IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

EFFECT OF CORE EXERCISES WITH DIAPHRAGMATIC BREATHING ON PULMONARY FUNCTION AND ABDOMINAL ENDURANCE IN YOUNG HEALTHY FEMALES

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Abstract

Background: Previous study has evaluated the impact of breathing in relation to abdominal exercises in young and healthy males. Thus, the aim of this study is to evaluate whether, as compared with a training protocol of common core exercises, these exercises plus breathing exercises particularly diaphragmatic breathing would more greatly enhance abdominal fitness, and respiratory function in young healthy females.
Materials and Methods: A total of 30 young healthy females were screened for the study as per the inclusion and exclusion criteria. The subjects were conveniently divided into 3 group. Each group comprised of 10 subjects each. Experimental Group 1 (EG1) performed core exercises with diaphragmatic breathing, Experimental Group 2 (EG2) performed only core exercises and Control Group (CG) was not given any kind of exercises during 6 weeks. Pre and post data was collected in terms of Pulmonary Function Test (PFT) and ACSM curl-up (cadence) test after 6 weeks in all the three group. Results were tested for normal distribution using a Shapiro-Wilk test. One-way ANOVA tests were used to measure differences in PFT variables, ACSM curl-up test scores, between groups. A dependent-measure t-test was used to determine pre- and post-test differences within the groups. Confidence interval was set at 95% and any value <0.05 was considered as significant and <0.001 as highly significant.
Results: Significant changes in ACSM curl-up test scores, and all pulmonary parameters were recorded in the experimental groups: EG1 and EG2 at the post-training assessment, whereas in the control group, no significant differences over baseline were observed in any parameters.
Conclusion: Core exercises with diaphragmatic breathing is more effective in improving pulmonary function and abdominal endurance in young healthy females.

Keywords: Diaphragmatic breathing, pulmonary function test, core stability

INTRODUCTION

In recent years, abdominal muscle training has gained increasing popularity, and exercises like “crunches” or “planks” have become an integral part of both fitness and rehabilitation programs. Abdominal training serves to improve core stability, which is the ability to strengthen the lumbopelvic complex and transfer forces from the upper to the lower limbs of the body while maintaining the spine in a neutral position. [1] [2]

The “core” region of the body has been anatomically described as a box, with the abdominals at the front, spinal and gluteal muscles at the back, the diaphragm on the top, and the pelvic floor and hip muscles on the bottom. [3] Specifically, the core is composed of the anterior rectus abdominis and transverse abdominis; posterior erector spinae, multifidus, gluteus maximus, and hamstrings; lateral gluteus medius, gluteus minimus, and quadrates lumborum; and medial adductor magnus, longus, brevis, and pectineus. [4] In addition, the base of the lumbopelvic hip complex is made up of the pelvic floor with the superior aspect consisting of the diaphragm. With efficient functionality of the entire lumbopelvic hip complex, one can maintain a strong, stable, and functional base for all movements. [5] [6]

The core acts through the thoracolumbar fascia, ‘‘nature's back belt.'' The transversus abdominis has large attachments to the middle and posterior layers of the thoracolumbar fascia. Additionally, the deep lamina of the posterior layer attaches to the lumbar spinous processes. In essence, the thoracolumbar fascia serves as part of a ‘‘hoop'' around the trunk that provides a connection between the lower limb and the upper limb. With contraction of the muscular contents, the thoracolumbar fascia also functions as a proprioceptor, providing feedback about trunk positioning.[11]

Two types of muscle fibers comprise the core muscles: slow-twitch and fast-twitch. Slow-twitch fibers make up primarily the local muscle system (the deep muscle layer). These muscles are shorter in length and are suited for controlling intersegmental motion and responding to changes in posture and extrinsic loads. Key local muscles include transversus abdominus, multifidi, internal oblique, deep transversospinalis, and the pelvic floor muscles. Multifidi have been found to atrophy in people with chronic low back pain (LBP). On the other hand, fast-twitch fibers comprise the global muscle system (the superficial muscle layer). These muscles are long and possess large lever arms, allowing them to produce large amounts of torque and gross movements. Key global muscles include erector spinae, external oblique, rectus abdominis muscles, and quadratus lumborum.[11]

The abdominals serve as a particularly vital component of the core. The transversus abdominis has received attention for its stabilizing effects. It has fibers that run horizontally (except for the most inferior fibers, which run parallel to the internal oblique muscle), creating a belt around the abdomen. ‘‘Hollowing in'' of the abdomen creates isolated activation of the transversus abdominis. The transversus abdominis and multifidi have been shown to contract 30ms before movement of the shoulder and 110ms before movement of the leg in healthy people, theoretically to stabilize the lumbar spine. However, patients with LBP have delayed contraction of the transversus abdominis and multifidi prior to limb movement. The internal oblique and the transversus abdominis work together to increase the intra-abdominal pressure from the hoop created via the thoracolumbar fascia. Increased intra-abdominal pressure has been shown to impart stiffness to the spine. The external oblique, the largest and most superficial abdominal muscle, acts as a check of anterior pelvic tilt. The abdominals (and multifidi) need to engage only to 5% - 10% of their maximal volitional contraction to stiffen spine segments. [11]

The hip musculature is vital to all ambulatory activities, and plays a key role in stabilizing the trunk and pelvis in gait. Poor endurance and delayed firing of the hip extensor (gluteus maximus) and abductor (gluteus medius) muscles have previously been noted in people with LBP and other musculoskeletal conditions such as ankle sprains. The psoas is only a feeble flexor of the lumbar spine. However, it does have the potential to exert massive compressive forces on the lumbar disks. In activities that promote maximal psoas contraction, such as full sit-ups, it can exert a compressive load on the L5-S1 disk equal to 100 kg of weight. Tightness of the hip flexor (psoas) can cause LBP by increasing compressive loads to the lumbar disks.[11]

The diaphragm serves as the roof of the ‘‘muscular box'' of the core, and the pelvic floor serves as the floor. Contraction of the diaphragm increases intra-abdominal pressure, thus adding to spinal stability. Pelvic floor musculature is coactivated with transversus abdominis contraction. Recent studies have indicated that people with sacroiliac pain have impaired recruitment of the diaphragm and pelvic floor. Thus, diaphragmatic breathing techniques and pelvic floor activation may be an important part of a core-strengthening program.[11]

Particular attention has been paid to the core because it serves as a muscular corset that works as a unit to stabilize the body and spine, with and without limb movement. In short, the core serves as the centre of the functional kinetic chain. In the alternative medicine world, the core has been referred to as the "powerhouse," the foundation or engine of all limb movement. [7]

As stated by Cook, [8] "The best core training programs require the spine to be held in a natural or neutral position while breathing and while moving the arms and legs in motions that mimic the functional ways the core will be stressed in a given sport or activity."

The most common traditional exercises and training methods to enhance abdominal strength and stability employ body weight exercises consisting of static or dynamic contractions in various body positions (e.g., supine, lateral) starting with isolated movements and then continuing through with more complex sequences such as crunches, sit-ups, and planks (prone or lateral). [9]

Correct breathing (especially as it involves the respiratory muscles) is vital to abdominal training because respiratory muscles are directly involved during common core stability exercises. [9] Among the deep breathing techniques, diaphragmatic breathing has been shown to reduce the work of breathing and improve ventilation efficiency. The abdomen in diaphragmatic breathing rises during inspiration and returns during expiration. [10] DePalo et al. found that the diaphragm is actively recruited in many resistance training exercises, including sit-ups. Other studies demonstrated that the respiratory muscles are involved in a variety of activities in which respiration is not primarily involved. Because breathing is one of the most basic patterns directly related to human movement, as seen in neonates, inefficient breathing may result in muscular imbalance and motor control alterations that can affect general motor quality. [9]

Contraction of the diaphragm increases intra-abdominal pressure, thus adding to spinal stability. Pelvic floor musculature is coactivated with transversus abdominis contraction. Recent studies have indicated that people with sacroiliac pain have impaired recruitment of the diaphragm and pelvic floor. Likewise, ventilatory challenges on the body may cause further diaphragm dysfunction and lead to more compressive loads on the lumbar spine. Thus, diaphragmatic breathing techniques may be an important part of a core-strengthening program. Furthermore, the pelvic floor musculature is coactivated with transversus abdominis contraction. [11]

Previous study has evaluated the impact of breathing in relation to abdominal exercises in young and healthy males. Thus, the aim of this study is to evaluate whether, as compared with a training protocol of common core exercises, [12] these exercises plus breathing exercises particularly diaphragmatic breathing would more greatly enhance abdominal fitness, and respiratory function in young healthy females. This may be useful for coaches or physical therapists when selecting core exercises to improve overall abdominal fitness and pulmonary function and to retrain correct diaphragmatic breathing in young healthy females.

METHODOLOGY

Young healthy females between the age of 17-30 years and BMI <30kg/m^2, from various colleges of South Gujarat were recruited in the study. The study was conducted from April 2020 to April 2021. All participants gave the written informed consent after having been informed about the objectives, scope, procedures, risks, and benefits of the study. The institutional Ethical committee of Uka Tarsadia University granted the ethical approval for this study. Exclusion criteria were: any musculoskeletal and neurological impairment, any pathological condition, any traumatic condition in past 6 months, non-smoker, any pulmonary disease and had undergone any surgical procedure recently.

PROCEDURE

A total of 30 females were included in the study. Participation was voluntary, and withdrawal from the study is permitted at any time. Before conduction of the study the participants are selected on the basis of inclusion and exclusion criteria and are assigned to three groups: Experimental Group 1(EG1), Experimental Group 2(EG2) and Control Group (CG) conveniently. Data is collected before and after 6 weeks of training. No other physical exercise, beside from that specified for the purposes of this study, was performed during the study period. The training protocols was administered for 15 minutes twice per week for 6 weeks in all the groups.

Pulmonary Function Test (PFT):

Respiratory measurements were taken with the subjects comfortably seated and the trunk at a 90° angle. Pulmonary function was measured with a portable spirometer (RMS Helios 401) while the subjects were wearing a nose clip. The test was repeated three to five times to obtain at least two acceptable trials (variability <100 mL), with a 2-minute rest interval between the trials to ensure adequate recovery. The best trial result for each subject was used for analysis. Respiratory measurements were taken according to general guidelines. [13] A single investigator interpreted the data according to established guidelines [14] to obtain a target value for each subject and to ensure that the manoeuvre had been performed correctly. Forced vital capacity (FVC), Forced expiratory volume in one second (FEV^1), and Peak expiratory flow (PEF) were evaluated **(Figure 1)**.

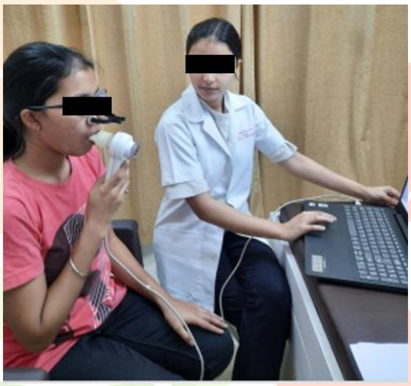

Figure 1: Illustrates subject performing PFT

American College of Sports Medicine (ACSM) Curl-up Test:

The American College of Sports Medicine (ACSM) curl-up (cadence) test **(Figure 2,3)**, is a simple, practical, valid, and reliable test [15] [16] [17], used to assess abdominal muscle fitness. The ACSM curl-up test evaluates local muscular endurance of the abdominal muscle groups, which are important for good posture and performing various daily tasks.

The ACSM curl-up test protocol is carried out with the subject lying on his or her back with knees bent at a 90° angle and feet on the floor. The arms are extended to the sides with the fingers touching a piece of masking tape. A second piece of tape is placed 12 cm beyond the first piece. For this study, the metronome was set to 40 beats per minute. At the first beep, the subject lifts his or her shoulder blades off the by flexing the spine until the fingertips reach the second piece of tape. At the next beep, the subject slowly returns the shoulder blades to the floor by flattening the lower back. The subject performs as many curl-ups as possible without stopping, up to a maximum of 75 repetitions. [16]

Figure 2: Illustrates subject performing ACSM curl-up test: starting position

Figure 3: Illustrates subject performing ACSM Curl-up Test: end position

Experimental Group 1 (EG1):

The EG1 exercises was focused on achieving and maintaining a proper diaphragmatic breathing pattern for 2–3 seconds during inspiration and 8–10 seconds during expiration. To do this, the subject inhales, expanding the lower abdominal region, the side and back of the abdomen, and the lower ribs. **(Figure 4)** The exercise sequence is as follows:

1. Crunch: The subject lies on his back with knees bent, feet on the floor, and hands resting on the chest. During inhalation, the shoulders are lifted off the ground; during exhalation, the subject returns to the starting position.
2. Crunch with rotation: The subject lies on his back with knees bent and feet on the floor. During exhalation, the trunk is lifted and rotated; during inhalation, the subject returns to the starting position.
3. Supine bridge: The subject lies on his back with knees bent and feet on the floor. During exhalation, the pelvis is lifted an inch off the floor while pressing into the soles of the feet. During inhalation, the subject returns the pelvis to the floor.
4. Prone bridge: The subject begins prone in a "table position" with knees under the hips and arms under the shoulder; on inhalation, the right leg is simultaneously lifted straight out and behind, and the left arm is lifted straight out in front.

The routine for exercise numbers 1 and 2 consisted of two series of 15 repetitions each. Exercise numbers 3 and 4 consisted of two series for 10 seconds in isometric contraction. All sessions were supervised to ensure that the exercises were properly performed.

Figure 3.4: Core Exercises: a) Crunch b) Crunch with Rotation c) Supine Bridge d) Prone Bridge

Experimental Group 2 (EG2):

The EG2 exercises are same as the exercises of EG1, however, instead of diaphragmatic breathing the subjects practiced spontaneous breathing and a rhythm (1 second for inspiration and 1 second for expiration) is maintained.

Control Group (CG):

The CG group did not perform any kind of exercise during this 6-week period.

STATISTICAL ANALYSIS

Statistical analysis was carried out using SPSS Version 22.0 software. Results were tested for normal distribution using a Shapiro-Wilk test. One-way ANOVA tests were used to measure differences PFT test variables, ACSM curl-up test scores, between groups. A dependent-measure t-test was used to determine pre- and post-test differences within the groups. Confidence interval was set at 95% and any value <0.05 was considered as significant and <0.001 as highly significant.

RESULTS

Demographic Data

Each group comprised of 10 subjects each [EG1] n = 10, mean age 22.0 ± 3.8 years, mean BMI 20.51 ± 2.18 kg/m^2, [EG2] n= 10, mean age 20.8 ± 2.82 years, mean BMI 21.52 ± 2.43 kg/m^2 and [CG], n = 10, mean age 21.2 ± 3.88 years, mean BMI 21.7 ± 2.5 kg/m^2). There was no significant difference between the group in regards of age and BMI.

Pulmonary function test and ACSM curl-up test difference between and within the groups:

There was significant improvement found between pre and post-training PFT and ACSM measurements between as well as within both EG1 and EG2 after 6 weeks of training. However, the difference was highly significant in EG1 as compared to EG2. At the same time there were no significant change found in the CG group after the training.

Table 1: Illustrates one-way ANOVA results of post PFT and ACSM curl-up test between the groups

PFT Variables	Groups	Sum of Squares	Df	Mean Square	F	Sig.
FVC POST	Between Groups	2.121	2	1.060	15.72	<.001
	Within Groups	1.820	27	.067		
	Total	3.941	29			
FEV_1 POST	Between Groups	1.077	2	.539	6.230	.006
	Within Groups	2.334	27	.086		
	Total	3.411	29			
PEF POST	Between Groups	12.358	2	6.179	8.340	.002
	Within Groups	20.005	27	.741		
	Total	32.364	29			

Table 4.2 Illustrates mean comparison of pre and post PFT and ACSM curl-up test within each group

Parameters	Groups	Pre	Post	P-value
FVC (L)	EG1	1.76 ± 0.50	2.41 ± 0.35	<0.001
	EG2	1.74 ± 0.40	2.12 ± 0.19	0.005
	CG	1.71 ± 0.24	1.76 ± 0.18	0.483
FEV1 (L)	EG1	1.68 ±0.41	2.22 ±0.38	<0.001
	EG2	1.70 ±0.39	1.98 ±0.27	0.008
	CG	1.66 ± 0.24	1.76 ±0.19	0.235
PEF (L/s)	EG1	4.74 ±0.61	6.15 ±0.50	<0.001
	EG2	4.39 ± 1.45	5.74 ±0.74	0.007
	CG	4.57 ±1.20	4.63 ±1.18	0.736
ACSM	EG1	17.7±4.59	24.6±4.24	<0.001
	EG2	19.4±6.48	25.90±8.46	0.648
	CG	15.80±6.08	16.20±5.84	<0.001

DISCUSSION

Result of the present study showed that 6 weeks training of exercises significantly improved Pulmonary Function and abdominal endurance in female participants of EG1 and EG2. However, the improvement in pulmonary function and abdominal endurance was more significant in EG1 as compared to the EG2. At the same time there was no change in the pulmonary function and abdominal endurance in CG after 6 weeks.

In present study, EG1 and EG2 showed improvement in both pulmonary function and abdominal endurance because core strength training has been shown to change the physiological parameters. [18] Most of the previous research confirmed the finding of the present study. It is apparent that training adaptations are very specific to the movement pattern, velocity of movement, contraction type and contraction speed. [19] As both the group: EG1 and EG2 has shown improvement in pulmonary function which is explained by Miller and Morehouse (1971), [20] who stated that repeated and continuous physical exercises may produce extensive change in the respiratory system, the increased stretching of the long tissue can accommodate more air. So, the amount of vital capacity may be increased after a period of training programme.

In the present study, EG1 exercises was focused on achieving and maintaining a proper diaphragmatic breathing pattern along with the core exercises. After 6 weeks of training there was significant improvement in the pulmonary function variables as compared to the EG2, who performed core exercises with normal spontaneous breathing. The findings on FVC are supported by Fluge et al.[21] and Weiner et al. [22]who also demonstrated significant increases in FVC following breathing training. Similarly, the findings of Courtney [23] and Fluge et al. [21] are the same as those of the present study, which demonstrated that breathing training could significantly increase FEV1. The increases in FVC and FEV1 could indicate a reduction in airway obstruction [24] and this could have been achieved by increasing inspiratory force, which may have resulted from the diaphragm becoming elongated and placed at a mechanical advantage and by lengthening the intercostals and accessory muscle fibres. [25] [26] Our results were in contrast of Masami Yokogawa, [10] who found that, for women, the improvement in ventilatory efficiency with deep breathing was superior during normal breathing compared to that during diaphragmatic breathing. This may be because in women, the respiratory rate was lower during normal breathing compared to that during diaphragmatic breathing, combined with an increase in tidal volume. Therefore, alveolar ventilation may have contributed to increased ventilatory efficiency in women during normal breathing.

We also found that there was significant improvement in abdominal endurance in EG1, who performed diaphragmatic breathing, as compared to EG2. The possible reason for this could be: Firstly, proper diaphragmatic breathing is directly linked to better functional movement. Secondly, using a correct diaphragmatic breathing pattern promotes co-contraction of the abdominal muscles in the so-called bracing technique, which provides trunk stiffness and stability. The combined EG exercises may offer several other advantages such as recruitment of the deep abdominals increases intra-abdominal pressure and coactivation of the entire abdominal wall, which has a fundamental role in providing adequate support for spine and trunk stiffness. [9]

The present study also found that there was no significant change in the abdominal endurance and pulmonary function in CG, who did not perform any kind of exercise during the 6 weeks. This is explained by Lewit, [27] who suggests that if healthy breathing patterns are not in place, then no other movement pattern can be. He believed that if an individual did not demonstrate proper breathing patterns, the diaphragm likely lacked the coordination, endurance, and strength to function in its role of a postural stabilizer. As in sports or activities of daily living, people rarely flex the rib cage to the pelvis, thus shortening the rectus abdominis. [9] Breathing influences muscular function and posture because the habitual use of breathing muscles during respiration affects how these muscles are used for nonbreathing movement and postural support. [28] Based on Lewit's work, breathing may well be considered a competency in which further movement development is based upon, and developing efficient breathing patterns should be prioritized. [27]

Thus, Strength and conditioning specialists should consider breathing pattern assessment and retraining for athletes because better breathing habits may positively affect core stability and ultimately improve the overall conditioning. [28]

The present study has several limitations. Firstly, electromyographic assessment of the abdominal muscles was not performed. Secondly, we did not evaluate the long-term effect of core exercises and diaphragmatic breathing and it remains unknown for how long the effect of core exercises and diaphragmatic breathing will last.

Future research is needed to compare diaphragmatic breathing with other form of core exercises in order to clarify the combination of breathing and core exercises in improving motor control in fitness and rehabilitation programs.

CONCLUSION

The present study demonstrated that the core exercises performed with diaphragmatic breathing has proven to be more effective than the core exercises performed with spontaneous breathing, in improving pulmonary function and abdominal endurance in young healthy females. Thus, they may be useful for coaches or physical therapists when selecting core exercises to improve overall abdominal fitness and pulmonary function and to retrain correct diaphragmatic breathing and whole-body movements.

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