle thickness showed relative increases of 19.2% in the shoulder extension resistance condition and 14.7% in the shoulder horizontal abduction resistance condition compared with the traditional crunch exercise. The lower rectus abdominis showed relative increases of 15.7% and 11.4%, respectively, indicating greater muscle thickness changes in both resistance conditions compared with the traditional crunch exercise. These findings are directionally consistent with previous studies reporting increases of 12.1% for shoulder extension resistance and 2.8% for horizontal abduction resistance;[15,16] however, differences in the magnitude of change were observed, which may be attributable to methodological differences such as resistance intensity, participant characteristics, and measurement timing.[15,16] With respect to the underlying mechanisms of each resistance condition, shoulder extension activates posterior muscle groups such as the latissimus dorsi and posterior deltoid,[33] and activation of these posterior muscles may have contributed to trunk stability by facilitating co-contraction of the rectus abdominis through functional antagonism. Previous studies have reported that under high-intensity or fatiguing conditions, activation of both agonist and antagonist muscles increases to contribute to trunk stability.[34] In contrast, the shoulder horizontal abduction condition may increase the moment arm of the upper extremity, thereby increasing external torque around the lumbopelvic axis of rotation during the crunch exercise. The resulting increase in trunk loading demand may have contributed to greater recruitment of the rectus abdominis.

Although no significant differences in upper or lower rectus abdominis thickness changes were observed between the two resistance conditions, this may indicate that both conditions produced similar levels of abdominal muscle loading through different biomechanical mechanisms. In other words, both resistance conditions elicited greater muscle thickness changes than the traditional crunch exercise through their respective mechanisms, suggesting that upper-extremity movement direction and applied resistance may influence abdominal muscle recruitment patterns. However, because the muscle thickness measurements obtained in the present study reflect acute morphological responses rather than direct measures of neuromuscular recruitment, future studies incorporating electromyography are needed to more directly verify these mechanisms.

For the external oblique, muscle thickness increased by 16.4% in the shoulder extension resistance condition and by 28.9% in the shoulder horizontal abduction resistance condition compared to the traditional crunch, with the latter being 12.5% greater than the former. While a previous study reported a 9.5% increase for the horizontal abduction resistance condition compared to the traditional crunch, no statistically significant difference was found,[16] likely due to methodological differences. The present study applied resistance while the shoulder was positioned at 90° horizontal abduction, rather than at 90° flexion with horizontal abduction force, as in the previous study.[16] Positioning the arm in full horizontal abduction increases the moment arm and mechanical load on the trunk, shifting the center of mass laterally. This requires greater activation of trunk stabilizers, particularly the external oblique, to resist trunk rotation and maintain lateral stability. Indeed, previous research has shown that horizontal abduction produces greater external oblique activation than shoulder flexion or extension,[18] with activity levels exceeding 60% of maximal voluntary isometric contraction in this position.[35] Thus, applying resistance in a horizontally abducted position is likely more effective for external oblique activation than in a flexed or extended position, providing a useful strategy for targeted external oblique strengthening.

For the internal oblique, muscle thickness increased by 19.2% in the shoulder extension resistance condition and by 14.6% in the shoulder horizontal abduction resistance condition compared to the traditional crunch, with no significant difference between the two resistance conditions. Previous studies have also reported thickness increases with horizontal abduction resistance,[16] consistent with the functional role of the internal oblique in trunk rotation, balance, and postural stability.[27] Sugaya et al. (2014) reported increases in internal oblique thickness under isometric resistance during both neutral and rotational trunk positions,[36] while Park et al. (2022) and Bae et al. (2023) found increases during crunch exercises involving trunk rotation.[16,37] These findings suggest that resistance conditions involving upper limb movement increase trunk instability, eliciting internal oblique activation regardless of whether the movement is shoulder extension or horizontal abduction. Given the deep location and thin structure of the internal oblique, hypertrophic responses may be limited under short-duration, high-intensity stimulation, possibly contributing to the lack of difference between the two resistance conditions.

For the transversus abdominis, no significant differences in muscle thickness were observed among the three exercise conditions, although slight non-significant decreases of approximately 1.8% in the shoulder extension resistance condition and 0.6% in the shoulder horizontal abduction resistance condition were observed compared with the traditional crunch exercise. Previous research reported an increase in transversus abdominis thickness during horizontal abduction resistance exercises;[16] however, the magnitude of change was relatively small and not statistically significant, which is consistent with the present findings. One possible explanation is related to the functional characteristics of the transversus abdominis. This muscle is known as a deep stabilizing muscle characterized by feedforward activation during anticipatory trunk stabilization rather than large-amplitude trunk flexion movements.[27,38] In addition, the transversus abdominis may exhibit less pronounced immediate thickness changes during dynamic trunk flexion tasks compared with the superficial abdominal muscles because of its primary stabilizing role.[39] During dynamic crunch exercises, greater activation demands are placed on the rectus abdominis and oblique muscles, which act as the primary movers responsible for trunk flexion. Consequently, the relative contribution of the transversus abdominis during these exercise conditions may have been limited. Furthermore, because the present study evaluated immediate changes in muscle thickness during short-duration isometric contractions, the findings should not be interpreted as indicating an absence of transversus abdominis activation. Future studies incorporating electromyographic measurements and controlled breathing conditions are needed to clarify the activation characteristics of the transversus abdominis during resistance-based abdominal exercises.

Limitations

This study has several limitations. First, the participants were limited to healthy university students, which restricts the generalizability of the findings to populations with different ages or clinical characteristics. In addition, although physiological differences between males and females may influence abdominal muscle responses during exercise, sex-specific analyses were not performed in the present study. Therefore, future studies should include participants with diverse ages, fitness levels, and health conditions, while also considering sex-related physiological characteristics through separate analyses for males and females. Second, this study relied solely on ultrasonographic measurements of muscle thickness and did not include indicators of neuromuscular activity, such as electromyography, or functional performance assessments, including core stability, muscular endurance, and strength. In addition, because the present study evaluated immediate muscle thickness changes during relatively short-duration isometric contractions, the observed responses may differ from those occurring during prolonged contractions or repetitive exercise tasks. Therefore, future studies should incorporate both ultrasonographic and electromyographic assessments along with various functional outcome measures to provide a more comprehensive evaluation of abdominal muscle performance. Third, all exercises were performed using only the dominant arm; therefore, potential differences in muscle responses of the non-dominant side or during bilateral resistance application were not examined. Future studies should investigate bilateral exercise conditions and symmetry-related factors to better understand the effects of upper-extremity resistance direction on trunk stabilization and abdominal muscle responses.

This study compared changes in abdominal muscle thickness according to arm position and the use of elastic band resistance during crunch exercises. The findings demonstrated that crunch exercises with shoulder extension or shoulder horizontal abduction resistance were more effective than traditional crunch exercises in increasing the thickness of the upper and lower rectus abdominis, external oblique, and internal oblique muscles. Notably, the external oblique exhibited the greatest increase in thickness during the shoulder horizontal abduction resistance condition. In contrast, no significant differences were observed for the transversus abdominis across all exercise conditions. These results suggest that adding resistance, such as an elastic band, to the arms during crunch exercises is an effective strategy for enhancing abdominal muscle thickness and may be beneficial for improving trunk stability and core muscle conditioning in both clinical rehabilitation and athletic training settings. In particular, shoulder horizontal abduction resistance may be useful for selectively emphasizing external oblique activation in exercise programs targeting rotational trunk stability and functional core performance.

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