Indian Journal of Physiotherapy and Rehabilitation Science

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

RANDOMIZED CONTROLLED TRIAL ON THE EFFECT OF LOW-INTENSITY AEROBIC EXERCISES ON PHYSICAL ACTIVITY AND LUNG FUNCTIONS IN CHILDREN WITH DUCHENNE MUSCULAR DYSTROPHY

Anandan D[1], Anandh V[2]., Arunachalam. R[2], Rajkumar Krishnan Vasanthi[3], Daniel Rajasundaram S[4], Shanthidevi M[4], Arun B[5*]

1. Ph.D. Scholar, Department of Physiotherapy, Madhav University, Rajasthan. India.
2. Professor, Department of Physiotherapy, Madhav University, Rajasthan. India.
3. Faculty of Health and Life Sciences, INTI International University, Persiaran Perdana Nilai, Nilai- 79000, Negeri Sembilan, Malaysia
4. Senior Physiotherapist, Department of Physiotherapy, Institute of muscular dystrophy and research Centre, Jeevan Foundation, Veeravanalur, Tirunelveli Dist. Tamil Nadu, India.
5. Physiotherapist Grade II, Physiotherapy Department, Government District Headquaters Hospital, Erode. Tamil Nadu, India.

Submission: 7th May 2023

Revised: 17th May 2023

Publish: 24th May 2023

URL:https://www.ijptrs.com/view-issue/93/Fulltext

DOI:
https://www.ijptrs.com/public/images/content/672RANDOMIZED%20CONTROLLED%20TRIAL%20ON%20THE%20%20%20EFFECT%20OF%20LOW.pdf

Table of content

Abstract

Background: Duchenne muscular dystrophy (DMD) is a genetic disorder affecting many males in India, necessitating a multidirectional management approach focused on enhancing the quality of life. Physiotherapy play crucial roles in management; however, there is a lack of recommended exercises for DMD. Therefore, this study aimed to investigate the impact of low-intensity aerobic exercises on physical activity and lung function in children with DMD.

Materials and Methods: A randomized controlled trial was conducted with 66 DMD children. The participants were divided into three groups: Group I received low-intensity aerobic exercises, Group II performed a range of motion exercises, and Group III underwent conventional exercises. All groups followed a 60-minute exercise regimen, and each child received a home program. The study spanned ten weeks.

Result: The data collected included physical activity assessments using the Physical Activity Questionnaire for Children (PAQ-C) and lung function measurements utilizing spirometry (FVC, FEV1, FEV1/VC). Assessments were conducted at baseline, after 10 weeks, and at the 20th week. Parametric tests and Kruskal-Wallis tests were employed for data analysis.

Discussion: The results demonstrated significant improvements in physical activity and lung function after the intervention. The PAQ-C analysis yielded a Kruskal-Wallis test statistic 39.65 ($p < 0.001$), indicating significant differences among the groups. Repeated measures ANOVA analysis showed significant improvements in FEV1, FVC, and FEV1/FVC with F values of 252.945, 31.43, and 78.35, respectively.

Conclusion: Compared to the range of motion and conventional exercises, low-intensity aerobic exercises yielded superior results. Therefore, incorporating low-intensity aerobic exercises into managing Duchenne muscular dystrophy could be beneficial.

Keywords: Duchenne muscular dystrophy, Low intensity aerobic exercsies, Range of motion exercises, Physical training in children, Lung funcitons.

Indian Journal of Physiotherapy and Rehabilitation Science

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

Introduction

Duchenne Muscular Dystrophy (DMD) is a genetic disorder that predominantly affects children. DMD is characterized by gradual muscle weakness and degeneration due to a mutation in a protein called dystrophin, vital in developing healthy muscle cells. It is the most common and debilitating disease, with a prevalence of 15.9 to 19.5 new borns per 100,000 (Jean, 2014). Fairclough (2011) reported that the dystrophin gene mutation leads to the deficiency of the dystrophin protein, causing an X-linked recessive illness that affects one in every 3500 children. DMD is a rare inherited muscle disorder that weakens skeletal muscles (Emery, 2002).

The absence of dystrophin protein is observed in most DMD patients. Dystrophin, which plays a crucial role in muscle as a connection between the extracellular matrix and the internal cytoskeleton, becomes unstable without dystrophin, reducing member protein levels (Straub, 1997). This instability causes membrane leakage and gradual fibre degradation. The loss of DAPC's signalling function also results in altered pathology in muscle (Blake et al., 2002). Goldstein (2010) found that the absence of dystrophin makes the plasma membrane more friable, slightly rigid, and leaky, which exposes dystrophin-deficient muscle to hypoosmotic conditions and leads to membrane blebbing.

In skeletal muscle, fibrosis is most commonly associated with muscular dystrophies, a clinically and molecularly heterogeneous group of diseases. The loss of myofibers is typically caused by necrotic cell death, coupled with fibrosis that gradually replaces myofibers. However, the mechanisms for repairing membranes may be active, and restored muscle fibres may display a dysfunctional intracellular membrane. The extracellular matrix's remodelling of surviving muscle fibres also damages muscle function (Petrof, 1993).

Currently, there are no specific treatments for DMD, and the only aim is to address problems and symptoms (Birnkrant, 2018). However, several drugs have been utilized to treat DMD and prevent further deterioration. Additionally, gene and steroid therapy has been discovered as treatments that help control dystrophin protein levels and restore muscle function (Bushby, 2009).

Physiotherapy plays a crucial role in DMD, preventing musculoskeletal issues and maintaining muscle contractility, improving joint mobility, maintaining symmetry, and preventing or minimizing contractures and deformities at all stages (Bushby, 2010; Birkrant, 2018). However, the effect of exercise on DMD remains questionable (Ansved, 2001; Lindeman, 1999), especially since muscles are weaker in DMD. Aerobic exercises are recommended to improve cardiovascular fitness and muscular endurance (Punia, 2016). These exercises use significant muscle groups and improve oxygen consumption in the body. They may be low-intensity and use carbohydrates as an energy source, which are converted to energy using ATP at the mitochondria. Mitochondria generally rely on oxygen to metabolize carbs, proteins, and fats (McArdle, 2006). Meta-analyses show that aerobic exercises significantly change muscle strength, improve fitness, and enhance the quality of life (Reiner, 2013; Ueshima, 2010).

Since no studies compare aerobic exercises to DMD, studies on aerobics are done extensively for the older population and cancer patients. Since the effect of the treatment remains the same, this study tries

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

to identify the role of aerobics in DMD children. So, the study aims to identify the effect of low-intensity aerobic exercises on lung functions and physical activity in children with DMD.

Materials and Methods

The study is a randomized trial with three active treatment groups, conducted at the Institute of Muscular Dystrophy and Research Center, Jeevan Foundation, Veeravanalur, Tirunelveli District, Tamil Nadu, India. The participants were selected from a cluster of children and randomly allocated into the three groups with equal numbers. The sampling method used was systematic sampling. The study aimed to evaluate the effectiveness of different therapies on boys aged 6 to 13 years diagnosed with Duchenne muscular dystrophy (DMD) based on DNA study.

The inclusion criteria included boys in the ambulation phase who could perform daily activities with minimal support and took less than five seconds to get up from the floor. The sample size of 66 children was determined based on a previous study by Alemdaroğlu et al. (2015) using a 95% confidence interval. However, specific details regarding the sample size calculation method used in the previous study.

The study employed single-blinding, where the researcher had knowledge of the therapy, but the participants remained blinded. The participants were thoroughly assessed, and those meeting the selection criteria were included in the study. The random allocation into the three treatment groups was done using computer-assisted evaluation. Before beginning the trial, parents/guardians provided written consent, and the children were randomly assigned into three groups. Group I consisted of twenty-two children who underwent low-intensity aerobic exercises for sixty minutes with frequent rest periods. Group II consisted of twenty-two children who underwent range of motion exercises for sixty minutes with frequent rest periods. Group III consisted of twenty-two children who underwent conventional physiotherapy for sixty minutes with frequent rest periods. All the groups underwent 30 minutes of regular physiotherapy. The study was conducted for 20 weeks on alternate days, and a separate physiotherapist was deputed to conduct the study for the three groups.

All the treatment programmes are provided without disturbing their regular school schedules. The home programme is also taught to the children, parents or guardians, and the therapist monitors them frequently through video or telephone. Every child will take the exercise programme for six months, 20 weeks. Those who completed the 20-week schedule were taken for the final analysis, and the blinded researcher collected their data.

Group I received, Walking and cycling are done for 30 minutes on alternative days. With this, exercises for the upper and lower limbs are given. This exercise programme was applied for two to three sets of 5—10 repetitions which includes leg press, Hip forward flexion, hip forward and backward movements, hip sideward movements, hip rotations, knee curls, ankle movements, ankle circles, toe curls for the lower limbs and bench press, shoulder movements in all directions, diagonal movements of the shoulder, elbow bending, wrist circles, finger curls and thumb movements for upper limbs. Repetitive breaks were given during these exercises to prevent fatigue. Participants exercised 3 days a week for the first 3 weeks, 4 days a week for the next 5 weeks,

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

and 5 days a week afterwards. The children's exercise program lasts 60 minutes (Cup, 2007; MacInnis, 2017).

Group II receives an active range of motion exercises that should be performed on every joint. All the joints should be moved for ten counts and repeated twice daily—active or active assisted range of motion exercises to be imparted to each joint. Forearm supination, pronation, shoulder flexion, extension, abduction, and adduction are all subjected to active range of motion exercises. Finger forward bending, abduction, adduction, and extension; flexing the wrist, extension, and rotations. Alternatively, bending forward of the hips, backwards swinging, inwards and outward movements, knee bending, ankle forward and backward motions, subtalar inversion and eversion, and toe flexion and extensions are all movements of the lower extremity. In the spine, cervical flexion, extension, lateral flexion and rotations, and lumbar spine flexion and extension (Vignos et al., 1996).

Group III receives, conventional physiotherapy which included range of motion exercises, stretching exercises and postural correction exercises. All the joints should be moved for ten counts and repeated twice daily—active or active assisted range of motion exercises to be imparted to each joint. Stretching needs to hold for 15 seconds three time (Mayhew et al., 2013).

All the participants underwent a respiratory exercise. These exercises were given to all the participants. The parents were also taught about the technique and advised to monitor the children when they do the exercises. Respiratory exercises have started with deep breathing exercises (Ma et al., 2017).

The outcome measures for the study were lung functions, measured using a spirometer, and physical activity, measured using the Physical Activity Questionnaire for Children (PAQ-C). The data were collected at regular intervals and were taken for analysis. Day 1 data was considered the pre-test, the 10th-week data was the post-test I, and the 20th-week data was the post-test II. SPSS 22.0 was used to analyze the collected data.

Results

Table I Descriptive data

Shapiro-Wilk test			
	Statistic	df	Sig.
FEV1.PRE TEST	0.911	48	0.001
FVC.PRE TEST	0.944	48	0.023
FEV1/VC.PRE TEST	0.901	48	0.001

Table I shows the demographic analysis of the participants in all the groups. This table shows that the participants average age is 6.45 years, this study includes first child and second child as well.

Table II Test of Normality

Shapiro-Wilk test			
	Statistic	df	Sig.
FEV1.PRE TEST	0.911	48	0.001
FVC.PRE TEST	0.944	48	0.023
FEV1/VC.PRE TEST	0.901	48	0.001

Table II shows the test of Normality using Shapiro-Wilk test, it shows that there is no significance difference in between the pre test groups prior to the start of the treatment.

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

Table III: Non-Parametric Analysis for PAQ-C using Friedman's Two-way analysis

	LIAE Group	ROM Group	Conventional Group
Total N	22	22	22
Test Statistic	28.795	0.2727	0.0682
Degree of Freedom	2	2	2
Asymptotic Sig. (2-sided test)	0.0001*	0.872	0.9965

*Denotes statistically significance

Table III shows the non-parametric analysis for the PAQ-C scale using Friedman's two-way analysis of variance by ranks between the pre-test, post-test I, and post-test II. This table shows that the ROM and Conventional groups don't provide significant results between the test values. Further, the post hoc test was conducted to identify the group differences.

Table IV: Repeated measures ANOVA for FEV_1—Within group

Groups	Pretest Mean ± S.D	Post-test I Mean ± S.D	Post-test II Mean ± S.D	F value	p value
LIAE	27.32 ± 9.97	35.95 ± 9.22	41.18 ± 8.36	264.59	0.0001*
ROM	27.18 ± 9.45	27.32 ± 9.70	27.36 ± 9.80	2.294	0.1134**
Conventional	27.09 ± 9.49	27.14 ± 9.52	27.23 ± 9.95	2.49	0.0949**

* Statistically significant @ 0.05% level ** Statistically not significant @ 0.05% level

Table V: Repeated measures ANOVA for FVC—Within groups

Groups	Pretest Mean ± S.D	Post-test I Mean ± S.D	Post-test II Mean ± S.D	F value	p value
LIAE	32.32 ± 6.97	35.31 ± 8.62	37.32 ± 12.56	38.076	0.0001*
ROM	32.33 ± 5.83	32.40 ± 5.93	32.42 ± 6.05	2.814	0.0713**
Conventional	32.27 ± 6.64	32.30 ± 6.73	32.32 ± 6.83	2.594	0.0866**

* Statistically significant @ 0.05% level ** Statistically not significant @ 0.05% level

Table VI: Repeated measures ANOVA for FEV_1/ FVC—Within groups

Groups	Pretest Mean ± S.D	Post-test I Mean ± S.D	Post-test II Mean ± S.D	F value	p value
LIAE	44.41 ± 4.61	45.05 ± 3.99	48.64 ± 4.83	85.577	0.001*
ROM	44.45 ± 4.92	44.50 ± 4.90	44.59 ± 4.58	2.492	0.0949**
Conventional	44.36 ± 5.11	44.41 ± 5.30	44.45 ± 5.30	1.537	0.227**

* Statistically significant @ 0.05% level ** Statistically not significant @ 0.05% level

Tables IV, V and VI show the within-group analysis using the repeated measures ANOVA. The LIAE group shows significance in all the values (FEV1, FVC & Fev1/FVC), whereas the other groups don't produce a significant result. Further, the post hoc test was conducted to identify the group difference

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

Table VII: Non-Parametric Analysis for PAQ-C using Kruskal-Wallis Test

	Post-test I	**Post-test II**
Total N	22	22
Test Statistic	23.988	39.695
Degree of Freedom	2	2
Asymptotic Sig. (2-sided test)	0.0001*	0.0001*

*Denotes statistically significance

Table VII shows the Kruskal-Wallis analysis for the PAQ-C to compare the Posttest I & Posttest II values between all the groups. The calculated test statistics show marked significance at 0.001. Further, this implies that the LIAE group significantly improves PAQ-C than the other two groups.

Table VIII: Repeated measures ANOVA for FEV_1—Between groups

Groups	**Outcomes**	**LIAE**	**ROM**	**Conventional**	**F value**	**p value**
Post-test I Mean ± S.D	**FEV_1**	45.05 ± 3.99	44.50 ± 4.90	44.41 ± 5.30	98.236	0.001*
Post-test II Mean ± S.D		48.64 ± 4.83	44.59 ± 4.58	44.45 ± 5.30	252.945	0.001*
Post-test I Mean ± S.D	**FVC**	35.31 ± 8.62	32.40 ± 5.93	32.30 ± 6.73	14.41	0.001*
Post-test II Mean ± S.D		37.32 ± 12.56	32.42 ± 6.05	32.32 ± 6.83	31.43	0.001*
Post-test I Mean ± S.D	**FEV_1 / FVC**	45.05 ± 3.99	44.50 ± 4.90	44.41 ± 5.30	3.967	0.001*
Post-test II Mean ± S.D		48.64 ± 4.83	44.59 ± 4.58	44.45 ± 5.30	78.35	0.001*

*Statistically significant @ 0.05% level

Table VIII shows the between-group analysis using repeated measures ANOVA. It was inferred from the table that marked significant differences exist among the groups on the post-test I value and post-test II values. The LIAE group shows significance in all the values (FEV1, FVC & Fev1/FVC), whereas the other groups don't produce a significant result.

Discussion

Muscle diseases, such as Duchenne muscular dystrophy (DMD), are inherited disorders caused by gene mutations (Mercuri & Muntoni, 2013). Unfortunately, there is currently no cure for DMD, and the best available treatment options aim to extend the lifespan of affected children (Arora, 2019). However, low-intensity aerobic exercise has been found to offer numerous benefits to individuals with various disorders, including those with DMD.

One of the main advantages of low-intensity aerobic exercise is that it improves health-related quality of life (HRQOL). When individuals engage in low-intensity aerobic exercise, oxygen flow to their muscles increases, allowing physiological processes to continue without undue fatigue.

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

(Shahana et al., 2010). This increase in blood flow also promotes the formation of additional blood vessels, allowing for even greater oxygen delivery to the muscles during exercise Aerobic exercise can also cause physical adaptations in the muscles. For example, it can alter the cross-sectional area of slow-twitch muscle fibers, leading to increased muscular endurance (Abernethy et al., 1990). In addition, Terjung (1995) found that aerobic exercise can positively impact bone mass and minerals. Exercise can also help mobilize fat and enhance the body's ability to oxidize fat using muscle enzymes (Wilmore and Costill , 2005).

Research has also shown that low-intensity aerobic exercise can significantly improve body composition, cardiovascular function, and muscular endurance. For example, a study by Mahendran et al. (2009) found that 12 weeks of aerobic exercise improved body composition, cardiovascular function, and muscular endurance. Similarly, a study by Esleman et al. (2022) found that 12 weeks of aerobic training significantly improved cardiovascular fitness and body composition in school students.

Low-intensity aerobic exercise is any physical activity that increases heart rate and respiratory volume to meet the oxygen demand of the muscles during contraction (Wu et al., 2020). Because it strengthens respiratory muscles like the the diaphragm and intercostals, low-intensity aerobic exercise can also enlarge the chest and improve lung capacity (Bassi et al., 2015). In addition, this type of exercise can increase VO2 max and help activate previously inactive alveoli, improving overall lung function (Park et al., 2017).

Finally, research has shown that low-intensity aerobic exercise can help improve various lung function parameters in children with DMD. For example, Lee (2016) found that repeated inspiratory and expiratory stimulation during exercise increased alveolar compliance, improving forced vital capacity (FVC). Similarly, studies by Song et al. (2016) and Rawashdeh (2018) showed that exercise helped restore respiratory and trunk muscles, improving FEV1/FVC.

Overall, the benefits of low-intensity aerobic exercise on physical activity and lung function in children with DMD are clear. A recent study found a strong positive relationship between low-intensity aerobic exercise, physical activity, and lung function parameters in children. The low-intensity aerobic exercise group showed significant improvement in all parameters compared to the other groups. Based on the statistical analysis and previous research, it is clear that low-intensity aerobic exercise can significantly improve physical activity and lung function in children with DMD.

Conclusion

Based on the study's findings, it can be concluded that low-intensity aerobic exercises are the most effective intervention for improving lung function and physical activity in children with Duchenne muscular dystrophy. At the same time, conventional and range-of-motion exercises were less effective than low-intensity aerobic exercises. Therefore, healthcare professionals and caregivers should consider incorporating low-intensity aerobic training into the treatment plans for children with Duchenne muscular dystrophy to improve their overall physical health and well-being. These findings highlight the importance of incorporating low-intensity aerobic exercises into the treatment and management plans for individuals with this condition. Further research and exploration could provide additional insights and optimize exercise interventions for better outcomes in Duchenne muscular dystrophy patients.

IJPTRS Vol 2(2) April-May-June 2023 pp 8- 17 E-ISSN 2583-4304

Acknowledgment

The author expresses gratitude to Madhav University's management and the parents and children who volunteered for the study, recognizing their contributions to the successful completion of the research.

Conflict of Interest: No potential conflict of interest to this article was reported.

Source of Funding: NIL declared by the authors.

References:

1. Abernethy, P. J., Thayer, R., & Taylor, A. W. (1990). Acute and chronic responses of skeletal muscle to endurance and sprint exercise. Sports Medicine, 10(6), 365-389.
2. Alemdaroğlu, I., Karaduman, A., Yilmaz, Ö. T., & Topaloğlu, H. (2015). Different types of upper extremity exercise training in Duchenne muscular dystrophy: effects on functional performance, strength, endurance, and ambulation. *Muscle & nerve*, *51*(5), 697-705.
3. Ansved, T. (2001). Muscle training in muscular dystrophies. Acta physiologica scandinavica, 171(3), 359-366.
4. Arora, H. (2019). Duchenne muscular dystrophy: Still an incurable disease. Neurology India, 67(3), 717.
5. Bassi, R., Sharma, S., Sharma, A., Kaur, D., & Kaur, H. (2015). The effect of aerobic exercises on peak expiratory flow rate and physical fitness index in female subjects. National Journal of Physiology, Pharmacy and Pharmacology, 5(5), 376-376.
6. Birnkrant, D. J., Bushby, K., Bann, C. M., Apkon, S. D., Blackwell, A., Brumbaugh, D., ... & DMD Care Considerations Working Group. (2018). Diagnosis and management of Duchenne muscular dystrophy, part 1: diagnosis, and neuromuscular, rehabilitation, endocrine, and gastrointestinal and nutritional management. The Lancet Neurology, 17(3), 251-267.
7. Blake, D. J., Weir, A., Newey, S. E., & Davies, K. E. (2002). Function and genetics of dystrophin and dystrophin-related proteins in muscle. Physiological reviews.
8. Bushby, K., Finkel, R., Birnkrant, D. J., Case, L. E., Clemens, P. R., Cripe, L., ... & DMD Care Considerations Working Group. (2010). Diagnosis and management of Duchenne muscular dystrophy, part 1: diagnosis, and pharmacological and psychosocial management. The Lancet Neurology, 9(1), 77-93.
9. Bushby, K., Finkel, R., Birnkrant, D. J., Case, L. E., Clemens, P. R., Cripe, L., ... & DMD Care Considerations Working Group. (2010). Diagnosis and management of Duchenne muscular dystrophy, part 2: implementation of multidisciplinary care. The Lancet Neurology, 9(2), 177-189.
10. Cup, E. H., Pieterse, A. J., Jessica, M., Munneke, M., van Engelen, B. G., Hendricks, H. T., ... & Oostendorp, R. A. (2007). Exercise therapy and other types of physical therapy for patients with neuromuscular diseases: a systematic review. Archives of physical medicine and rehabilitation, 88(11), 1452-1464.
11. Emery, A. E. (2002). Muscular dystrophy into the new millennium. Neuromuscular disorders, 12(4), 343-349.
12. Esleman, A., Geberemariam, B. Y., & Aychiluhim, W. (2022). Effects of twelve-week aerobic exercise on selected health-related physical fitness variables on Gonji preparatory school male students. East African Journal of Biophysical and Computational Sciences, 3(1), 9-16.
13. Fairclough, R. J., Bareja, A., & Davies, K. E. (2011). Progress in therapy for

Duchenne muscular dystrophy. Experimental physiology, 96(11), 1101-1113.
14. Goldstein, J. A., & McNally, E. M. (2010). Mechanisms of muscle weakness in muscular dystrophy. Journal of General Physiology, 136(1), 29-34.
15. Jean K. Mah, Lawrence Korngut, Jonathan Dykeman, Lundy Day, Tamara Pringsheim, Nathalie Jette, (2014). A systematic review and meta-analysis on the epidemiology of Duchenne and Becker muscular dystrophy, Neuromuscular Disorders, Volume 24, Issue 6; 482-491.
16. Lee B, Park S, Han D. (2016). Analysis of the influential factors of maximal-effort expiratory capacity of elderly women. J Phys Ther Sci.28:2924-2928.
17. Lindeman E, Spaans F, Reulen J, Leffers P, Drukker J (1999) Progressive resistance training in neuromuscular patients. Effects on force and surface EMG. J Electromyogr Kinesiol 9: 379–384.
18. Ma X, Yue ZQ, Gong ZQ, Zhang H, Duan NY, Shi YT, Wei GX, Li YF. (2017). The Effect of Diaphragmatic Breathing on Attention, Negative Affect and Stress in Healthy Adults. Front Psychol.6;8:874. doi: 10.3389/fpsyg.2017.00874. PMID: 28626434
19. MacInnis MJ, Gibala MJ (2017). Physiological adaptations to interval training and the role of exercise intensity. J Physiol.595(9):2915-2930. doi:10.1113/JP273196
20. Mahendran P. (2009). Effect of 12 Weeks aerobic exercises on selected health-related physical fitness and physiological variables of adolescents. Unpublished MSc Thesis, Pondicherry University, Pondicherry.128.
21. Mayhew, A., Mazzone, E. S., Eagle, M., Duong, T., Ash, M., Decostre, V., ... & Main, M. (2013). Development of the Performance of the Upper Limb module for Duchenne muscular dystrophy. Developmental Medicine & Child Neurology, 55(11), 1038-1045.
22. McArdle WD, Katch FI, Katch VL. (2006). Essentials of exercise physiology. Lippincott Williams & Wilkins.
23. Mercuri E, Muntoni F. (2013) Muscular dystrophy: new challenges and review of the current clinical trials. Curr Opin Pediatr;25:701-707.
24. Park J, Han D. (2017). Effects of high intensity aerobic exercise on treadmill on maximum-expiratory lung capacity of elderly women. J Phys Ther Sci. 29(8):1454-1457.
25. Petrof, B.J.; Shrager, J.B.; Stedman, H.H.; Kelly, A.M.; Sweeney, H.L (1993). Dystrophin protects the sarcolemma from stresses developed during muscle contraction. Proc. Natl. Acad. Sci. USA, 90, 3710–3714.
26. Punia S, Kulandaivelan S, Singh V, Punia V (2016). Effect of Aerobic Exercise Training on Blood Pressure in Indians: Systematic Review. Int J Chronic Dis.1370148. doi:10.1155/2016/1370148.
27. Rawashdeh A, Alnawaiseh N.(2018) The Effect of High-Intensity Aerobic Exercise on the Pulmonary Function Among Inactive Male Individuals. Biomed Pharmacol J;11(2).
28. Reiner M., Niermann C., Jekauc D., Woll A. (2013). Long-term health benefits of physical activity—a systematic review of longitudinal studies. BMC Public Health. ;13(1, article 813):1–9.
29. Shahana A, Usha SN. Hasrani SS.(2010). Effect of Aerobic exercise program on Health-Related physical fitness components of middle-aged women Br. J. Sports Med. 4 (4): 19- 23.

30. Song J.W, Kim G.D (2016). Effects of core stability training on the pulmonary function and trunk muscle activity in chronic stroke patients. Asia-pacific Journal of Multimedia Services convergent with Art.6:101-108.
31. Straub V, Campbell KP (1997) Muscular dystrophies and the dystrophin–glycoprotein complex. Curr Opin Neurol 10: 168–175
32. Terjung RL (1995). Muscle adaptations to aerobic training. Sports Science Exchange. 8:1–4.
33. Ueshima K., Ishikawa-Takata K., Yorifuji T., et al. (2010). Physical activity and mortality risk in the Japanese elderly. A cohort studies. American Journal of Preventive Medicine. 38(4):410–418.
34. Vignos PJ, Wagner MB, Karlinchak B, Katirji B (1996). Experience at the University Hospitals of Cleveland. Evaluation of a program for long-term treatment of Duchenne muscular dystrophy. J Bone Joint Surg Am. 78(12):1844–1852
35. Wilmore JH, Costill DL (2005). Physiology of Sport and Exercise: 3rd Edition. Human Kinetics Publishing.;56-75.
36. Wu X, Gao S, Lian Y (2020). Effects of continuous aerobic exercise on lung function and quality of life with asthma: a systematic review and meta-analysis. J Thorac Dis., 12(9):4781-4795. doi: 10.21037/jtd-19-2813