Research Paper: Efficacy of Dynamic Neuromuscular Stabilization Breathing Exercises on Chest Mobility, Trunk Muscles, and Thoracic Kyphosis: A Randomized Controlled 6-Week Trial

Nasser Mohammad Rahimi[1], Reza Mahdavinejad[1*], Seyyed Reza Attarzadeh Hosseini[2], Hossein Negahban[3,4]

1. Department of Sports Injuries and Corrective Exercises, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran.
2. Department of Exercise Physiology, Faculty of Sports Sciences, Ferdowsi University of Mashhad, Mashhad, Iran.
3. Department of Physical Therapy, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran.
4. Orthopedic Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.

Use your device to scan and read the article online

Citation: Mohammad Rahimi N, Mahdavinejad R, Attarzadeh Hosseini SR, Negahban H. Efficacy of Dynamic Neuromuscular Stabilization Breathing Exercises on Chest Mobility, Trunk Muscle, and Thoracic Kyphosis: A Randomized Controlled 6-Week Trial. Iranian Rehabilitation Journal. 2020; 18(3):329-336. http://dx.doi.org/10.32598/irj.18.3.969.1

http://dx.doi.org/10.32598/irj.18.3.969.1

Article info:
Received: 27 Sep 2019
Accepted: 13 Jan 2020
Available Online: 01 Sep 2020

Keywords:
Dynamic neuromuscular stabilization, Breathing exercise, Chest wall mobility, Thoracic kyphosis, Integrated spinal stabilizing system

ABSTRACT

Objectives: Dynamic Neuromuscular Stabilization (DNS) approach evaluates and activates the spinal stabilizers to optimize the performance of posture and respiratory system. This study investigated the effects of DNS breathing exercises on upper and lower chest wall mobility (UCM and LCM), trunk extensor endurance, and thoracic kyphosis in a group of sedentary students with poor posture.

Methods: In this randomized, controlled 6-week trial, 52 participants were randomly divided into two groups: a DNS breathing exercise group (n=26) and a control group (n=26). First, a pre-test of the UCM, LCM, trunk muscle endurance and thoracic kyphosis was done on each participant in random order. DNS breathing exercise protocol (six times a week for six weeks) was implemented and after its completion, all post-test parameters were taken. Descriptive statistical and the paired-sample t test were used to analyze the obtained data.

Results: Significant improvements were observed in the post-test compared with pre-test in DNS breathing exercise group in UCM (6.2±1.6 vs 4.4±0.9 cm, P<0.001), LCM (7.7±1.7 vs 5.5±1.0 cm, P<0.001), trunk muscle endurance (110.1±33.5 vs 88.7±34.1 s, P<0.001), and thoracic kyphosis (146.9±5.5 vs 142.7±4.0 degree, P<0.001). In contrast, the change in these parameters in the control group was not statistically significant.

Discussion: DNS breathing exercise with a focus on the integrated spinal stabilizing system and breathing techniques is an effective protocol to significantly improve UCM and LCM, trunk muscle endurance, and thoracic kyphosis. It is suggested that DNS breathing exercises be introduced to improve chest mobility and posture and provide physiological stabilization for the overall health and performance of student

*** Corresponding Author:**
Reza Mahdavinejad, PhD.
Address: *Department of Sports Injuries and Corrective Exercises, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran.*
Tel: *+98 (313) 7932573*
E-mail: *r.mahdavinejad@spr.ui.ac.ir*

Highlights

- Correcting and improving a weak respiratory pattern is imperative in any prosperous rehabilitation program.

- For breathing in continuously developmental lines, the DNS breathing exercises are practical and become a choice program.

- The surmise is that when the thoracic spine is erect, the rib cage is independently mobile, and alignment of the thorax allows respiratory muscles to regulate posture and breathing pattern.

Plain Language Summary

The thoracic spine is related to neuromuscular weakness and mechanical and neural disadvantage of the postural-respiratory muscles. Hence, straightening of the spine and caudal chest alignment is required for this function. In this study, DNS breathing exercise was used to improve chest mobility, thoracic alignment, as well as trunk endurance muscles. The results showed significant improvement in these parameters. Therefore, this approach can be used for improving posture and respiratory system.

1. Introduction

Alignment and motor function of the chest wall are important elements for both breathing and postural stabilization and function [1]. In a physiologically normal condition, the chest can move independent of the thoracic spine and the thoracic spine segments straighten without co-movement with the chest [1]. Movement or the neutral 'lower' alignment of the chest with a simultaneous straightening of the spine depends on the costovertebral joints or rib movements [1]. A change in this function and chest wall configuration and mobility has a marked kinesiological or pathokinesiological significance, contributing to neuromuscular weakness and mechanical and neural disadvantage of the respiratory muscles [2]. On the contrary, poor respiratory muscle coordination may alter breathing mechanics, reduce abdominal movements, and rib cage expansion [1]. So the people with a defect in the diaphragm or deep spinal stabilizers often raise the lower rib cage during inspiration as compensation for breathing [3].

Training of spinal straightening and having an optimal breathing pattern is crucial for physiological spinal stabilization. In subjects with postural defects, trunk stabilization requires to be regarded. Several studies have shown the relationship between the diaphragm and intercostal muscle activity with postural function [4]. Most often in subjects with defects in stabilization and movement in the thoracic spine as an individual segment, at first, the independent movement of the thorax of the thoracic spine should be provided.

The ideal spinal and rib alignment into training can be integrated and proper respiratory stereotype serves both breathing and spinal stability [4]. Although different core exercises [5], motor control exercises of the lumbar-pelvic region [6], and deep muscle training [7] on respiratory parameters and abdominal strength were efficient, the initial alignment and motor function of the thorax is essential for breathing and postural function. Also, the mechanical action of the diaphragm and respiratory advantage depends on the relationship and anatomical alignment of the rib cage [1] that has not been considered previously.

Optimal trunk stabilization forms a cornerstone for all training programs [8]. It is critical to correct postural defects, restore the mobility of costovertebral joints, and mobilize the intercostal tissue and trunk fascia in breathing disorders treatment [3]. Stabilization and breathing patterns are closely interconnected, since breathing muscles serve as stabilizers and vice versa. Therefore it is convenient to train respiratory-postural function together and in various positions [3]. Also, the impact of the deep spinal stabilization system must be preceded by exercises in developmental lines. Dynamic Neuromuscular Stabilization (DNS) approach that is an assessment and treatment approach and is based on developmental kinesiology models [8] may serve such purpose.

If the breathing pattern is abnormal, then there will be no normal pattern of movement [9]. Therefore, taking part in rehabilitation schedules that affect respiratory muscles is crucial for sedentary persons, notably those with poor posture, to deal with these postural, muscular, and respiratory alterations. The aim of DNS breathing exercise, as a prerequisite for an integrated correction program, is to improve respiration and the coordination of local and global muscle complexes. Hence, this study was conducted to evaluate the change in trunk muscle endurance, thoracic kyphosis, and chest wall mobility in response to DNS breathing exercises in sedentary students with poor posture.

2. Methods

The study design was a randomized, controlled, 6-week program. Before the start of the study, informed consent was taken from all participants who had the right to withdraw from the study at any time. After doing all initial assessments, the participants were randomly assigned to DNS breathing exercise (n=26) or control groups (n=26) via random number generation by an independent investigator.

Study participants

Potential participants were invited through posters and electronic notice boards. The interested participants were screened according to the standardized method [10]. This practical method utilizes the following classification of body posture: I. perfect, II. good, III. poor and IV. bad. The postural alignment was evaluated visually by a qualified examiner. The participant was examined in the habitual, relaxed posture that is usually adopted. In the standing positions and the sagittal left view, the assessment was the same as the observation for head to pelvic scanning (head and neck posture, shoulder, chest, spine, pelvic). The examinations of each posture quality levels have 5 postural parts and are scored from 1 to 4 [10]. Therefore, a low score points out better body segment alignment. In this way, the classification of participants was based on their postures, including perfect posture (5 points), good or almost perfect posture (6 – 10 points), poor posture (11 – 15 points), and bad posture (16 – 20 points). Finally, the students who scored 11 to 15 (poor posture) were selected as study subjects [10]. A standard survey (Tegner activity scale) was utilized to determine the activity level of the study volunteers. The survey is scored from 10 (competitive sports) to 1 (sedentary). All participants were at the sedentary level [11].

The participants would be included in the study if they were between 19 - 23 years old, had a poor posture score between 11 to 15 points, had an activity level score of 1 (the sedentary level) and lacked spinal or thoracic surgery, respiratory, cardiovascular, orthopedic or any other diseases that would affect musculoskeletal system and posture, and acute pain. All referrals were interviewed by phone, given the full description of the study and if still interested, were invited to the laboratory for an initial assessment.

Chest wall mobility

Chest wall mobility (the difference between maximum inhalation and exhalation excursion), was measured in the standing position. A 200-cm tape measure was used and rib cage circumference at three different levels was measured: 1: The anterior axillary line for Upper Chest Mobility (UCM) (the horizontal line of the spinous process of the fifth thoracic vertebrae and the third intercostal space (axillary line) at the mid-clavicular line); 2: The tip of the xiphoid (the horizontal line of the spinous process of the tenth thoracic vertebrae and tip of the xiphoid process) process for Lower Chest Mobility (LCM) [12]. To standardize all the measurements, the zero point at the tape was first put on the midline of the trunk, horizontally regulated with the markers, and then the other edge of the tape was moved [12]. The difference between maximum inspiration and maximum expiration (each position held his breath for at least 2 seconds) was determined for all three measured circumferences. The average of 3 trials for each measured circumference both in inspiration and expiration was used for statistical analysis. The high reliability of this measurement protocol has already been reported (ICC=0.81-0.91) [13].

Trunk muscle endurance

To measure extensor muscle endurance, the participants lied in a prone position with the sternum off the floor. To reduce the lumbar lordosis, a small pillow was set under the lower abdomen [14].

During the test, the participants maintain flexion of the cervical spine as long as possible and stable pelvic through gluteal muscle contraction. These cervical and pelvic alignments proved to be the most optimal posture not only for decreasing the lumbar lordosis but also for activating trunk extensors most effectively. All participants sustained the first status for as long as possible. The fulfillment time (in seconds) for which participants could control the status were compared between pre- and post-intervention [14].

Thoracic kyphosis assessment

A qualified and trained examiner assessed the thoracic kyphosis alignment. He was blind to the diagnosis and severity of poor posture and sedentary lifestyle symptoms. This assessment was conducted using photogrammetry in sagittal left and right views in a standing posture. As the left and right side views showed no noticeable difference, data from the left side were accepted for analysis. Moreover, all evaluations were performed similarly to what was explained in the poor posture evaluation [15]. The photogrammetry method includes quantitatively assessing posture utilizing a photograph [16–18] and provides the measurement of thoracic kyphosis angles. It is a reliable, non-invasive device of posture [16–18] that is approximately time- and cost-effective, and available for most clinicians. The participants were asked "you will stand if the photo is taken; attempt to be natural" to avoid changing their position during an evaluation. The participants were placed in front of a camera. The camera's tripod was located 2.7 m away from the stance situation and set at 1 m high ground level. The angle between the points of greatest concavity of cervical and lumbar spines, using the spot of greatest thoracic convexity as the point. For thoracic kyphosis, the lower value represents a more kyphotic measure. The resultant photos were analyzed in AutoCAD using the anatomical points [15] (Appendix 1).

DNS breathing exercise protocol

The participants performed six sessions per week (3 sessions of supervised exercise and 3 sessions of home-based exercise) for 6 weeks of the DNS breathing exercise program (the 20 stabilization developmental patterns). During assisted intervention in sessions of supervised exercise, the therapist guided and corrected the client both verbally, and manually to achieve and teach optimal adjustment of the pelvis, spine, ribcage, and scapulae while stabilizing the core properly in various positions [8, 19]. In the initial weeks of the intervention, all participants were individually educated in optimal breathing-stabilization DNS exercise (3 patterns). For another 5 weeks, the breathing-stabilization patterns in developmental positions according to the DNS approach were performed in such a way that each week, three to four new positions were introduced and trained while the positions exercised in previous weeks were quit. Using this protocol, within the 6 weeks of experiments, all students gradually practiced in all developmental positions as depicted on DNS educational posters (Appendix 2). During the exercise, special attention was paid to the stereotype of inhalation and exhalation. The participants were encouraged to expand proportionally the lower chest cavity and the whole abdominal wall during inhalation and to maintain adequate proportional tension of all abdominal wall sections during exhalation as described by DNS manual [8, 15, 20] (Appendix 1). The same DNS breathing exercise program was performed by the participants at home. Before every home exercise session, the participants attended the supervised practice session and were instructed on the proper method and mechanics for each exercise. To improve accuracy and compliance, the participants were also provided with an illustrated exercise booklet. The compliance was reported through a daily call by the participants. The participants agreed not to perform any other sport of physical activities during the 6 weeks' experiment period.

Supervised and home-based exercises were performed on the even (Saturday, Monday, Wednesday) and odd (Sunday, Tuesday, Thursday) days, respectively. The home-based exercises program was similar to the supervised exercise program and performed in 6 sessions per week similarly based on the protocol presented in the appendix.

Statistics analysis:

All statistical analysis was performed with the SPSS (SPSS Inc., Chicago, Illinois). Parameter outcomes were evaluated for each participant and then mean and standard deviation (Mean±SD) were computed for each one before and after the session. The Kolmogorov-Smirnov test was utilized to investigate the normality distribution. The paired-sample t test was used to compare the ratio between pre-test and post-test results. The effect size was evaluated with G Power 3.1 software [21].

3. Results

The participants of the DNS breathing exercise and control group (undergraduate male students) completed the 6-week study. The average age, weight, height, and BMI of the control, and DNS breathing exercise groups are presented in Table 1.

According to Table 2 findings, analysis of the changes in chest wall mobility (UCM and LCM), trunk muscle endurance, as well as in thoracic kyphosis of the DNS breathing exercise group before and after the intervention showed a significant increase. There is no significant difference in mean chest wall mobility (UCM and LCM), trunk muscle endurance, and thoracic kyphosis of the control group before and after 6 weeks of study.

4. Discussion

The results of this study as a non-invasive method showed that 6 weeks of DNS breathing exercises could lead to statistically significant improvement in the chest wall mobility, extensor trunk muscle endurance, and thoracic kyphosis.

This study evaluated the thoracic mobility at two levels: upper and lower. Based on the experimental results, a significant enhancement in chest expansion was observed at both levels. This finding is consistent with Bezzoli et al. (2016), Mongkol (2016), and Kim et al. (2015) study results. In the study of Bezzoli et al., in the first session of the motor control exercises, all patients were trained on how to activate the lumbar-pelvic cylinder muscles individually while having an easy diaphragmatic breathing and neutral lumbar posture in supine, sitting, and standing positions.

Table 1. The participants' demographics (Mean±SD) of age, weight, height, and body mass index

Variables	Mean±SD	
	DNS Breathing Exercise Group	Control Group
Age (y)	20.65±1.29	20.76±1.14
Weight (kg)	69.19±8.82	67.07±7.81
Height (cm)	176.07±7.28	174.53±6.27
Body mass index (kg/m²)	22.24±1.67	21.96±1.70

Iranian Rehabilitation Journal

Table 2. The changes of parameters from baseline to 6 weeks (Values are presented as Means±SD)

Parameters	Mean±SD				
	DNS Breathing Exercise Group			Control Group	
	Pre-test	Post-test	ES	Pre-test	Post-test
UCM (cm)	4.4±0.9	6.2±1.6*	0.93	4.06±1.0	4.16±0.8
LCM (cm)	5.5±1.0	7.7±1.7*	1.19	4.97±1.2	4.96±1.1
Trunk extensor endurance (s)	88.7±34.1	110.1±33.5*	0.75	85.6±24.2	82.3±23.2
Thoracic kyphosis	142.7±4.0	146.9±5.5*	0.73	142.6±4.8	140.6±5.5

Iranian Rehabilitation Journal

UCM: Upper Chest Mobility; LCM: Lower Chest Mobility;

*P<0.001; For thoracic kyphosis, the lower value represents a more kyphotic measure.

So they concluded with a significant improvement in chest mobility as a result of participation in motor control exercises [6]. Nevertheless, in the DNS breathing exercise, we utilized deep diaphragmatic breathing and neutral lumbar posture in various positions, including 20 patterns of developmental kinesiology. Therefore, this intervention can be a functional method to coordinate and improve proper breathing patterns via thoracic mobility. Besides, our results are also consistent with Mongkol's findings, who declared that Yoga exercise as a kind of exercise with force breathing would develop both muscle flexibility and chest wall expansion [22]. In this study, repetitive DNS deep breathing exercise resolved the stiffness of the rib cage and aligned thoracic kyphosis as a requirement of physiological stabilization [1]. Because the position of the thoracolumbar spine directly influences the rib cage, the patients with weakness of the diaphragm or deep spinal stabilizers usually elevate the lower rib cage throughout inspiration as a compensation pattern for breathing [3]. In the present study, it seems that breathing exercises in different patterns of DNS could provide proper trunk stabilization via independent movement of the rib cage and so developing chest mobility and activating trunk muscle stabilizers [1].

Moreover, straightened thoracic spinal curvature causes adaptive alterations in the lumbopelvic region and promotes posture. Accordingly, we considered that the intervention targeted extensor trunk muscles. Respectively, the enhancement in extensor trunk muscle endurance and improvement in thoracic kyphosis were statistically significant. Obayashi et al. (2012) reported comparable results that confirmed the effect of breathing muscle exercise leading to an increase in thoracic kyphosis [23]. Trunk extensor endurance was significantly enhanced by DNS breathing exercises. These results are consistent with the findings of the Obayashi et al. study [23]. Decreased extensor trunk muscle function is one of the effective factors of changing thoracic spine curvature [23]. It seems that DNS breathing exercises with emphasis on the Integrated Spinal Stabilizing System (ISSS) [8], precise muscle timing, and coordination to have movement efficiency and breathing technique [8], significantly improve extensor trunk muscle endurance.

Thoracic stabilization can have a notable role in obtaining and maintaining upright alignment [24]"type":"article-journal","volume":"9"},"uris":["http://www.mendeley.com/documents/?uuid=88dcaed2-f2fc-3353-9b77-43a4d718bd7d"]}],"mendeley":{"formattedCitation":"[24]. The post-intervention results were better than the pre-intervention not only in thoracic kyphosis but also in extensor trunk muscle endurance means.

Abe et al. (1996) reported that the transverse abdominal muscle is the most influential abdominal muscles concerning respiration, especially in expiration [25]. DNS breathing exercise has particularly targeted the transverse abdominal muscle [19]. Activation of the transverse abdominal as one of the key local stabilizers and respiratory muscles raises intra-abdominal pressure, which is one of the goals of DNS breathing exercise and causes lumbar spines straightening [19]. Additionally, with having a good cylindrical shape of the abdominal region and intra-abdominal pressure, the rib cage can be upwardly pressed, not anteriorly flared [19] and consequently, the extension of the thoracic spine will be optimally allowed as well [23].

DNS is a functional approach view that integrates brain stimulation with postural awareness, breathing training, and education to achieve optimal and global body function [8, 19]. Moreover, it can be regarded as a "neutral" and "optimal" alignment of the head and neck, spinal, thorax, and pelvis and strongly recommends that a healthy sensorimotor system is required to design an optimal function that sets the joints in centration [8]. The outcome of joint centration is minimal mechanical stress on relevant passive tissues and dwindles the over activation of superficial muscles [8].

DNS used in this study has had a prominent influence on the improvement of the corrective exercise strategies. Also, one of the strong points of this study is its administration in 36 sessions (18 sessions of supervised exercise and 18 sessions of home-based exercise) along with participants' education and correction of breathing patterns in daily activities. Although this topic has remained controversial, searching the other reports about DNS breathing exercise as an intervention on trunk extensor endurance, chest wall mobility, and thoracic kyphosis change has not produced enough outcomes.

Study Limitations

The number of the sample size and age range of the study participants was small. Nevertheless, the study had enough power on statistical analysis to recognize differences. So, more studies are required to assess the effects of DNS breathing exercises during a prolonged period and on different age groups.

5. Conclusion

Our study results prove that confident muscular and postural improvements can be taken by using DNS breathing exercises. It is suggested that DNS breathing exercises based on ideal ontogenetic patterns be utilized on student's subjects, especially when the improvement influence is proposing to develop with weakened muscular and postural conditions.

Ethical Considerations

Compliance with ethical guidelines

Permission was obtained from the Ethics Committee of the Isfahan University, Isfahan, Iran (IR.UI.REC.1398.006)

Funding

This work was financially supported by Isfahan University.

Authors' contributions

All authors contributed equally in preparing all parts of the research.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors wish to express their particular thankfulness to Isfahan University for financial support.

References

[1] Bradley D, Chaitow L, Gilbert C. Recognizing and treating breathing disorders e-book. 2th ed. Amsterdam: Elsevier Health Sciences; 2014. https://www.lehmanns.de/shop/medizin-pharmazie/30185574-9780702054273-recognizing-and-treating-breathing-disorders-e-book

[2] Alter A, Aboussouan LS, Mireles-Cabodevila E. Neuromuscular weakness in chronic obstructive pulmonary disease: Chest wall, diaphragm, and peripheral muscle contributions. Current Opinion in Pulmonary Medicine. 2017; 23(2):129-38. [DOI:10.1097/MCP.0000000000000360] [PMID]

[3] Page P, Frank CC, Lardner R. Assessment and treatment of muscle imbalance: The Janda approach. Champaign: Human kinetics; 2010.

[4] De Troyer A, Wilson TA. Mechanism of the increased rib cage expansion produced by the diaphragm with abdominal support. Journal of Applied Physiology. 2015; 118(8):989-95. [DOI:10.1152/japplphysiol.00016.2015] [PMID]

[5] Cavaggioni L, Ongaro L, Zannin E, Iaia FM, Alberti G. Effects of different core exercises on respiratory parameters and abdominal

strength. Journal of Physical Therapy Science. 2015; 27(10):3249-53. [DOI:10.1589/jpts.27.3249] [PMID] [PMCID]

[6] Bezzoli E, Andreotti D, Pianta L, Mascheroni M, Piccinno L, Puricelli L, et al. Motor control exercises of the lumbar-pelvic region improve respiratory function in obese men. A Pilot Study. Disability and Rehabilitation. 2018; 40(2):152-8. [DOI: 10.1080/09638288.2016.1244292] [PMID]

[7] Szczygieł E, Blaut J, Zielonka-Pycka K, Tomaszewski K, Golec J, Czechowska D, et al. The impact of deep muscle training on the quality of posture and breathing. Journal of Motor Behavior. 2018; 50(2):219-27. [DOI:10.1080/00222895.2017.1327413] [PMID]

[8] Frank C, Kobesova A, Kolar P. Dynamic neuromuscular stabilization & sports rehabilitation. International Journal of Sports Physical Therapy. 2013; 8(1):62-73. [PMID] [PMCID]

[9] Lewit K. Relation of faulty respiration to posture, with clinical implications. The Journal of the American Osteopathic Association. 1980; 79(8):525-9. [PMID]

[10] Bendíková E, Görner K, Paugshová B. Exercise programme for schoolgirl with poor posture. Journal of Education, Health and Sport. 2016; 6(13):54-64. [DOI: 10.5281/zenodo.232974]

[11] Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfunctional breathing. International Journal of Sports Physical Therapy. 2017; 12(5):774-86. [DOI:10.26603/ijspt20170774] [PMID] [PMCID]

[12] Kim CB, Yang JM, Choi JD. The effects of chest expansion resistance exercise on chest expansion and maximal respiratory pressure in elderly with inspiratory muscle weakness. Journal of Physical Therapy Science. 2015; 27(4):1121-4. [DOI:10.1589/jpts.27.1121] [PMID] [PMCID]

[13] Bockenhauer SE, Chen H, Julliard KN, Weedon J. Measuring thoracic excursion: Reliability of the cloth tape measure technique. The Journal of the American Osteopathic Association. 2007; 107(5):191-6. [PMID]

[14] Ito T, Shirado O, Suzuki H, Takahashi M, Kaneda K, Strax TE. Lumbar trunk muscle endurance testing: An inexpensive alternative to a machine for evaluation. Archives Of Physical Medicine And Rehabilitation. 1996; 77(1):75-9. [DOI:10.1016/S0003-9993(96)90224-5]

[15] Canales JZ, Fiquer JT, Campos RN, Soeiro-de-Souza MG, Moreno RA. Investigation of associations between recurrence of major depressive disorder and spinal posture alignment: A quantitative cross-sectional study. Gait & Posture. 2017; 52:258-64. [DOI:10.1016/j.gaitpost.2016.12.011] [PMID]

[16] Ferreira EA, Duarte M, Maldonado EP, Bersanetti AA, Marques AP. Quantitative assessment of postural alignment in young adults based on photographs of anterior, posterior, and lateral views. Journal of Manipulative and Physiological Therapeutics. 2011; 34(6):371-80. [DOI:10.1016/j.jmpt.2011.05.018] [PMID]

[17] Luís Pimentel Do Rosário J. Photographic analysis of human posture: A literature review. Journal of Bodywork and Movement Therapies. 2014; 18(1):56-61. [DOI:10.1016/j.jbmt.2013.05.008] [PMID]

[18] Ruivo RM, Pezarat-Correia P, Carita AI. Intrarater and interrater reliability of photographic measurement of upper-body standing posture of adolescents. Journal of Manipulative and Physiological Therapeutics. 2015; 38(1):74-80. [DOI:10.1016/j.jmpt.2014.10.009] [PMID]

[19] Lim YL, Lepsikova M, Singh DKA. Effects of dynamic neuromuscular stabilization on lumbar flexion kinematics and posture among adults with chronic non-specific low back pain: A study protocol. In: Yacob N, Mohd Noor N, Mohd Yunus N, Lob Yussof R, Zakaria S, editors. Regional Conference on Science, Technology and Social Sciences, 2016; Singapore: Springer; 2018. [DOI:10.1007/978-981-13-0074-5_69] [PMID] [PMCID]

[20] Davidek P, Andel R, Kobesova A. Influence of Dynamic Neuromuscular Stabilization approach on maximum kayak paddling force. Journal of Human Kinetics. 2018; 61(1):15-27. [DOI:10.1515/hukin-2017-0127] [PMID] [PMCID]

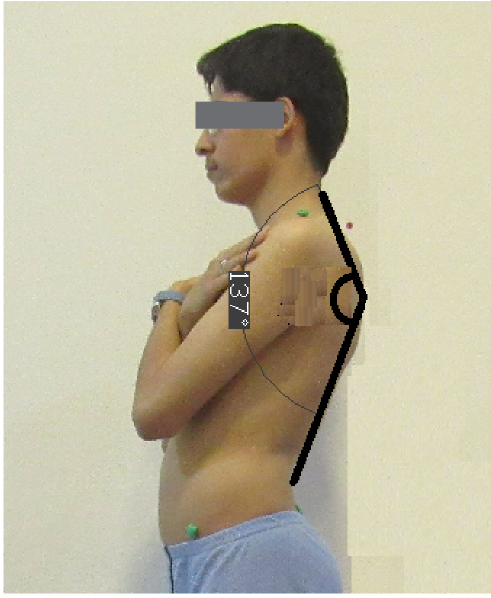
[21] Husted JA, Cook RJ, Farewell VT, Gladman DD. Methods for assessing responsiveness: A critical review and recommendations. Journal of Clinical Epidemiology. 2000; 53(5):459-68. [DOI:10.1016/S0895-4356(99)00206-1] [PMID]

[22] Mongkol S. The effects of yoga training on chest wall expansion and respiratory muscle strength in female subjects.Journal of Associated Medical Sciences. 2016; 49(3):363-9. [DOI: 10.14456/jams.2016.32]

[23] Obayashi H, Urabe Y, Yamanaka Y, Okuma R. Effects of respiratory-muscle exercise on spinal curvature. Journal of Sport Rehabilitation. 2012; 21(1):63-8. [DOI:10.1123/jsr.21.1.63] [PMID]

[24] Patroncini M. Impaired trunk muscle function in subacute neck pain: Etiologic in the subsequent development of low back pain? Manuelle Therapie. 2005; 9(4):187-8. [DOI:10.1055/s-2005-858780]

[25] Abe T, Kusuhara N, Yoshimura N, Tomita T, Easton PA. Differential respiratory activity of four abdominal muscles in humans. Canadian Journal of Applied Physiology. 1996; 80(4):1379-89. [DOI:10.1152/jappl.1996.80.4.1379] [PMID]



Appendix 1. Thoracic kyphosis angle

Iranian Rehabilitation Journal

Appendix 2. DNS breathing exercise protocol

Week and Session	Exercise Description	Set
Week 1 Sessions 1-6	Supine breathing exercise Prone breathing exercise breathing exercise 90/90	Set 1: ● 10 repetitions ● 1 second inhale: 2 seconds exhale ● 60-90 seconds rest period Set 2: ● 15 repetitions ● 2 seconds inhale: 4 seconds exhale ● 60-90 seconds rest period Set 3: ● 20 repetitions ● 3 seconds inhale: 6 seconds exhale ● 120-150 seconds rest period
Week 2 Sessions 7-12	Prone position: elbow support (3 months old position) Supine position 90/90: arm outside the body (3 months old position). Supine position 90/90: hand on the abdomen (4 months old position). Creeping position (one hip and knee in flexion): elbow support, ASIS, and medial epicondyle of the opposite knee (4.5 months old position).	
Week 3 Sessions 13-18	Rolling pattern (ipsilateral) position (5 months old position) Supine position 90/90: hand on the knee (5 months old position). Prone position: hand and knee support (elbow is an extension) (6 months old position). Supine position (hip and knee in 45-degree flexion): hand on the foot (6 months old position).	
Week 4 Sessions 19-24	Quadruped position (the angle between trunk and hip is 120 degrees) (7 months old position). Quadruped position (the angle between trunk and hip is 90 degrees) (7 months old position). Oblique sit position (side plank) with arm and lateral knee support (7 months old position). an oblique-sitting position with hand support (elbow is extended)(8 months old position)	
Week 5 Session 25-30	Crawling position (9 months old position). Sitting position (Keep the spine upright and elongated) (10 months old position). Side-lying (side plank) with hand, lateral knee, and opposite foot support (10 months old position). Raising position (Keep the spine forward and elongated and one leg kneeling) (11 months old position).	
Week 6 Sessions 31-36	High kneeling position (Keep the spine upright and elongated and one leg kneeling) (11 months old position). Bear position (12 months old position). Squat position (12 months old position). Standing position (initial standing position) (13 months old position).	

Iranian Rehabilitation Journal