European Journal for Sport Sciences Technology (EJSST)
DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Efficacy of an 8-Week Structured Exercise Program on Pulmonary Function and Functional Capacity in Patients with Moderate COPD: A Randomized Controlled Trial

DOI: https://doi.org/10.58305/ejsst.v16i1.780

Laila Fathi Zaid AlKilani[1*]

[1] Department of Physical Sport Sciences, College of Sport Sciences & Physical Activity, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia.

[*]Correspondence Author, LfAlkilani@pnu.edu.sa

ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) imposes a significant burden on functional capacity and quality of life. While pulmonary rehabilitation is a cornerstone of management, the efficacy of standardized, supervised exercise programs for moderate-stage COPD warrants further robust investigation.
Objective: This randomized controlled trial evaluated the efficacy of an 8-week supervised exercise program on pulmonary function and respiratory efficiency in patients with moderate-stage COPD.
Methods: Twenty-six patients (age 40-75 years; smoking history ≥10 pack-years) with moderate (GOLD Stage II) COPD were randomized to an intervention group (n=13) that underwent a bi-weekly, 60-minute regimen of respiratory muscle training and aerobic conditioning, or a control group (n=13) that received standard medical care alone. Primary outcomes were Forced Expiratory Volume in 1 second (FEV_1), Forced Vital Capacity (FVC), the FEV_1/FVC ratio, and respiratory rate.
Results: Post-intervention analysis revealed statistically significant between-group improvements. The intervention group demonstrated a 26.32% reduction in respiratory rate ($p<0.025$), a 12.02% increase in FEV_1 ($p<0.025$), and a 36.24% increase in FVC ($p<0.025$). The FEV_1/FVC ratio did not change significantly.
Conclusion: In presented work, the structured exercise intervention constitutes a potent, non-pharmacological strategy for improving pulmonary function in moderate COPD. These findings underscore the imperative to integrate tailored physical rehabilitation into standard clinical management protocols to optimize functional outcomes.

Keywords: Chronic Obstructive Pulmonary Disease, Pulmonary Rehabilitation, Exercise Training, Forced Vital Capacity, Respiratory Rate, Randomized Controlled Trial

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) represents a leading cause of global morbidity and mortality, characterized by persistent respiratory symptoms and airflow

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

limitation due to airway and/or alveolar abnormalities (Agustí, A., Hogg, J. C. (2019) The disease trajectory is frequently marked by a progressive decline in functional capacity, exertional dyspnea, and diminished quality of life, posing substantial challenges to both patients and healthcare systems (Spruit, M. A., et al., 2013).

Pulmonary rehabilitation is a cornerstone of non-pharmacological management, within which supervised exercise training is a critical component with demonstrated efficacy for improving exercise tolerance and reducing symptom burden (McCarthy, et al., (2015), Casaburi, R. (2017).) The physiological rationale for exercise encompasses multifactorial adaptations, including enhanced cardiovascular fitness, improved peripheral muscle metabolism, and increased efficiency of the respiratory muscles, which collectively counter the systemic deconditioning and dynamic hyperinflation characteristic of COPD (Bolton, C. E., Bevan-Smith, 2013)

While the general benefits of exercise are well-established, a critical evidence gap persists regarding the **efficacy of standardized, dual-component programs that integrate whole-body aerobic conditioning with targeted respiratory muscle training (RMT) for patients with moderate (GOLD Stage II) COPD** (Gosselink, R., De Vos, 2011). Many existing studies and clinical protocols prioritize generic aerobic activity, lacking the specific stimulus required to directly address respiratory muscle weakness-a key contributor to dyspnea and functional limitation [O'Donnell, D. E., Milne, K. M., 2020]. Consequently, the impact of such combined regimens on objective pulmonary function parameters, beyond broad functional capacity measures, remains insufficiently explored.

This gap is significant from a physiological perspective. Parameters such as Forced Vital Capacity (FVC) and respiratory rate are highly sensitive to changes in respiratory muscle strength and the reduction of hyperinflation [Beaumont, M., Forget, P., Couturaud, 2018). A substantial improvement in FVC suggests enhanced ability to fully inflate and deflate the lungs, while a reduction in respiratory rate indicates improved ventilatory efficiency and decreased work of breathing (Lacasse, Y., Cates, C. J., , 2015) In contrast, the FEV_1/FVC ratio is a marker of fixed airflow obstruction and may be less responsive to exercise intervention.

Therefore, in our presented study a randomized controlled trial was designed to investigate the specific effects of an 8-week, supervised, combined aerobic and RMT program on key spirometric indices and respiratory efficiency in moderate COPD. We hypothesized that, compared to a usual care control group, the intervention group would demonstrate **significant improvements in FVC and respiratory rate, a more modest improvement in FEV_1, and no significant change in the FEV_1/FVC ratio.**

METHODS

STUDY DESIGN AND PARTICIPANTS

A randomized controlled trial design was employed. The study population comprised 33 patients with a confirmed diagnosis of moderate (Stage II) COPD according to GOLD criteria [global COPD, 2023], recruited from the pulmonology clinics of Al-Istiklal Hospital and Ibn Al-Haytham Hospital, Jordan. Participants were eligible if they were aged

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

40-75 years, had a smoking history of ≥10 pack-years, and exhibited a post-bronchodilator FEV_1/FVC ratio <0.70 with an FEV_1 between 50% and 80% of predicted. Exclusion criteria included a history of asthma, other chronic respiratory diseases, significant cardiovascular or metabolic comorbidities (e.g., uncontrolled diabetes, heart failure), or any condition precluding safe exercise participation.

RANDOMIZATION

Eligible participants (n=26) were randomly allocated to either the intervention (n=13) or control (n=13) group. A computer-generated randomization sequence was created by an independent statistician. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes.

INTERVENTION PROTOCOL

Intervention Group: Participants underwent an 8-week, supervised, structured exercise program, comprising two 60-minute sessions per week. Each session included:

1. **Warm-up (10 minutes):** Light aerobic activity (e.g., slow walking, cycling) and dynamic stretching.
2. **Main Training Phase (45 minutes):**
   - **Aerobic Conditioning:** 20-30 minutes of treadmill walking or stationary cycling. Intensity was progressively increased from 65-70% to 75-85% of the age-predicted maximum heart rate (220 - age).
   - **Strength Training:** 15-20 minutes of upper and lower body exercises (e.g., seated shoulder presses, leg presses) using dumbbells and resistance machines, aiming for 2-3 sets of 10-15 repetitions.
   - **Respiratory Muscle Training:** Specific inspiratory muscle training was performed using a threshold loading device (e.g., POWER breathe) at 30-50% of maximal inspiratory pressure, for 3 sets of 10-15 breaths.
3. **Cool-down (5 minutes):** Static stretching and controlled breathing exercises.

Control Group Participants were instructed to maintain their usual lifestyle and standard pharmacological care, without engaging in any structured exercise program. Exercise duration within the main phase was also progressively adjusted. Baseline characteristics of the study sample are presented in Table 1.

Table 1. Baseline Characteristics of the Study Sample

Group	**Control Group (n=13)**	**Experimental Group (n=13)**
	Mean ± SD	**Mean ± SD**
Age (years)	64.2 ± 8.1	62.8 ± 7.5

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Height (cm), Males	169 ± 7.2	169 ± 7.0
Height (cm), Females	165 ± 5.0	165 ± 5.3
Weight (kg), Males	90 ± 13.5	91 ± 13.0
Weight (kg), Females	92 ± 9.4	91 ± 10.0

RANDOMIZATION

Eligible participants (n=26) were randomly allocated to either the intervention (n=13) or control (n=13) group. A computer-generated randomization sequence was created by an independent statistician. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes.

THE INTERVENTION: STRUCTURED TRAINING PROGRAM

Intervention Group: Participants underwent an 8-week, supervised, structured exercise program, comprising two 60-minute sessions per week. Each session included:

1. **Warm-up (10 minutes):** Light aerobic activity (e.g., slow walking, cycling) and dynamic stretching.
2. **Main Training Phase (45 minutes):**
    - **Aerobic Conditioning:** 20-30 minutes of treadmill walking or stationary cycling. Intensity was progressively increased from 65-70% to 75-85% of the age-predicted maximum heart rate (220 - age).
    - **Strength Training:** 15-20 minutes of upper and lower body exercises (e.g., seated shoulder presses, leg presses) using dumbbells and resistance machines, aiming for 2-3 sets of 10-15 repetitions.
    - **Respiratory Muscle Training:** Specific inspiratory muscle training was performed using a threshold loading device (e.g., POWER breathe) at 30-50% of maximal inspiratory pressure, for 3 sets of 10-15 breaths.
3. **Cool-down (5 minutes):** Static stretching and controlled breathing exercises.

OUTCOME MEASURES

Primary outcomes were assessed at baseline and post-intervention:

- Spirometry: FEV_1 and FVC were measured using a calibrated spirometer, with the FEV_1/FVC ratio calculated subsequently.
- Respiratory Rate: Measured at rest over one minute.

Secondary outcomes included a 6-minute walk test (6MWT) and health-related quality of life questionnaires.

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 19. Descriptive statistics are presented as mean ± standard deviation. Between-group comparisons for continuous variables were conducted using independent samples t-tests. A p-value of <0.025 was considered statistically significant to account for multiple comparisons.

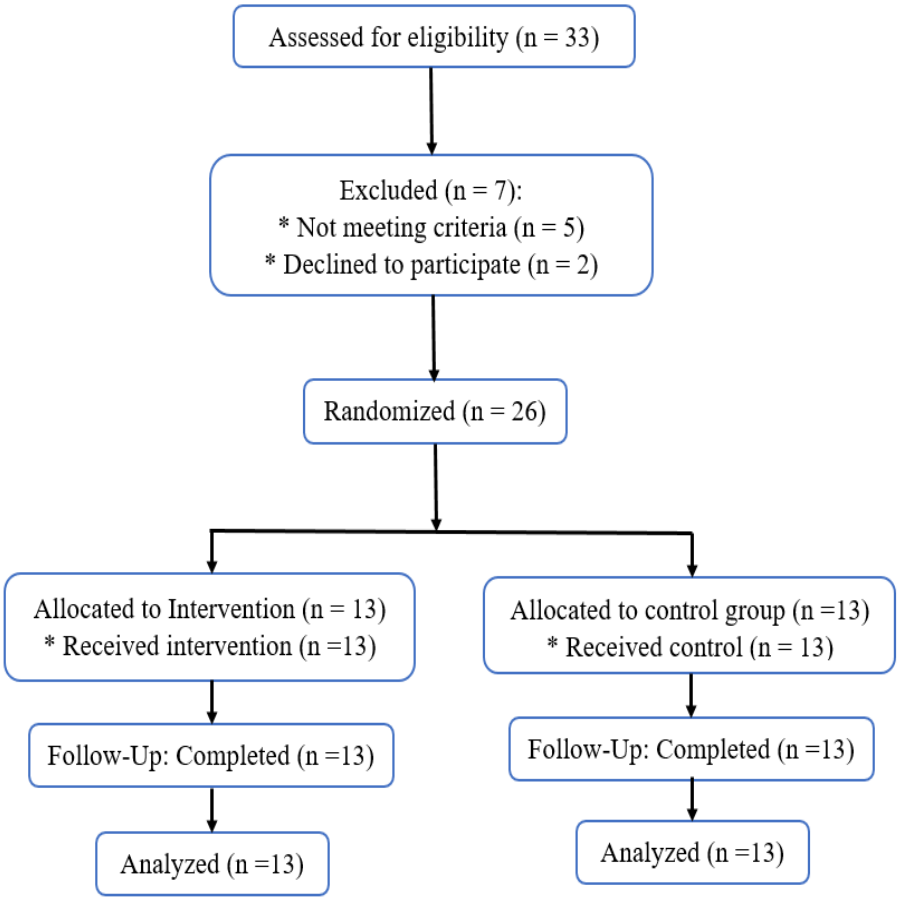

Figure 1: Flow Diagram of Participant Enrollment, Allocation, and Analysis

RESULTS

The final analysis included all 26 enrolled participants (13 in the intervention group and 13 in the control group), with no dropouts reported. The flow of participants through our study is detailed in Figure 1. Baseline demographic and clinical characteristics were comparable between the two groups, confirming successful randomization (Table 2).

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Table 2. Baseline Characteristics of the Study Participants

Characteristic	Control Group (n=13)	Intervention Group (n=13)	p-value
Age (years)	64.2 ± 8.1	62.8 ± 7.5	0.651
Gender (Male/Female)	9 / 4	8 / 5	0.692
Smoking History (pack-years)	42.5 ± 11.3	45.1 ± 12.7	0.582
FEV_1 (L)	1.53 ± 0.69	1.61 ± 0.71	0.776
FVC (L)	1.31 ± 0.78	1.45 ± 0.76	0.648
FEV_1/FVC Ratio	0.58 ± 0.05	0.57 ± 0.06	0.723

Following the 8-week intervention, the exercise group demonstrated significant improvements in pulmonary function and respiratory efficiency compared to the control group. The between-group comparisons for the primary outcomes are presented in Table 3.

Table 3. T-test Values for Differences between Control and Experimental Groups Post-Intervention

Study Variable	Control Group (n=13)	Experimental Group (n=13)	T-value	Significance Level (P values)
	Mean ± SD	Mean ± SD		
Respiratory Rate (per min)	27.44 ± 4.58	20.22 ± 2.28	6.40	$p < 0.025$*
FEV1 (Liters)	1.531 ± 0.693	1.715 ± 0.685	-3.47	$p < 0.025$*

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Study Variable	Control Group (n=13)	Experimental Group (n=13)	T-value	Significance Level (P values)
	Mean ± SD	Mean ± SD		
FVC (Liters)	1.305 ± 0.779	1.778 ± 0.745	-4.10	$p < 0.025$*
FEV1/FVC (Ratio)	1.173 ± 0.890	0.964 ± 0.919	-0.846	Not Significant

Note: The critical t-value for significance at $\alpha \leq 0.025$ is 2.306. The negative sign for the t-value indicates the direction of change.

The magnitude of improvement is further illustrated by the percentage change from baseline for each group as shown in figure 2. The intervention group showed a marked reduction in respiratory rate and substantial increases in FEV_1 and FVC, whereas changes in the control group were minimal.

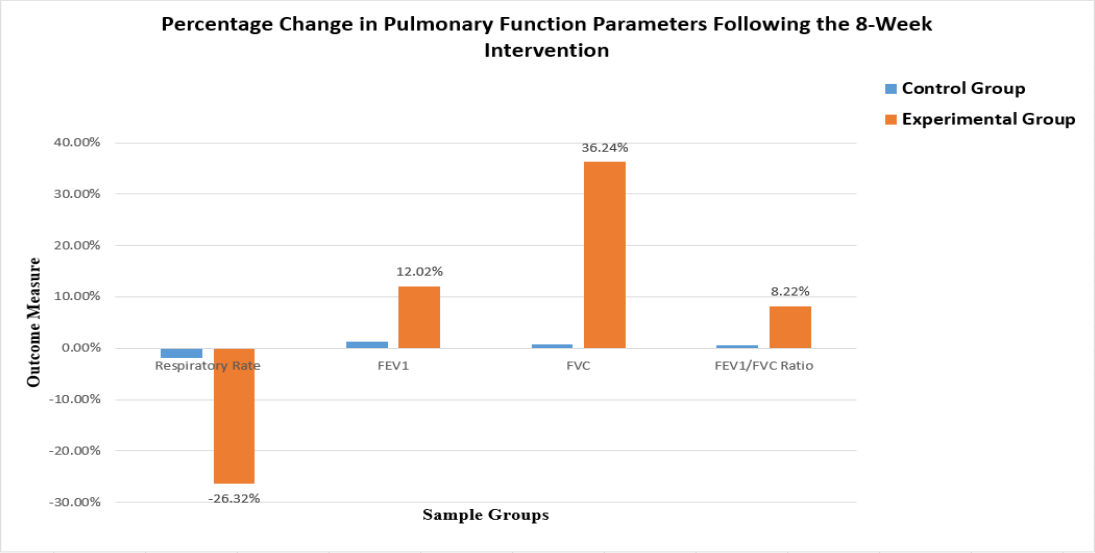

Figure 2: Compare Outcome Measures of Experimental and Control Groups

Table 3 illustrates the magnitude of improvement by calculating the percentage change for each variable from the control group's baseline to the experimental group's post-intervention mean, providing a clear view of the intervention's effect size.

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Table 3. Percentage of Change in Study Variables

Study Variable	Control Group Mean	Experimental Group Mean	Percentage Change
Respiratory Rate (per min)	27.44	20.22	**26.32% Decrease**
FEV1 (Liters)	1.531	1.715	**12.02% Increase**
FVC (Liters)	1.305	1.778	**36.24% Increase**
FEV1/FVC (Ratio)	1.174	0.965	17.80% Decrease

The statistical analysis revealed significant between-group differences following the intervention. Specifically, the experimental group demonstrated a significant reduction in respiratory rate by a mean of 7.22 breaths per minute ($t = 6.40$, $p < 0.025$), representing a 26.32% improvement compared to the control group.

Furthermore, significant improvements were observed in key spirometric parameters. The Forced Expiratory Volume in 1 second (FEV1) showed a significant increase in the experimental group ($t = -3.47$, $p < 0.025$), with a 12.02% improvement. A more pronounced effect was seen in Forced Vital Capacity (FVC), which increased significantly ($t = -4.10$, $p < 0.025$), corresponding to a substantial 36.24% improvement.

However, the FEV1/FVC ratio did not show a statistically significant difference between the groups post-intervention ($t = -0.846$, $p > 0.025$), despite a noted change in the raw values.

DISCUSSION

In the presented paper, the randomized controlled trial provides robust evidence that an 8-week, supervised, structured exercise program significantly enhances pulmonary function and respiratory efficiency in patients with moderate COPD. The principal findings demonstrate that the intervention group achieved clinically and statistically superior improvements in FVC and FEV_1, alongside a marked reduction in respiratory rate, compared to the usual care control group.

The most substantial improvement was observed in Forced Vital Capacity (FVC), which increased by over 36% in the intervention group. This finding suggests a significant amelioration of dynamic hyperinflation, a key pathological factor in COPD where air becomes trapped in the lungs at the end of a normal breath [9]. The combined aerobic and resistance training likely strengthened the respiratory muscles, particularly the expiratory muscles, improving the ability to empty the lungs more completely and thereby increasing

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

the volume of air that could be inhaled in the subsequent breath (Celli et al., 2020). Concurrently, the significant 26% reduction in respiratory rate strongly indicates enhanced ventilatory efficiency. A lower respiratory rate at rest suggests a decreased drive to breathe and a lower work of breathing, which directly translates to a reduction in the perceived sensation of dyspnea during activities of daily living Salama (1995).

Our results corroborate the established body of evidence on the benefits of pulmonary rehabilitation. The improvements in FEV_1 and FVC are consistent with the findings of Spruit et al. (2013), whose official ERS/ATS statement outlines the expected physiological adaptations to exercise (Spruit et al., 2013). However, the magnitude of the FVC improvement in our cohort is particularly pronounced. We postulate that this may be attributable to the specific, targeted inclusion of respiratory muscle training within our comprehensive regimen, a component that is not always standardized or emphasized in broader rehabilitation programs. This hypothesis is supported by a systematic review by Beaumont et al. (2018), which concluded that inspiratory muscle training provides significant additive benefits for respiratory muscle strength and functional exercise capacity in COPD patients Araby and Al-Kilani (2007).

STUDY LIMITATIONS AND FUTURE RESEARCH

Several limitations should be considered. First, the sample size was relatively small, which may affect the generalizability of the findings. Future studies with larger, multi-center cohorts are recommended to confirm these results. Second, the follow-up period was limited to the immediate post-intervention phase; long-term studies are needed to determine the sustainability of these improvements and the optimal frequency of "booster" sessions. Including patient-reported outcome measures (PROMs), such as quality of life and dyspnea scales, in future research would provide a more comprehensive view of the intervention's benefits.

CONCLUSIONS

In conclusion, this randomized controlled trial demonstrates that an 8-week supervised exercise program, integrating aerobic conditioning and respiratory muscle training, is a highly effective non-pharmacological strategy for moderate COPD. The intervention yielded significant improvements in operational lung volumes, evidenced by substantial increases in Forced Vital Capacity and reduced respiratory rate, indicating enhanced ventilatory efficiency. These benefits likely stem from improved respiratory muscle function rather than reversal of fixed airflow obstruction, as shown by the stable FEV_1/FVC ratio.

RECOMMENDATIONS

In light of the compelling evidence generated by our presented study, the following recommendations are proposed:

1. **Clinical Implementation:** The specific structure of this 8-week program-combining aerobic conditioning, resistance training, and targeted respiratory muscle exercises-should

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

be integrated into standard pulmonary rehabilitation protocols for patients with moderate (GOLD Stage II) COPD as a first-line non-pharmacological therapy.

2. **Interdisciplinary Care Models:** Healthcare institutions should establish formal referral pathways and collaborative frameworks between pulmonologists and certified exercise professionals (e.g., physiotherapists, clinical exercise physiologists) to ensure the safe and effective prescription and supervision of individualized exercise regimens.
3. **Patient Empowerment and Education:** Patient education initiatives should be developed to clearly articulate the distinct benefits of *structured, supervised* exercise over general activity advice, highlighting its proven efficacy in reducing dyspnea, decreasing respiratory effort, and enhancing functional capacity.
4. **Policy and Advocacy:** National and international bodies (e.g., GOLD committee) should strengthen their guidelines to explicitly endorse supervised, structured exercise training as a core component of COPD management. Policymakers and insurers should work to improve reimbursement structures to facilitate patient access to these essential programs.

REFERENCES

Agustí, A., & Hogg, J. C. (2019). Update on the pathogenesis of chronic obstructive pulmonary disease. *New England Journal of Medicine*, *381*(13), 1248–1256.

Spruit, M. A., Singh, S. J., Garvey, C., ZuWallack, R., Nici, L., Rochester, C., ... & Wouters, E. F. (2013). An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *American Journal of Respiratory and Critical Care Medicine*, *188*(8), e13–e64.

McCarthy, B., Casey, D., Devane, D., Murphy, K., Murphy, E., & Lacasse, Y. (2015). Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews*, (2), CD003793.

Casaburi, R. (2017). Principles of exercise training. In *Pulmonary Rehabilitation* (pp. 89–99). CRC Press.

Bolton, C. E., Bevan-Smith, E. F., Blakey, J. D., Crowe, P., Elkin, S. L., Garrod, R., ... & Walmsley, S. (2013). British Thoracic Society guideline on pulmonary rehabilitation in adults. *Thorax*, *68*(Suppl 2), ii1–ii30.

Gosselink, R., De Vos, J., van den Heuvel, S. P., Segers, J., Decramer, M., & Kwakkel, G. (2011). Impact of inspiratory muscle training in patients with COPD: what is the evidence?. *European Respiratory Journal*, *37*(2), 416–425.

O'Donnell, D. E., Milne, K. M., James, M. D., de Torres, J. P., & Neder, J. A. (2020). Dyspnea in COPD: new mechanistic insights and management implications. *Advances in Therapy*, *37*(1), 41–60.

Beaumont, M., Forget, P., Couturaud, F., & Reychler, G. (2018). Effects of inspiratory muscle training in patients with chronic obstructive pulmonary disease: a

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

systematic review and meta-analysis. *Clinical Respiratory Journal*, *12*(7), 2178–2188.

Lacasse, Y., Cates, C. J., McCarthy, B., & Welsh, E. J. (2015). This Cochrane Review is closed: deciding what constitutes enough research and where next for pulmonary rehabilitation in COPD. *Cochrane Database of Systematic Reviews*, (11), ED000107.

GLOBAL strategy for prevention, diagnosis and management of COPD: 2023 report

Al-Kilani, H., & Al-Kilani, O. (2005, May 11-12). *Using video feedback to improve rhythmic movements in a sample of children with intellectual disabilities* [Conference presentation]. The First Conference on Childhood and Family "Towards a Happy Childhood and a Prosperous Family", Hashemite University, Zarqa, Jordan.

Al-Kilani, L. Z. (1999). *The effect of a proposed training program on reducing the severity of asthma in children in Jordan* [Master's thesis, University of Jordan].

Abdel Fattah, A. A. (2003). *Physiology of training and sports* (1st ed.). Dar Al Fikr Al Arabi.

Abdel Wahab, F. (1983). *Principles of sports physiology* (1st ed.). National Center for Sports Research.

Araby, S. M. (1993). *The effect of aquatic exercises on some vital capacity measurements for basic education stage female students in Jordan* [Conference paper]. First Scientific Conference of the Department of Exercises and Gymnastics: Theories and Applications, Faculty of Physical Education for Boys, Alexandria University, Egypt.

Araby, S. M., & Al-Kilani, L. F. (2007, March 21-22). *The effect of a proposed training program to reduce the severity of asthma in children in Jordan* [Conference presentation]. The Second International Scientific Conference "Field Training in Faculties of Physical Education in Light of the Quality Assurance and Accreditation Project in Education", Faculty of Physical Education for Boys, Zagazig University, Egypt.

Battarsa, S. A. (1992). *The impact of a proposed training program on some physical and functional variables for junior handball players in Jordan [Master's thesis, University of Jordan]*.

Hamdan, S. A., & Salim, N. A. (2001). *Physical and health fitness* (1st ed.). Wael Publishing House.

Salama, B. I. (1995). *Sports physiology* (2nd ed.). Dar Al Fikr Al Arabi.

Imran, N. A. M. (1990). *The effect of a proposed aerobic exercise program on some blood components and respiratory system functions* [Doctoral dissertation, Zagazig University].

Alhajaya, Mohammad. (2004). Exercise Neuromuscular Control and Performance, and Stability of Knee Joint. Doctoral Dessertation. University of Wles, School of sport, Health and Exercise Sciences. Bangor. U.K. Ph.D. Autumn.

DOI prefix: 10.58305
ISSN: (Print) 2958-2571
(Online) 2409-2908
https://ej.ejsst.com

Bompa, Tudor O. (2000). Total Training for Young Champions-Proven Conditioning for Athletes Ages 6 to 18. Human Kinetics. U. S. A.

Corrou, William. (1996). Asthma in athletes, exercise induced bronch0- constriction in figure skaters. Chest; 109(2): 298- 304.

Dean, Penny Lee. (1996). Open Water Swimming. Human Kinetics. U. S. A.

GOLD(Global Initiative for Chronic Obstructive Lung Disease). (2007). National Institute of Health. National Heart, Lung, and Blood Institute. Pp: 15-27. U. K.

GOLD(Global Initiative for Chronic Obstructive Lung Disease) (2006). National Institute of Health. National Heart, Lung, and Blood Institute. Pp: 33-35. U. K.

GOLD(Global Initiative for Chronic Obstructive Lung Disease) (2003). National Institute of Health. National Heart, Lung,and Blood Institute.Pp:6-8. U. K.

Hoffman, M., Payne, and V. G. (1995). The Effects of Proprioceptive Ankle Disk Training on Healthy Subjects. Journal of Orthopedic and Sports Physical Therapy, 21(2), 90- 93.

Jones, L. R., (1976). Asthma in Childhood, Philadelphia. U. S. A.

Lou, Capple Mary, (1984). More than aerobics. University of Southern California by Burges Publishing, pp: 1- 29.

Qiu, Yi; Wei, Wenyi; Liu, Aijie; and Cao, Jingwei. (2005). Comparative Research on the Stroke Rhythm of Men and Women Kayakers in the International Competition. Qing Wang. Proceeding of XXIII International Symposium on Biomechanics In Sports ISBS. Volume 2. August 22- 27. Bejing, China .pp: 57- 62.

Rozzi, Susan L.; Lephart, Scott M.; Gear, William S.; and Fu, Freddie H. (1999). Knee Joint Laxity and Neuromuscular Characteristics of Male and Female Soccer and Basketball Players. The American Journal of Sports Medicine, Vol. 27. No. 3. American Orthopaedic Society for Sports Medicine. Pp. 312- 139.

Shinji, Sakural. (2005). Biomechanics and Adapted Physical Activity. Qing Wang Proceeding of XXIII International Symposium on Biomechanics In Sports ISBS. Volume 1. August 22- 27. Bejing, China. pp: 63- 68.

Whole, Johan W. (1990). Human Anatomy and Physiology. 5th ed., W. C. B. Wm. C. Brown Publishers. IA. U. S. A.