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The effect of a rehabilitation program using dynamic neuromuscular stabilization exercises on lower back pain among artistic gymnasts.

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Abstract:

This study aims to determine the effect of a rehabilitation program using dynamic neuromuscular stabilization (DNS) exercises on lower back pain for female gymnasts. Method: The experimental method was used for the sample under study and pre- and post-measurements were conducted on it. The study was conducted on a sample of 10 female artistic gymnasts 14-15 years old at Alex-Olympic Club. The sample was chosen intentionally and placed in an equal group according to the basic variables and physical tests. The rehabilitation program was implemented 4 sessions per week for 10 weeks, and data was collected before and after the rehabilitation program. Results: The rehabilitation program helped increase internal abdominal pressure (IAP) and activate the integrated spinal stabilizing system (ISSS), which reducing lower back pain for female gymnasts. This was demonstrated by the results of the numerical pain assessment scale, the modified oswestry disability questionnaire, fear avoidance beliefs questionnaire, breath holding time during inspiration and Expiration, respiratory rate, and back muscle strength ($P < 0.05$). Conclusion: It is suggested that DNS is necessary to reduce lower back pain in female gymnasts and improve back muscle strength

Keywords: *(dynamic neuromuscular stabilization, Low back pain, artistic gymnasts)*

Introduction:

Sports injuries are considered one of the most important problems facing athletes in artistic gymnastics because of the great development witnessed in gymnastics skills on all apparatuses from a technical aspect, which have become more complex and require great physical characteristics, flexibility, agility, and strength of the upper and lower limbs of the body.

Artistic gymnastics skills also require intense weight bearing in the upper part, which places extraordinary pressure on the joints of the upper limbs of the body and exposes them to injury. In addition, the body control required during flight skills requires precise landing techniques to avoid injury to the spine and lower extremities (Campbell et al., 2019).

The results of studies also showed that pain in the lower back (35.8% of all gymnasts), knee (19.1% of all gymnasts), ankle (16.2% of all gymnasts), wrist (9.8% of all gymnasts), and shoulder pain. (19.1% of all gymnasts). In general, 69.5% of artistic gymnasts suffer from sports injuries (Caine et al., 2003)

There are many reasons for lower back injuries in gymnasts. These reasons include high training volume and intensity, as well as performing skills that involve rotation, flight, hyperextension, incorrect technical performance and landings, and force imbalance. The most common back injuries suffered by artistic gymnasts are spondylolysis, spondylolisthesis, muscle strain, and herniated discs (Kruse & Lemmen, 2009; Sands et al., 2016).

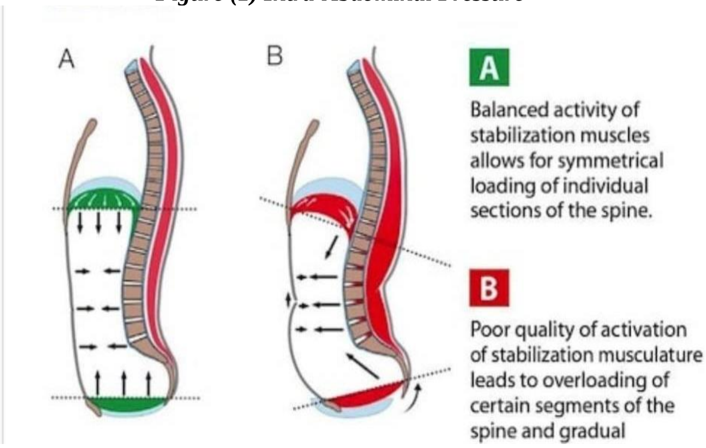
Dynamic Neuromuscular Stabilization (DNS) is a neuromuscular and functional approach from the Prague Institute of Rehab based on developmental kinesiology models that utilize infant movement developmental process to assess and treat motor disorders. DNS focuses on the relationship with the nervous system and the motor programs of the body that allow for postural control, movement, and gait. Movement patterns or motor programs in early childhood can be predicted in advance, for example, the infant does not need to be taught when and how to raise his head up, hold a toy, turn over, or crawl, and this leads to the maturation of the central nervous system automatically, which enables the infant in controlling body posture and moving purposefully through muscle activity.

The foundation of these principals finds itself in the ability to generally intra-abdominal pressure IAP and activate the integrated spinal stabilizing system ISSS (Davidek et al., 2018; Frank et al., 2013; Kolar & Kobesova, 2010; Milic, 2020; Son et al., 2017).

Intra-abdominal pressure is a pressure generated by taking an IAB (intra-abdominal breath) or simply put a belly breath. This creates an outward pressure that helps stabilize the spine but also creates a stable foundation from which limbs are attached. The diaphragm, pelvic floor and transversus abdominis regulate intra-abdominal pressure

and provide anterior lumbopelvic postural stability.The inability to create IAB results in a disunion between the rib cage and the pelvis that can lead to low back pain, core weakness and an even longer list of extremity dysfunctions (El-Rich et al., 2004; Shirazi-Adl et al., 2002) (Fig.1)
The integrated spinal stabilizing system (ISSS) as described by (Kolar,2006) is comprised of balanced co-activation between the deep cervical flexors and spinal extensors in the cervical and upper thoracic region, as well as the diaphragm, pelvic floor, all sections of the abdominals and spinal extensors in the lower thoracic and lumbar region.
These intrinsic spinal stabilizing muscles provide spinal stiffness in coordination with IAP, which serves to provide dynamic stability of the spine (Milic, 2020; Gandevia et al., 2002).

Figure (1) Intra-Abdominal Pressure



Through the researchers' work in the field of sports injuries and artistic gymnastics, the researchers noticed an increase in the incidence of lower back pain among artistic gymnasts, which prompted the researchers to conduct a rehabilitation program using dynamic neuromuscular stability exercises and its effect on lower back pain and balance among artistic gymnasts.

Aim of the study:

The study aims to reduce lower back pain in artistic gymnasts through:

1. Design a rehabilitation program using dynamic neuromuscular stability exercises and their effect on lower back pain.
2. Determine the impact of the rehabilitation program on:
   - Back muscle strength among female artistic gymnasts.
   - Respiratory indicators in artistic gymnasts (inspiratory breath hold time, expiratory breath hold time and the inspiratory rate).

Research hypotheses:

1. There are statistically significant differences between the pre- and post-measurements of lower back pain indicators among artistic gymnasts in favor of the post-measurement.
2. There are statistically significant differences between the pre- and post-measurement of breathing indicators (inspiratory breath hold time, expiratory breath hold time and the inspiratory rate) among artistic gymnasts in favor of the post-measurement.
3. There are statistically significant differences between the pre- and post-measurements of back muscle strength among artistic gymnasts in favor of the post-measurement.

Study procedures:

The method used:

The researcher used the experimental method for the sample under study and conducted pre- and post-measurements on it.

The study sample:

The study was conducted on a sample of 10 female artistic gymnasts aged 14-15 years at Olympic Club. The sample was purposively selected and placed in an equal group according to the basic variables and physical tests. Medical examinations were conducted to ensure the health safety of the female players in the sample under study.

Sample selection conditions:

- The athlete must be registered with the Egyptian Gymnastics Federation.
- The player must be suffering from lower back pain (first-degree spondylolisthesis at the LV5-SV1). This is associated with LV5-SV1posterior disc protrusion compromising the related nerve roots.
- The Practice period of the female player must not be less than 6-8 years.
- The approval of the player's parents to participate in the application of some study procedures to her.

Research measurements:

1. **Numeric Pain Rating Scale (NPRS):** It is a numerical scale from 0 (no pain) to 10 (severe pain) to evaluate

lower back pain. The patient chooses the number depending on the severity of the pain. As the intensity of the pain increased, they chose the higher number. Scores range from 0-10, with lower scores meaning less pain. No pain 0, mild pain 1-3, moderate pain-4-6, severe pain 7-10. Test-retest reliability (r = 0.95-0.96) and validity (r =.86–.95) (Hawker et al., 2011).

2. **Modified Oswestry Disability Questionnaire MODQ:** The questionnaire contains 10 questions related to degrees of severity of lower back pain while performing daily physical activity (personal care, lifting weights, walking, sitting, standing, sleeping, social activities, travel, and work), and each question has a score from 0 to 5 (from minimum to maximum) depending on the severity of the pain. The total score is summed, divided by the total number of question scores (50), and multiplied by 100 to determine the percentage of disability. Scores range from 0-100%, with lower scores meaning less pain. Mild pain 0 - 20 %, moderate pain 20-40 %, severe pain 41 - 60 %, crippled 61 - 80 %, bed-bound 81-100 % (Baradaran et al., 2016; Maughan & Lewis, 2010). Test-retest reliability of the MODQ was calculated in our study as well (r = .92).
3. **The Fear-Avoidance Beliefs Questionnaire – physical activity (FABQ PA):** It is a questionnaire consisting of four questions (2-5) through which the participant's beliefs related to fear avoidance of lower back pain during daily physical activity are assessed. Each question has a score from zero (strongly disagree) to six (strongly agree). A higher score indicates higher levels of fear-avoidance beliefs for lower back pain during physical activity and work. The total score is calculated by summing the scores for all 16 questions (Hajebrahimi et al., 2012). Test-retest reliability of the (FABQ PA) was calculated in our study as well (r = .90)
4. **Breathe-Hold- Time:** It is the maximum time (in seconds) that participants can hold their breath after the maximum inhalation (Inspiratory Breath-Hold Time) and after the maximum exhalation (Expiratory Breath-Hold Time). The participant sits on a chair and breathes normally for one minute, after which he performs a maximum inhalation and then holds the breath using a nose clip, followed by a maximum exhalation, and then holding the breath. The examiner counts the start and end times of the breath hold when any movement in the abdomen and chest is observed. This test is repeated 3 times - with a 5-minute break between trials (Iliukhina & Zabolotskikh, 2000). Test-retest reliability of Inspiratory Breath-Hold Time and Expiratory Breath-Hold Time was 0.92 and 0.93 in our study, respectively.
5. **Respiratory Rate:** In this study, respiratory rate was calculated as the number of breaths taken per minute while sitting in a chair with test-retest reliability 0.92. The measurement was done by counting the times the chest rises in one minute (Hoffman et al., 2020).
6. **Back Lift Strength Test:** To perform a back and leg strength measurement, a gymnast holds the handle with both hands while standing on the back muscles dynamometer, then extends the straight back to exert force to view the measurement (John & Dagenais, 2012).

Table (1)
Statistical characterization of the basic variables of the research sample (n= 6)

Basic variables	*Mean*	*SD*	*Median*	*Skewness*	*Kurtosis*
Age	***15.98***	***0.15***	***15.95***	***0.42***	***0.42***
Height	***156.33***	***3.50***	***156.50***	***- 0.12***	***- 0.12***
Weight	***53.83***	***2.98***	***53.25***	***1.07***	***1.07***
Practice period	***13.67***	***0.52***	***14.00***	***- 0.97***	***- 0.97***

Table 1 illustrates that the data are moderate, not dispersed, and characterized by a normal distribution for the sample, as the values of the skewness coefficient were limited to (- 0.97, 1.07), which confirms the moderateness of the data for the research sample.

Table (2)
Statistical characterization of research measurements (n= 6)

Research measurements	Mean	SD	Median	Skewness	Kurtosis
Numeric Pain Rating Scale (0-10)	8.00	1.10	8.00	-1.37	-1.37
Modified Oswestry Disability Questionnaire (0-100)	٥٥.00	2.76	67.00	0.00	0.00
The Fear-Avoidance Beliefs Questionnaire – physical activity (0-24)	21.00	1.55	21.00	0.00	0.00
Inspiratory Breath-Hold Time/ sec	27.68	1.05	27.70	0.17	0.17
Expiratory Breath-Hold Time/ Sec	25.01	1.06	24.88	- 0.09	- 0.09
Respiratory Rate (Number)	19.33	1.03	19.00	0.67	0.67
Back Lift Strength Test/ Kg	33.17	1.17	33.00	0.67	0.67

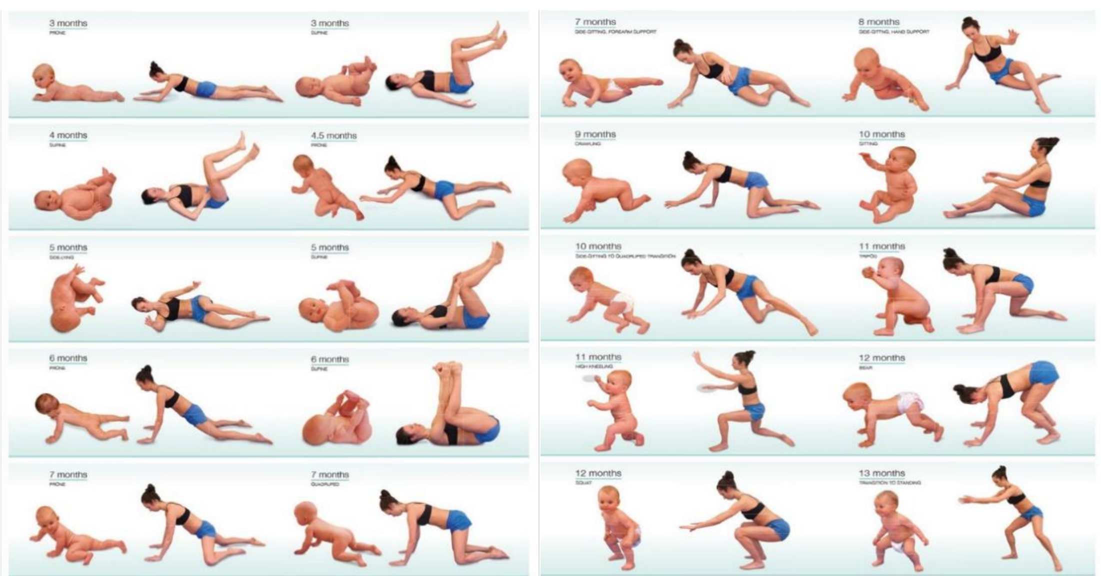
Table 2 shows that the data for the variables under research are moderate, not dispersed, and characterized by a normal distribution for the sample, as the values of the skewness coefficient were limited to (-1.37, 0.67), which confirms the moderateness of the data for the research sample.

Rehabilitation program protocol using DNS exercises:

- The training program period for research samples is 10 weeks.

The program included dynamic neuromuscular stabilization exercises aimed at reducing lower back pain for gymnasts in artistic gymnastics. The exercises included diaphragmatic breathing and infant development positions from 3 months to 13 months (prone position 3,4,5,6 months, supine position 3,4 months, side lying position 5 months, quadruped position 7 months, side sitting (forearm support) position 7 months, side sitting (hand support) position 8 months, Crawling (Quadruped) position 9 months, sitting position 10 months, side sitting to quadruped position10 months exercises, tripod position 11 months, kneeling 11 months, squat 12 months, and standing positions 13 months) (Frank et al., 2013) (Fig.2, 3).

Figure (2) Infant development positions from 3 months to 13 months



The program included dynamic neuromuscular stability exercises, 4 sessions per week, taking into account:

- The intensity of the training load ranges between 60-70% of each player's maximum ability (individual training).
- The repetitions for performing the exercises range between 25-30 reps and sets of 3-4.
- The session time ranges between (70-90) minutes, and the rest period between reps is 20-30 seconds and between sets is (2-3) minutes.

Figure (3) Dynamic neuromuscular stabilization exercises models

- Graduation in the intensity of the training load based on developmental positions that determine the automatic activation stereotype of stabilization and breathing of natural postural-locomotion patterns by developmental kinesiology and through the increase in the number of exercises, repetitions, and rest between exercises (Frank et al., 2013; Lim & Lepsikova, 2018).
- While performing the exercises, should focus on the stereotype of inhalation and exhalation, expand the lower chest cavity and the entire abdominal wall during inhalation and maintain appropriate equivalent tension for all sections of the abdominal wall during exhalation as described in the DNS manual (Canales et al., 2017; Davidek & Andel, 2018; Frank et al., 2013; Mahdia et al., 2020; Mohammad Rahimi et al., 2020).

Statistical Analysis:

- All data were analyzed using SPSS Version 25 at a confidence level of (0.95) corresponding to a significance level (probability of error) of 0.05, which is as follows:

- Mean.
- Standard deviation.
- Median
- Skewness coefficient.
- Flatness coefficient.
- Paired Samples T test

- Percentage change.

Results:

Table (3)

The significance of the differences between the pre- and post-measurements in the questionnaire variables for low back pain (n=6)

variables	*Pre - measurements*		*Post- measurements*		*Difference*	*T value*	*Change percentage %*
	Mean	*±SD*	*Mean*	*±SD*			
NPRS (0-10)	***8.00***	***1.10***	***1.50***	***0.55***	***6.50***	***19.03***	***81.25***
MODQ (0-100)	***55.00***	***2.76***	***18.67***	***2.42***	***36.33***	***78.64***	***66.05***
FABQ – physical activity (0-24)	***21.00***	***1.55***	***4.50***	***1.05***	***16.50***	***19.49***	***78.57***

Note. NPRS = Numeric Pain-Rating Scale, MODQ =Modified Oswestry Disability Questionnaire, FABQ = Fear-Avoidance Beliefs Questionnaire. Significance level of 0.05 in T- table = 2.571

Table 3 shows that there are statistically significant differences between the pre- and post-measurements in the variables (Numeric Pain-Rating Scale, Modified Oswestry Disability Questionnaire, Fear-Avoidance Beliefs Questionnaire), where the calculated T-value ranged between (19.03, 78.64), which are greater than T-table value at the level of (0.05), and the percentages of change are limited to (72.14, 81.25%) (Fig.4).

Figure (4) The mean of the pre- and post-measurements of the questionnaire variables

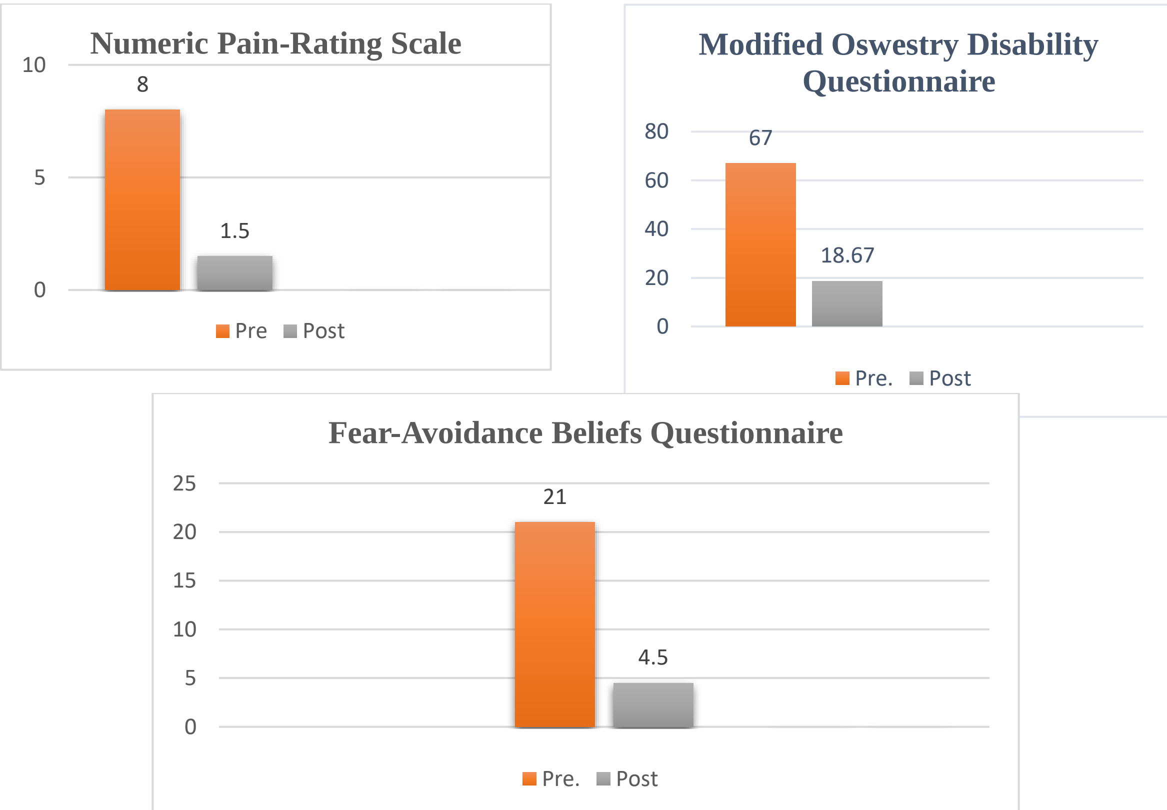


Table (4)

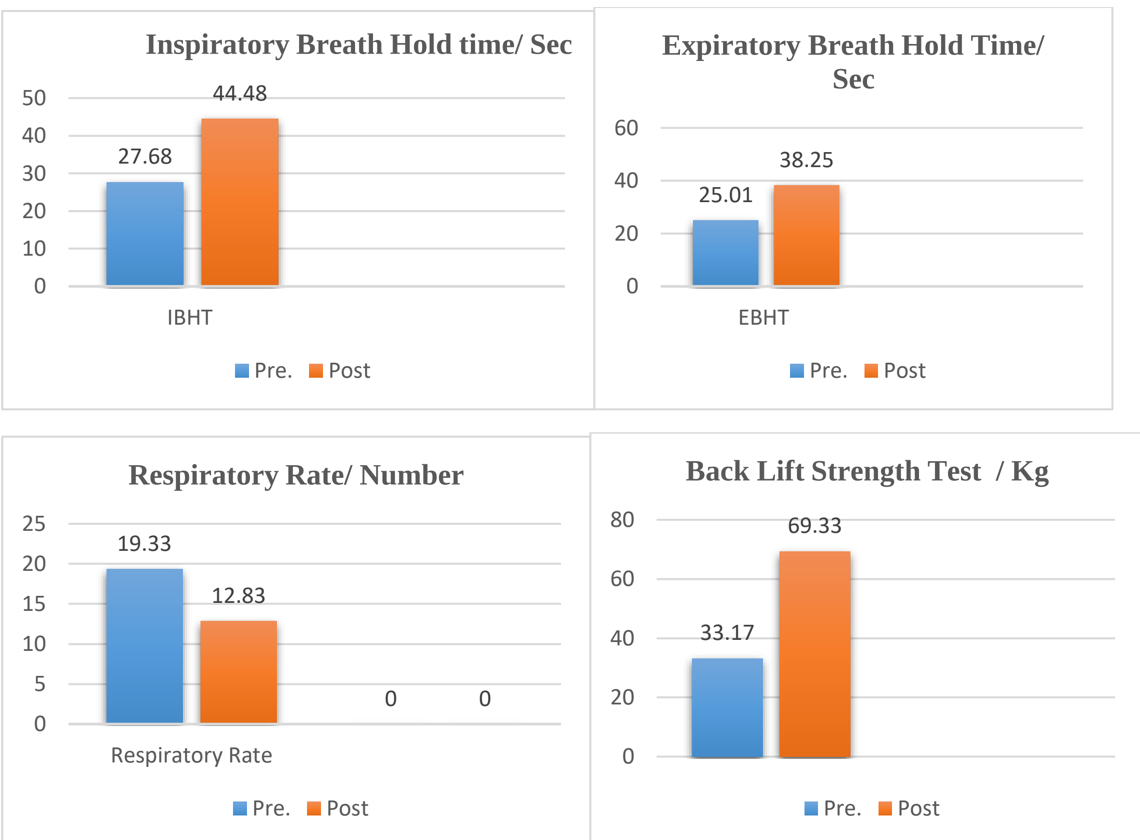
The significance of the differences between the pre- and post-measurements in the variables of breathing and back muscle strength (n=6)

variables	*Pre - measurements*		*Post-measurements*		*Difference*	*T value*	*Change percentage %*
	Mean	*±SD*	*Mean*	*±SD*			
IBHT / sec	***27.68***	***1.05***	***44.48***	***2.47***	***16.81***	***18.08***	***60.73***
EBHT / sec	***25.01***	***1.06***	***38.25***	***1.66***	***13.24***	***40.36***	***52.94***
RR (Number)	***19.33***	***1.03***	***12.83***	***0.75***	***6.50***	***29.07***	***33.62***
Back Lift Strength Test/ Kg	***33.17***	***1.17***	***69.33***	***2.27***	***36.17***	***31.19***	***109.05***

Note. IBHT = Inspiratory Breath Hold time, EBHT= Expiratory Breath Hold Time, RR= Respiratory Rate.
Significance level of 0.05 in T- table = 2.571

Table 1 illustrates that there are statistically significant differences between the pre- and post-measurements in all variables of breathing and back muscle strength, where the calculated (t) value ranged between (18.08, 40.36), which are values greater than T-table value at the level of (0.05), and the percentages of change are limited to (33.62 and 109.05%) (Fig.5).

Figure (5) The mean of the pre- and post-measurements in the variables of breathing and back muscle strength



Discussion:

The results of the post-measurements showed the positive effect of the rehabilitation program on lower back pain among female gymnasts 14-15 years old, as the significance of the differences between the pre- and post-measurements in the research variables was in favor of the post-measurements for the research sample after applying the rehabilitative program using dynamic neuromuscular stabilization exercises.

Table (3) of the differences between the pre- and post-measurements and the change percentage in pain intensity for low back pain for the research sample illustrates that there are statistically significant differences in favor of the post-measurement for each of the Numerical Pain Rating Scale, the Modified Oswestry Disability Questionnaire, and the Fear-Avoidance Beliefs Questionnaire, where the value of the calculated t was (19.3, 78.46, 19.49), which is greater than the t-table value (2.571) at the level of 0.05, and the change percentage was (81.25, 66.05, 78.57)%, respectively.

The mean value of Numeric Pain-Rating Scale decreased from 8 (severe pain) to 1.50 (mild pain) after implementing the rehabilitation program, the mean value of the results of the modified Oswestry Disability Questionnaire decreased from 55% (severe pain) to 18.67% (mild pain), and the average value of the Fear Avoidance Beliefs Questionnaire decreased from 21 (severe pain) to 4.40 (mild pain) after applying the rehabilitation program using dynamic neuromuscular stability exercises.

The researchers point out that this positive change in the severity of lower back pain for the research sample is due to the effectiveness of the rehabilitation program using dynamic neuromuscular stabilization exercises applied in the research. These results are consistent with the results of (Anderson & Bliven, 2017; Frank et al., 2013; Lim et al., 2018; Ross, 2017; Vajihe et al., 2022), which confirm the effective influence of dynamic neuromuscular stabilization exercises on lower back pain and the numerical pain rating scale, the modified oswestry Disability questionnaire, and the fear-avoidance beliefs questionnaire.

Table (4) of the differences between the pre- and post-measurements and the change percentage in respiratory indicators and back muscle strength for the research sample shows that there are statistically significant differences in favor of the post-measurement for inspiratory breath hold time, expiratory breath hold time, the inspiratory rate and the back muscle strength test using Dynamometer, where the calculated t value was (18.8, 40.36, 29.07, 31.19), respectively, which is greater than the t-table value (2.571) at the level of 0.05, and the change percentage was (60.73, 52.94, 33.62, 109.05)%, respectively.

The mean value of inspiratory breath hold time and expiratory breath hold time increased from (27.68, 25.05) seconds to (44.48, 38.25) seconds, respectively, and the mean value of the respiratory rate per minute decreased from 19.33 times to 12.83 times. The mean value of the back muscle strength test using Dynamometer also increased from 33.17 kg to 69.33 kg. These results are consistent with the results of (El-Rich et al., 2004; Frank et al., 2013; Kobesova & Kolar, 2014; Milic, 2020; Inani & Selkar, 2013; Son et al., 2017; Vajihe et al., 2022), which confirms the effective influence of dynamic neuromuscular stabilization exercises on improving intra-abdominal pressure (IAP), which is the pressure resulting from taking intra-abdominal breath (IAB). This creates external pressure that helps stabilize the spine and improves the integrated spinal stabilization system (ISSS), which consists of balanced co-activation between the deep cervical flexors and spinal extensors in the cervical and upper thoracic region, as well as the diaphragm, pelvic floor, all sections of the abdominals and spinal extensors in the lower thoracic and lumbar region. These intrinsic spinal stabilizing muscles provide spinal stiffness in coordination with IAP, which serves to provide dynamic stability of the spine.

Conclusion:

The results of the present study confirmed that the rehabilitation program using DNS exercises led to:

1. Reducing lower back pain and improving the Numerical Pain Rating Scale, the Modified Oswestry Disability Questionnaire, and the Fear Avoidance Beliefs Questionnaire.
2. Improving breathing indicators (inspiratory breath hold time, expiratory breath hold time and the inspiratory rate) for artistic gymnasts, which confirms the effective influence of the DNS system on improving intra-abdominal pressure (IAP), which creates external pressure that helps stabilize the spine and improves the integrated spinal stabilization system (ISSS).
3. Improving the strength of the back muscles of artistic gymnasts.

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