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Effects of Three Week 3D Pilates Breathing Exercise on Spinal Curvature, Trunk Imbalance and Alignment of Healthy Adults

Background: Breathing is the essential step of Pilates exercise and can be used to activate core muscles. Although the effects of breathing exercise on pain, breathing muscles, and cervical posture have been extensively studied, little is known about the impact of Pilates breathing on spinal posture and alignment.
Purpose: To determine the effect of 3D-Pilates breathing exercise on spinal curvature and alignment of healthy adults during corrected to normal alignment.
Design: One group pre-post test design
Methods: Eighteen participants were given a 3D-pilates breathing exercise twice a week (20 minutes per session) for three weeks and warmed up for 10 minutes before each exercise session. To examine spinal curvature and alignment of each subject, this study used radiation free rasterstereography (Formetric Ⅲ, Germany). Paired t-test and Wilcoxon signed rank test were performed to determine the difference between pre and post exercise.
Results: There were statistically significant differences in height ($p<.001$), kyphosis angle ($p<.05$), trunk imbalance ($p<.05$), kyphotic apex ($p<.01$), cervical fleche ($p<.05$), pelvic tilt ($p<.01$), and lateral deviation ($p<.05$) between before and after 3D Pilates breathing exercise. However, there was no significant difference in lordosis angle.
Conclusions: The study results indicated that three week 3D-pilates breathing exercise program could be presented as an effective rehabilitation method for improving spinal curvature and alignment.

Key words: *Breathing exercise, Pilates, spine, alignment, posture*

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INTRODUCTION

The vertebrae spine functions as a pillar, connecting skeletal structure between the skull and the pelvic. In the sagittal plane, the kyphosis angle and the lordosis angle intersect in S-curve and make an overall balance [1]. However, as the modern society develops, there is an increase in the number of patients who complain musculoskeletal pain about the vertebrae spine due to abnormal life style such as poor alignment, diminished functional activities, and long-time use of information technology (IT) equipment [2]. Although spinal disease due to lifestyle is not lethal, it can cause chronic fatigue and pain, negatively affect a person's daily life, and increase social medical costs. Thus, active care of spinal disease is required [3]. According to precedent research about bad life-style and spinal musculoskeletal disease, pain is accompanied by deformity of spinal alignment [4]. Deformity of spinal alignment means abnormal alignment of spine, including scoliosis, lordosis, kyphosis, forward-head, and tilted pelvic [5].

Several approaches can be used to manage spinal deformity, including surgery, manual therapy, physical exercise, and brace. Current treatments for spinal deformity include non-operative bracing and surgery to stabilize the affected portion of the spine. Strengthening the medial trunk muscles is one of methods to improve abnormal alignment, trunk balance, and stability. It has been reported that exercise is efficient for improving the alignment [6, 7]. In addition, precedent studies have reported that after participating in a core muscle strengthening exercise program, abnormal spinal alignment is improved to normal range [8, 9, 10, 11].

Participation in Pilates exercise has increased over the last 10 years [12]. Recent studies have reported that Pilates exercises are effective in improving scoliosis, body balance, and body alignment [13]. Pilates breathing is the most basic step of Pilates exercise. It can be used to activate core muscles [14].

Pilates breathing exercise is a type of respiration that is different from normal breathing. Pilates breathing requires deep breathing while keeping the abdomen pulled in by means of active contraction of the transverse abdominis and pelvic floor muscles [15]. Although Pilates breathing is getting popular in both fitness and rehabilitation areas, scientific research on this subject is scarce.

Understanding what constitutes ideal respiratory mechanics is important because this lays the foundation for developing efficient core stabilization and improving the activation of the deep myofascial system. We have repeatedly seen dramatic improvements in posture, reduction of chronic muscle tension, and increases in strength when individuals discover how to breath and coordinate activation of their deep myofascial system [16].

Previous studies have determined effects of Pilates exercise on alignment [17, 18]. However, little is known about the effect of Pilates breathing exercise on body alignment and spinal posture. Recent studies have reported that breathing exercise is needed to improve musculoskeletal disease such as cervical pain [19], forward-head, and rounded shoulder [20]. Abnormal breathing method not only weakens breathing muscle, but also weakens shoulder and neck muscles [21]. Although studies on effects of breathing exercise on pain, breathing muscles, and cervical posture have been conducted, studies on effects of Pilates breathing on spinal posture and alignment are lacking. Thus, the purpose of this study was to determine the effect of 3D-Pilates breathing exercise on spinal curvature, trunk imbalance and alignment of healthy adults while corrected to normal alignment.

SUBJECTS AND METHODS

Subjects

Eighteen 'K' university students (3 males and 15 females) participated in this study. Those with neurologic or cardiovascular disease or previous experience with Pilates exercise were include. Study objectives, procedures, and potential risks were explained to study subjects. They were also informed that they could withdraw from this study at any time. They voluntarily agreed to participate in this study. The Ethics Committee and Institutional Review Board of Kyunganam University approved this study (KN1040460-A-2019-011). General features of these subjects are summarized in (Table 1).

Table 1. Characteristics of subjects

General characteristic	Mean±SD
Age (yr)	21.28±1.27
Height (cm)	163.33±6.25
Weight (kg)	60.58±10.52

3D Pilates Breathing Exercise Program

All participants are given a 3D-Pilates breathing exercise twice a week and warm up for 10 minutes before exercise. [22, 23, 24]. 3D-Pilates breathing exercise was performed according to the recommendations of Menezes (2000) [25]: "Keep the neck and shoulders relaxed; Allow the respiration to flow: do not hold your breath at any point; Breathe through your nose without allowing your shoulders to lift; Without stopping, breathe out through your mouth with a sigh; Breathing out through your teeth, with your lips pursed". In addition to deep breathing, the abdomen had to be kept pulled in by active contraction of the transverse abdominis and pelvic floor muscles [15]. Improving 3D breathing can have a profound effect on individuals who have not been breathing efficiently. One should bring their awareness to an area where they may not be breathing well, encourage 3D-Pilates breathing with light palpation, start with fewer breaths (one to three at a time), and then let them return to their normal strategy of breathing between cycles [16].

Breathing education for all participants was provided by the same physical therapist experienced in Pilates. The 3D-Pilates breathing exercise process was as follow. First, subjects were instructed to supine hook lying with neutral posture (pelvic imprint and head nods) corrected by physical therapist. Second, they were asked to inhale through the nose (expanding ribs superior, lateral, and posterior) for 5 seconds, palpating lateral 7–9th ribs using subjects' both hands. Third, subjects were asked to perform ribcage isometric contraction while holding breath for 3 seconds. Forth, subjects were asked to exhale through the mouth for 8–10 seconds, closing the ribcage. After 3 times breathing, subjects took a rest for 30 seconds.

Measurement Methods

Spinal Curvature and Alignment

To assess subject's spinal alignment, each subject underwent a Formetric–Ⅲ (Diers, Germany) 3D–analysis test which measured their back and spine conditions. The Formetric–Ⅲ instrument system is a reliable method for three–dimensional (3D) back shape analysis of spinal alignment using a halogen lamp without radiation exposure. The rasterstereographic device's formetric 3D measured kyphosis angle, lordosis angle, trunk imbalance, kyphotic apex, cervical fleche, pelvic tilt, and lateral deviation. Rasterstereography is a method for stereophotogrammetric surface measurement of the back. It was developed in the 1980s by Hierolzer and Drerup [26]. Based on the principle of triangulation, it provides a radiation– and contact–free method for detecting and measuring human posture [27, 28, 29]. Two cameras recorded the back shape. In rasterstereography, a projector that projects the raster containing the grid on the object under investigation replaces one of the cameras. Parallel white light lines are projected on the back surface of the subject with a slide projector. If three dimensional back shape leads to deformation of parallel light lines, it can be detected by the camera [30].

Patients were in a standing position in a darkened room. Their body was illuminated from behind with parallel light lines. A picture was taken from a certain angle from above to below. The equipment's total distance was 3 m. All subjects were instructed to adopt a standing relaxed posture with neck flexed at 10~15° to check the presentation of C7.

Anatomical terms and measurement factors used in this study are as follows. (1) Kyphotic Angle: Maximum kyphosis angle of thoracic spine; (2) Lordotic Angle: Maximum lordosis angle of Lumbar spine; (3) Pelvic Tilt: Height difference between both posterior superior iliac spine; (4) Trunk Imbalance: Right and left distance between vertical line from C7 and both posterior superior iliac spine on frontal plane; (5) Lateral Deviation: Distance of deviation from median plane to spinal vertebrae; (6) Kyphotic Apex: Distance from C7 to maximum kyphosis thoracic spine; (7) Cervical Fleche: Distance from maximum lordosis cervical spine to vertical line of maximum kyphosis thoracic spine.

Data Analysis

Data analysis was conducted using SPSS Version 18.0. The Shapiro–Wilk test was applied to establish data frequency distribution and data of height, kyphosis angle, lordosis angle, trunk imbalance, kyphotic apex, and cervical fleche presented normality whereas data of pelvic tilt and lateral deviation failed to present normality. Paired t–test was used to determine differences in height, kyphosis angle, lordosis angle, trunk imbalance, kyphotic apex, and cervical fleche between pre– and post–exercise. Wilcoxon signed–rank test was used to determine the difference in pelvic tilt and lateral deviation between pre– and post–exercise. The level of significance was set at $p<.05$.

RESULTS

Change of height, kyphosis angle, lordosis angle, trunk imbalance, kyphotic apex and cervical fleche after Pilates breathing exercise.

Pilates breathing exercise significantly increased height temporarily ($p<.001$), kyphosis and trunk imbalance were significantly decreased ($p<.05$). Besides, the kyphotic apex was significantly improved ($p<.01$), and cervical fleche was significantly decreased ($p<.05$). However, the lordosis angle did not show significant changes.

Table 2. Change of height, kyphosis angle, lordosis angle, trunk imbalance, kyphotic apex and cervical fleche after Pilates breathing exercise

	pre	post	t	*p*
Height (cm)	163.33±6.25	163.33±6.25	−5.902	.001***
Kyphosis angle (°)	41.34±9.61	37.13±5.80	2.564	.020*
Lordosis angle (°)	38.83±7.87	39.01±6.55	−.159	.876
Trunk imbalance (mm)	15.68±13.32	6.25±4.49	2.856	.011*
Kyphotic apex (mm)	−138.00±38.47	−92.44±42.21	−3.667	.002**
Cervical fleche (mm)	36.17±12.89	27.89±8.46	2.612	.018*

Means±SD
* p<.05, ** p<.01, *** p<.001

Change of height pelvic tilt and lateral deviation after Pilates breathing exercise

There were significant differences in pelvic tilt ($p<.01$) and lateral deviation ($p<.05$) between pre- and post-exercise.

Table 3. Change of height pelvic tilt and lateral deviation after Pilates breathing exercise

	Negative ranks			Positive ranks			Test statistics		
	n	Mean rank	Sum of ranks	n	Mean rank	Sum of ranks	Ties	Z	p
(Post Pelvic tilt) - (Pre pelvic tilt)	11	6.64	73	1	5	5	6	−2.801	.005
(Post Lateral deviation) - (Pre Lateral deviation)	13	10.08	131	4	5.50	22	1	−2.580	.01

Means±SD
* p<.05, ** p<.01, *** p<.001

DISCUSSION

The purpose of this study was to examine effects of 3-week 3D Pilates breathing exercise in spinal curvature, trhnk imbalance and alignment on healthy adults. There were statistically significant differences in height, kyphosis angle, trunk imbalance, kyphotic apex, cervical fleche, pelvic tilt, and lateral deviation($p<.05$) between before and after 3D Pilates breathing exercise.

Pilates breathing is able to increase respiratory volumes in healthy adults compared to normal breathing [31]. It is necessary to breathe deeply while maintaining the abdomen contracted by active contraction of the local and overall stabilizing muscles of the lumbar spine in addition to the diaphragm muscle and the pelvic floor muscles [24]. According to Barr et al. (2005) [32], the diaphragm muscle works as the roof of a cylinder of muscles that surround the spine and assists with stability. It is one of the main contributors to the maintenance of intra-abdominal pressure and prevention of displacement of the viscera mainly by contraction of the transverse abdominis muscle.

Developing awareness and control of neutral alignment is an extremely important component of developing a more efficient core stabilization strategy. Neutral posture is where joints are in a relatively low-load position. It is also considered a physiologically efficient position because it requires the least amount of effort to maintain. Neutral posture has also been shown to be one of the best positions for activating muscles of the deep myofascial system such as the transverse abdominis and pelvic floor [33]. In this study, Pilates based 3D breathing exercise while keeping normal alignment improved spinal curvature, made spine longer, and increased height by activating the core muscle such as the multifidus muscle and pelvic floor muscle, consequentially leading to alignment improvement.

In light of recent research, we can now say with confidence that Pilates breathing plays another significant role in our body-stabilization. It has been demonstrated that the diaphragm has a dual role of supporting both respiration and posture [34]. While actions of the transverse abdominis and diaphragm oppose each other (contraction of the diaphragm increases the volume or the thoracic cavity whereas contraction of the transverse abdominis decreases the volume), both muscles are constantly contributing to respiration and postural control and the development of intra-abdominal pressure.

Lee (2011) [35] has shown that the upper trapezius, latissimus dorsi, oblique muscle, and rectus abdominis muscle are activated during breath-holding section. Thus, alignment muscles might have been activated by 5 seconds of breath-holding, leading to alignment improvement.

All we can surmise is that because of their attachments on the thoracic, they are likely have a role in respiration and therefore in postural control. Muscles that are the most active during quiet respiration are generally listed as primary muscles or respiration muscles. When these muscles become inhibited or their functions are altered, posture and stabilization can be dramatically affected as accessory muscles (primarily the sternocleidomastoid, upper trapezius, levator scapula, and pectoralis) have to be overactive to aid respiration [16].

According to results of the present study, 3-week 3D-breathing exercise program improved alignment such as thoracic kyphosis, pelvic tilt, and trunk imbalance in healthy adults in their 20s. Thus, it can be said that such exercise can improve spinal curvature and alignment. However, the number of subjects was not sufficient enough to track changes in spinal curvature or alignment. In addition, the research period was short. To present an effective exercise for subjects with abnormal alignment, a follow-up study that considers posture during exercise is needed.

CONCLUSION

Results of this study demonstrate that 3D Pilates breathing exercise can affect height, kyphosis angle, trunk imbalance, kyphotic apex, cervical fleche, pelvic tilt, and lateral deviation. Thus, 3D Pilates breathing can be presented as an effective rehabilitation method for improving spinal curvature and alignment.

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