RESEARCH PAPER

Effect Of Core Exercises With Diaphragmatic Breathing On Peak Expiratory Flow Rate And Abdominal Strength In Recreational Swimmers: A Randomized Controlled Trial

Rabia Sharief[1*], Ganesh B.R[2]

[1*]Post-Graduate Student, CVTS Physiotherapy, KLE Institute Of Physiotherapy, Belagavi-590010, Karnataka, India, Email ID: rabiasharief65@gmail.com ORCID ID: 0009-0000-9146-7148

[2]MPT, Ph.D Professor and Head of Department, CVTS Physiotherapy, KLE Institute Of Physiotherapy, Belagavi-590010, Karnataka, India, Email ID: ganeshbr@klekipt.edu.in, ORCID ID: 0000-0002-5235-1764

ABSTRACT

Background:

Swimming is a unique physical activity requiring coordinated interaction between respiratory mechanics and trunk stability for optimal performance and fatigue resistance [1,3]. Recreational swimmers often exhibit inadequate breathing patterns and poor core muscle endurance, which negatively affect stroke efficiency and performance[2,3] . Although diaphragmatic breathing and core strengthening have individually demonstrated benefits, evidence regarding their combined effect remains limited [2,9].

Objective:

To evaluate the effect of combined diaphragmatic breathing and core exercises on pulmonary function, abdominal strength, and swimming efficiency in recreational swimmers.

Methods:

A randomized controlled trial was conducted among 40 recreational swimmers aged 18-35 years. Participants were allocated into two groups: Group A (diaphragmatic breathing with core exercises) and Group B (core exercises alone). Outcome measures included Peak Expiratory Flow Rate (PEFR), Double Leg Lowering Test (DLLT), and SWOLF index. Pre and postintervention data were analyzed using paired and independent t-tests.

Results:

Group A demonstrated significant improvements in PEFR, DLLT, and SWOLF scores ($p<0.001$), whereas Group B showed minimal improvements. Between-group comparison revealed statistically significant superiority of Group A in PEFR and DLLT ($p<0.05$), with greater clinical improvement in SWOLF.

Conclusion:

The integration of diaphragmatic breathing with core exercises significantly enhances respiratory function, abdominal muscle strength, and swimming efficiency, suggesting a synergistic effect beneficial for recreational swimmers.

Keywords:

Diaphragmatic breathing, core strengthening, pulmonary function, recreational swimmers, peak expiratory flow rate, swimming efficiency.

How to cite this article: Sharief R, Ganesh BR. Effect of Core Exercises with Diaphragmatic Breathing on Peak Expiratory Flow Rate and Abdominal Strength in Recreational Swimmers: A Randomized Controlled Trial. Int J Drug Deliv Technol. 2026;16(60s):1579-1588. DOI: 10.25258/ijddt.16.60s.141

Source of support: Nil.

Conflict of interest: None

CTRI registration number - CTRI/2025/09/095257

INTRODUCTION

Swimming is a complex, whole-body activity that imposes unique physiological and biomechanical demands due to the aquatic environment, horizontal body positioning, and intermittent breathing patterns [1,3]. Unlike land-based activities, hydrostatic pressure restricts thoracic expansion and increases the workload on respiratory muscles, particularly the diaphragm and intercostal muscles[2,3]. These factors necessitate efficient coordination between breathing mechanics and trunk stability to maintain optimal performance.

Respiratory muscle fatigue is a significant limiting factor in swimming, leading to reduced ventilatory efficiency, increased dyspnoea, and early onset of fatigue[1,3]. Inadequate breathing patterns, such as shallow thoracic breathing or poor expiratory control, may disrupt stroke rhythm and reduce oxygen availability during swimming [3,5]. Recreational swimmers, who often lack structured breathing training, are particularly susceptible to these impairments [2,5].

Core musculature, comprising the diaphragm, abdominal muscles, pelvic floor, and spinal stabilizers, plays a central role in maintaining trunk stability and facilitating efficient force transmission during swimming [7,8]. Poor core stability results in increased drag, inefficient propulsion, and higher energy expenditure, ultimately compromising swimming performance[7,8]. Additionally, inadequate core strength may alter breathing mechanics by restricting

*Author for Correspondence: rabiasharief65@gmail.com

diaphragmatic movement and reducing respiratory efficiency [8,9].

The diaphragm functions as both a primary respiratory muscle and a key component of the core stabilization system [9]. During diaphragmatic breathing, coordinated activation of the diaphragm and abdominal muscles enhances intra-abdominal pressure regulation, improves spinal stability, and optimizes ventilation[5,9]. Previous studies have demonstrated that diaphragmatic breathing improves pulmonary function, reduces respiratory muscle fatigue, and enhances exercise performance [5,6].

Similarly, core strengthening exercises have been shown to improve respiratory parameters by enhancing expiratory muscle strength and ventilatory efficiency [1,9]. The interaction between respiratory and postural systems suggests that combining diaphragmatic breathing with core exercises may produce synergistic effects, improving both respiratory function and trunk stability [9].

Despite evidence supporting the individual benefits of these interventions, there is limited research examining their combined effects in recreational swimmers [2,8]. Therefore, the present study aims to evaluate the effect of combined diaphragmatic breathing and core exercises on peak expiratory flow rate, abdominal strength, and swimming efficiency.

METHODS

This randomized controlled trial was conducted among recreational swimmers recruited from swimming centers in Belagavi. The study was approved by the Institutional Ethics Committee, and all procedures were conducted in accordance with ethical guidelines.

A total of 40 participants aged 18 - 35 years were included based on predefined inclusion and exclusion criteria [5,7] . Participants were randomly allocated into two groups using a sealed envelope method to ensure allocation concealment.

Outcome measures included Peak Expiratory Flow Rate (PEFR), Double Leg Lowering Test (DLLT), and SWOLF index. PEFR is a reliable indicator of expiratory muscle strength and airway function ($r=0.97$) [10]. The DLLT assesses abdominal strength and lumbopelvic stability ($r=0.95$) [11,12]. The SWOLF index evaluates swimming efficiency by combining stroke count and time [13].

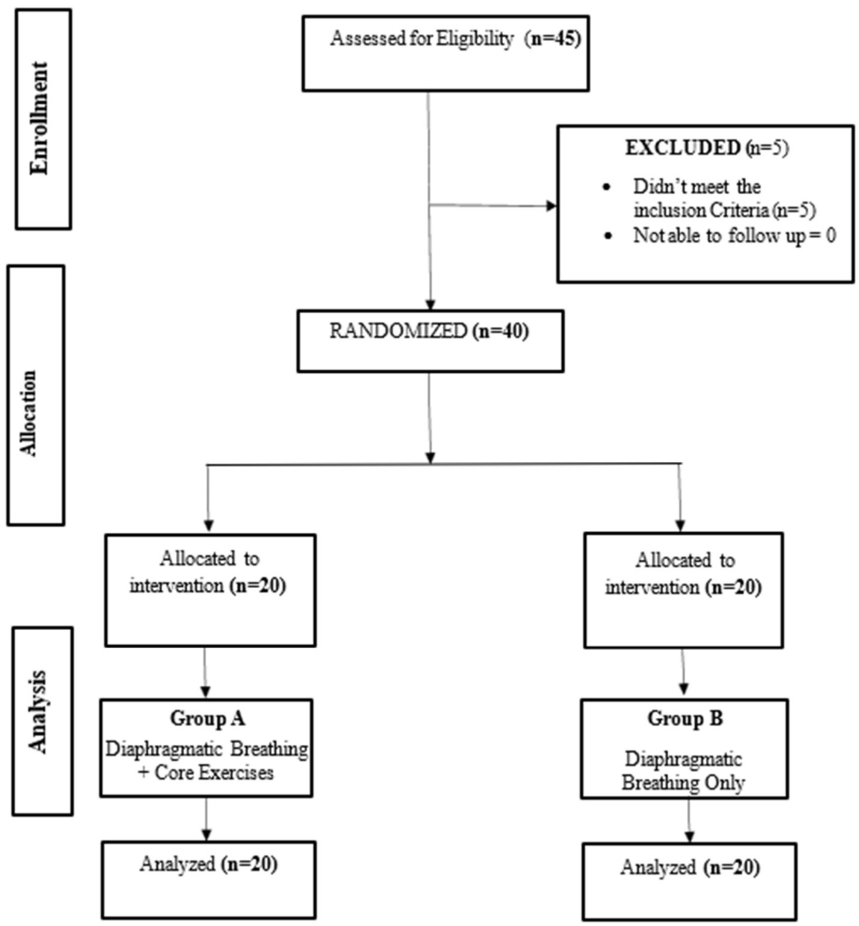
The intervention was conducted for four weeks, with sessions performed four times per week. Group A received diaphragmatic breathing combined with core exercises, while Group B performed core exercises alone. Diaphragmatic breathing involved controlled inhalation and prolonged exhalation to enhance diaphragmatic activation [5,6]. Core exercises included crunches and rotational crunches aimed at improving abdominal strength and trunk stability. [5,6]

Data were analyzed using SPSS software. Normality was assessed using the Shapiro–Wilk test. Paired t-tests were used for within-group analysis, and independent t-tests were used for between-group comparisons. Statistical significance was set at $p<0.05$.

PROCEDURE

After obtaining approval from the Institutional Ethics Committee and registration with the Clinical Trial Registry of India (CTRI), recreational swimmers meeting the inclusion criteria were recruited for the study. The purpose and procedure of the study were explained to all participants, and written informed consent was obtained prior to enrollment. Participants were randomly allocated into two groups using the sealed envelope method: Group A (Diaphragmatic Breathing with Abdominal Core Exercises) and Group B (Abdominal Core Exercises alone). Baseline assessments of Peak Expiratory Flow Rate (PEFR), abdominal strength using the Double Leg-Lowering Test, and swimming efficiency using the SWOLF Index were recorded before the intervention. Group A received diaphragmatic breathing training with 2–3 seconds of inspiration and 8–10 seconds of expiration combined with crunches and crunches with rotation (15 repetitions, 2 sets), while Group B performed only the abdominal core exercises with the same dosage. All intervention sessions were supervised by a physiotherapist and conducted over a four week period. Following completion of the intervention, all outcome measures were reassessed and compared with baseline values to determine the effectiveness of the intervention.

FIGURE 1- CONSORT CHART



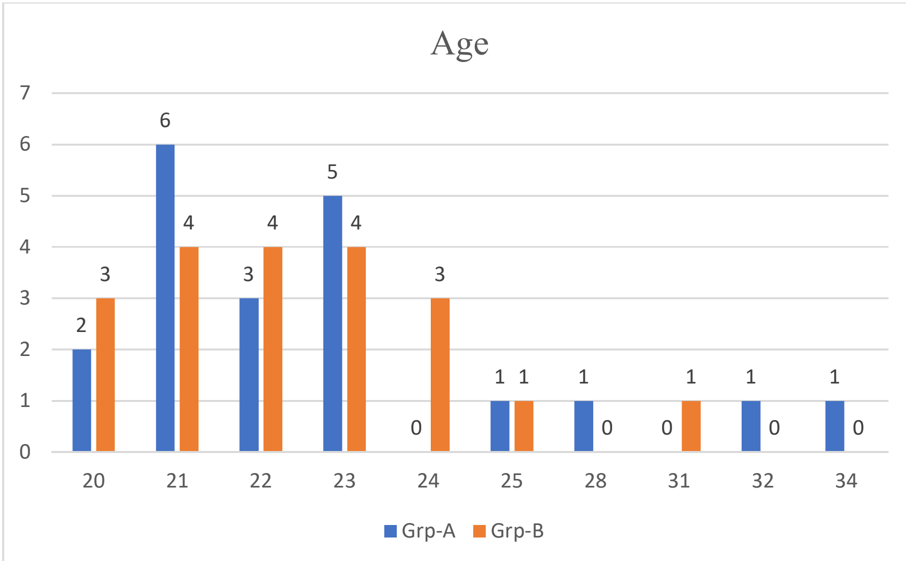
RESULTS

A total of 40 participants completed the study, with equal distribution between the two groups. Baseline characteristics, including age and gender distribution, were comparable between groups (p>0.05).

Table 1 : Age-wise Distribution of Participants in Both Groups

		Group		Total
		Grp-A	Grp-B	
Age	20.00	2	3	5
	21.00	6	4	10
	22.00	3	4	7
	23.00	5	4	9
	24.00	0	3	3
	25.00	1	1	2
	28.00	1	0	1
	31.00	0	1	1
	32.00	1	0	1
	34.00	1	0	1
Total		20	20	40

Graph 1 : Age Distribution of Participants in Group A and Group B



A total of 40 participants were included in the study, with 20 participants allocated to each group. The age of participants ranged from 20 to 34 years, with comparable distribution between Group A and Group B, indicating homogeneity at baseline (Table 1)

Graph 2 : Gender Distribution of Participants in Group A and Group B

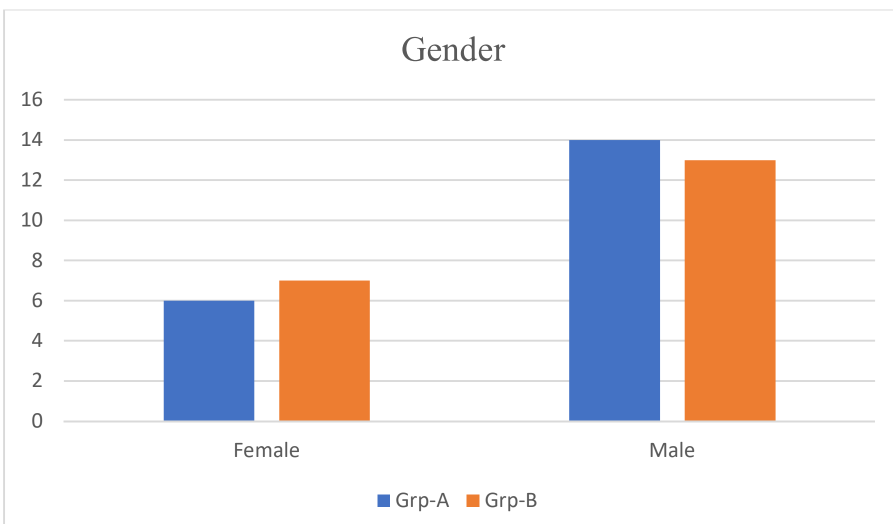


Table 2 : Gender Distribution between Group A and Group B

		Group		Total
		Grp-A	Grp-B	
Gender	Female	6	7	13
	Male	14	13	27
Total		20	20	40

Gender distribution was also similar between groups, with 6 females and 14 males in Group A and 7 females and 13 males in Group B (Table 2), suggesting no demographic bias between groups

Table 3 : Normality Test of Outcome Measures using Shapiro–Wilk Test

Variable	Time Frame	GROUP A		GROUP B	
		z-value	p-value	z-value	p-value
PEFR (L/min)	Pre	0.941	0.249	0.895	0.050
	Post	0.923	0.115	0.902	0.050
DLLT (Angle°)	Pre	0.946	0.314	0.912	0.068
	Post	0.925	0.121	0.915	0.079
SWOLF	Pre	0.856	0.050	0.878	0.050
	Post	0.879	0.050	0.879	0.051

The Shapiro–Wilk test demonstrated that all outcome variables followed normal distribution ($p > 0.05$), allowing the use of parametric tests for further analysis

Table 4 : Within-Group Comparison of Peak Expiratory Flow Rate in Group A and Group B (Paired t-test)

Group	Time Frame	Mean	SD	Mean Diff.	SD Diff.	Effect size	t-value	p-value
Group A	Pre	331.00	85.89	53.25	27.69	1.92	8.602	0.001
	Post	384.25	78.88					
	Pre	331.25	70.37					

Group A demonstrated a statistically significant increase in PEFR from 331.00 ± 85.89 L/min to 384.25 ± 78.88 L/min ($p = 0.001$), with a large effect size ($d = 1.92$).
In contrast, Group B showed a non-significant change from 331.25 ± 70.37 L/min to 323.65 ± 73.88 L/min ($p = 0.180$), with a small effect size ($d = 0.31$) .This indicates that diaphragmatic breathing combined with core exercises significantly enhances expiratory muscle performance.

Table 5 : Within group Pre and Post Test for Double Leg Lowering Test by paired sample test

Group	Time Frame	Mean	SD	Mean Diff.	SD Diff.	Effect size	t-value	p-value
Group A	Pre	51.60	5.88	21.30	4.60	4.63	20.704	0.001
	Post	30.30	6.98					
	Pre	54.25	7.12					

Group A showed a highly significant improvement in DLLT scores, decreasing from 51.60 ± 5.88° to 30.30 ± 6.98° ($p = 0.001$), with a very large effect size ($d = 4.63$) . Group B demonstrated a smaller improvement from 54.25 ± 7.12° to 53.25 ± 7.32° ($p = 0.021$), with a moderate effect size ($d = 0.56$).These findings suggest superior improvement in abdominal muscle strength and lumbopelvic control in Group A.

Table 6 : Within group Pre and Post Test for SWOLF by paired sample test

Group	Time Frame	Mean	SD	Mean Diff.	SD Diff.	Effect size	t-value	p-value
Group A	Pre	72.60	26.43	12.90	9.32	1.38	6.191	0.001
	Post	59.70	23.78					
	Pre	64.55	18.79					

Group A exhibited a significant reduction in SWOLF score from 72.60 ± 26.43 to 59.70 ± 23.78 ($p = 0.001$), with a large effect size ($d = 1.38$) .
Group B showed a smaller reduction from 64.55 ± 18.79 to 63.30 ± 19.17 ($p = 0.023$), with a moderate effect size ($d = 0.55$) .
This indicates improved swimming efficiency following the combined intervention.

Table 7 : Between-Group Comparison of PEFR (Independent t-test)

Variable	Time Frame	Group	Mean	SD	t-value	p-value
PEFR	Pre	Grp-A	331.00	85.89	0.010	0.992
		Grp-B	331.25	70.37		
	Post	Grp-A	384.25	78.88	**2.508**	**0.017**
		Grp-B	323.65	73.88		

No significant difference was observed at baseline (p = 0.992), confirming group comparability. However, post-intervention comparison showed a statistically significant difference (p = 0.017), with Group A demonstrating superior improvement.

Graph 3 : Pre and Post Comparison of PEFR in Group A and Group B

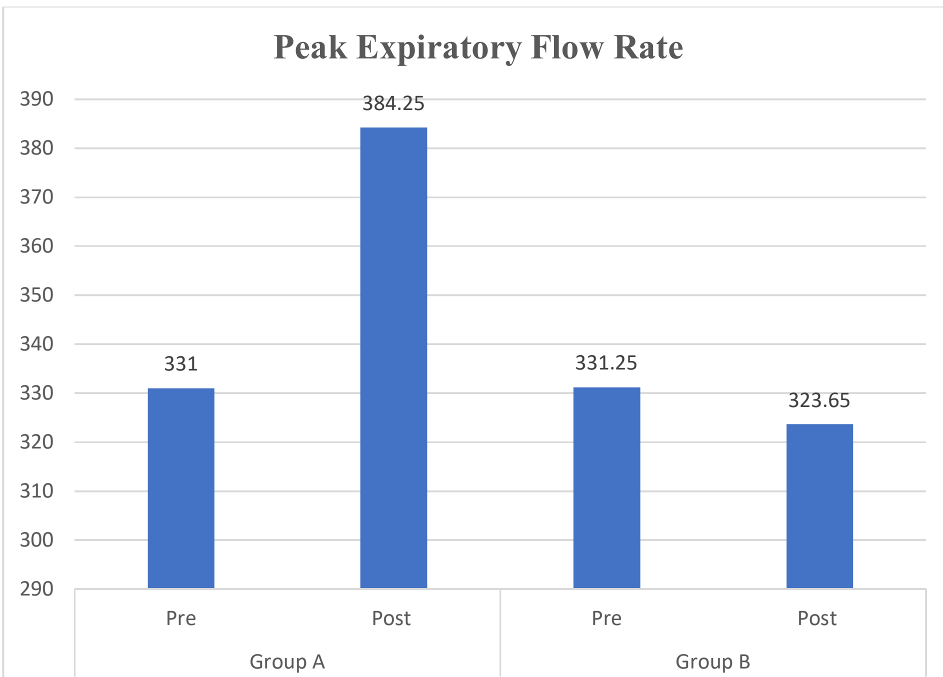


Table 8 : Between-Group Comparison of DLLT (Independent t-test)

Variable	Time Frame	Group	Mean	SD	t-value	p-value
DLLT	Pre	Grp-A	51.60	5.88	1.283	0.207
		Grp-B	54.25	7.12		
	Post	Grp-A	30.30	6.98	**10.147**	**0.001**
		Grp-B	53.25	7.32		

Baseline values were comparable (p = 0.207). Post-intervention comparison revealed a highly significant difference (p = 0.001), indicating greater improvement in Group A

Graph 4 : Pre and Post Comparison of DLLT in Group A and Group B

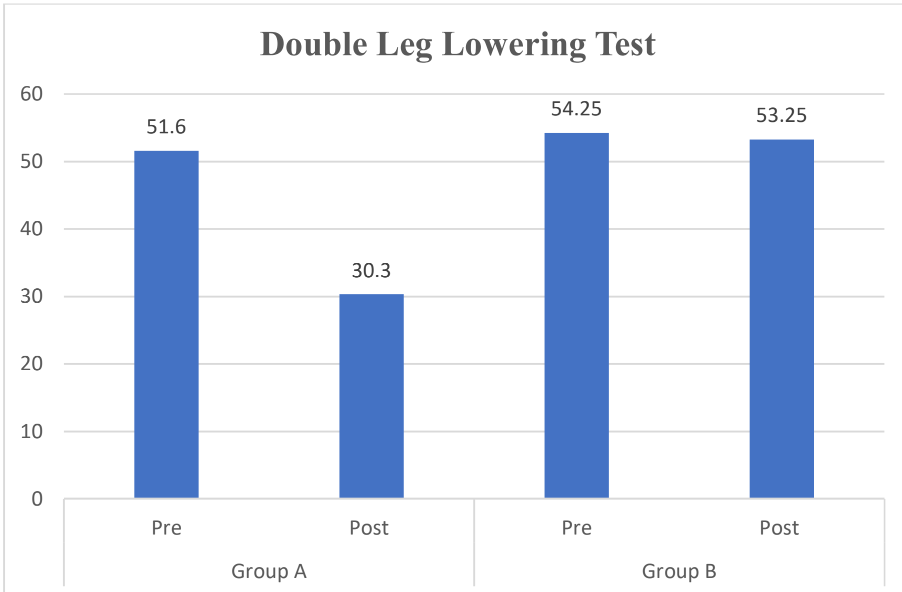


Table 9 : Between-Group Comparison of SWOLF Score (Independent t-test)

Variable	Time Frame	Group	Mean	SD	t-value	p-value
SWOLF	Pre	Grp-A	72.60	26.43	1.110	0.274
		Grp-B	64.55	18.79		
	Post	Grp-A	59.70	23.78	0.527	0.601
		Grp-B	63.30	19.17		

No statistically significant difference was observed between groups at baseline (p = 0.274) or post-intervention (p = 0.601).However, effect size analysis indicated clinically meaningful improvement in Group A.

Graph 5 : Pre and Post Comparison of SWOLF in Group A and Group B

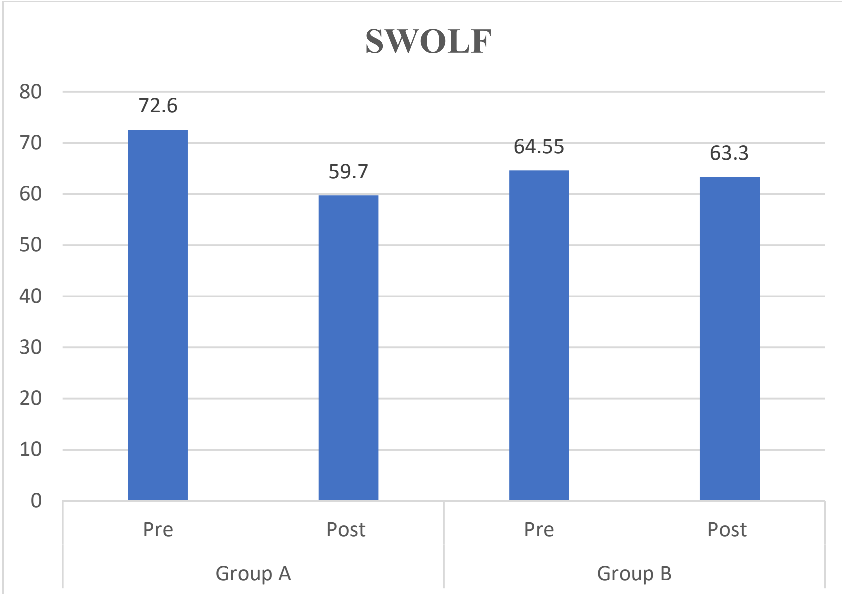


Table 10 : Comparison of Treatment Outcomes based on Effect Size (Cohen's d) (Clinical Significance)

Variable	Group	Effect size	Result
PEFR (L/min)	Group A is better	**1.92**	Group A is better
	Group B is better	0.31	
DLLT (Angle°)	Group A is better	**4.63**	Group A is better
	Group B is better	0.56	
	Group A is better	**1.38**	

Effect size analysis demonstrated that Group A showed substantially greater improvements across all outcome measures compared to Group B .
A large effect in PEFR (d = 1.92) indicates meaningful improvement in expiratory muscle strength and breathing efficiency, which is essential for effective ventilation during swimming. In contrast, Group B showed only a small effect (d = 0.31), suggesting limited respiratory benefit from core exercises alone.
A very large effect in DLLT (d = 4.63) reflects significant enhancement in abdominal strength and trunk stability, contributing to better body alignment and reduced drag in water. Group B showed only moderate improvement (d = 0.56).
A large effect in SWOLF (d = 1.38) indicates improved swimming efficiency through better coordination and stroke economy, whereas Group B demonstrated smaller gains (d = 0.55).
Overall, these findings suggest that combining diaphragmatic breathing with core exercises produces clinically meaningful improvements in respiratory function, core stability, and swimming performance, compared to core training alone.

DISCUSSION

The findings of the present study demonstrate that combining diaphragmatic breathing with core exercises results in significant improvements in pulmonary function, abdominal strength, and swimming efficiency in recreational swimmers.
The observed increase in PEFR indicates enhanced expiratory muscle strength and improved ventilatory efficiency [10]. This improvement may be attributed to increased diaphragmatic excursion and coordinated activation of respiratory muscles during breathing exercises [5,6]. Enhanced expiratory force facilitates more efficient ventilation during swimming, particularly during limited breathing intervals.
The significant improvement in DLLT scores reflects enhanced core stability and neuromuscular control[11,12]. Core muscles play a critical role in maintaining trunk alignment and facilitating efficient force transmission during swimming movements [7,8]. Improved abdominal strength contributes to better posture, reduced drag, and enhanced propulsion.
The reduction in SWOLF scores indicates improved swimming efficiency, likely resulting from better coordination between breathing patterns and stroke mechanics [13]. Efficient breathing reduces unnecessary muscular tension and optimizes oxygen delivery, thereby improving endurance and performance [3,16].
The synergistic effect observed in the intervention group can be explained by the integrated function of the diaphragm within the core stabilization system [9]. Coordinated activation of respiratory and postural muscles enhances both breathing efficiency and trunk stability, leading to improved functional performance.
These findings are consistent with previous studies demonstrating the effectiveness of respiratory muscle

training and core stabilization in improving athletic performance [1,5,17]. The present study extends this evidence by highlighting the combined effect of these interventions in recreational swimmers.

LIMITATIONS AND STRENGTHS

The present study has certain limitations that should be considered while interpreting the findings. The sample size was relatively small, which may limit the generalizability of the results to a wider population. The duration of the intervention was short (4 weeks), and therefore long-term effects and retention of improvements were not assessed. Environmental factors such as variations in pool conditions, training intensity, and participant effort could not be fully controlled. Additionally, the study focused on recreational swimmers, which may restrict the applicability of the findings to competitive or elite athletes. The absence of long-term follow-up and the lack of advanced pulmonary function tests beyond PEFR are further limitations.

Despite these limitations, the study has several strengths. It employed a randomized controlled trial design, enhancing the internal validity of the findings. The use of reliable and clinically relevant outcome measures such as PEFR, DLLT, and SWOLF allowed comprehensive assessment of respiratory function, core strength, and swimming efficiency. The intervention was simple, cost-effective, and easily reproducible in clinical and sports settings. Furthermore, the study addresses a relevant gap in the literature by evaluating the combined effect of diaphragmatic breathing and core exercises, providing valuable evidence for integrated training approaches in recreational swimmers.

CONCLUSION

The present study demonstrates that combining diaphragmatic breathing with core exercises significantly improves pulmonary function, abdominal strength, and swimming efficiency in recreational swimmers. This integrated approach provides a clinically relevant and performance-oriented intervention that can be incorporated into training and rehabilitation programs.

CONFLICT OF INTEREST AND FINANCIAL DISCLOSURE

Authors affirm that they do not have any conflicts of interest. Additionally, the authors themselves affirm that they did not obtain any funding for the research.

REFERENCES

1. Cavaggioni L, Ongaro L, Zannin E, Iaia FM, Alberti G. Effects of different core exercises on respiratory parameters and abdominal strength. J Phys Ther Sci. 2015 Oct;27(10):3249-53. doi: 10.1589/jpts.27.3249. Epub 2015 Oct 30. PMID: 26644685; PMCID: PMC4668176.
2. Ansari, Aarzoo Minnat and Dr. Anil Mishra. "EFFECT OF CORE EXERCISES WITH DIAPHRAGMATIC BREATHING ON PULMONARY FUNCTION AND ABDOMINAL ENDURANCE IN YOUNG HEALTHY FEMALES." (2022).
3. Sable M, Vaidya SM, Sable SS. Comparative study of lung functions in swimmers and runners. Indian J Physiol Pharmacol. 2012 Jan-Mar;56(1):100-4. PMID: 23029972.
4. Pescatello LS, American College of Sports Medicine: ACSM's Guidelines for Exercise Testing and Prescription. Lippincott Williams & Wilkins, 2013
5. Cavaggioni L, Ongaro L, Zannin E, Iaia FM, Alberti G. Effects of different core exercises on respiratory parameters and abdominal strength. J Phys Ther Sci. 2015 Oct;27(10):3249-53. doi: 10.1589/jpts.27.3249. Epub 2015 Oct 30. PMID: 26644685; PMCID: PMC4668176.
6. Ansari, Aarzoo Minnat and Dr. Anil Mishra. "EFFECT OF CORE EXERCISES WITH DIAPHRAGMATIC BREATHING ON PULMONARY FUNCTION AND ABDOMINAL ENDURANCE IN YOUNG HEALTHY FEMALES." (2022).
7. Sable M, Vaidya SM, Sable SS. Comparative study of lung functions in swimmers and runners. Indian J Physiol Pharmacol. 2012 Jan-Mar;56(1):100-4. PMID: 23029972.
8. Pescatello LS, American College of Sports Medicine: ACSM's Guidelines for Exercise Testing and Prescription. Lippincott Williams & Wilkins, 2013
9. Madou, T., Vanluyten, K., Martens, J., & Iserbyt, P. (2021). Assessment and Prediction of Swimming Performance Using the SWOLF Index. International Journal of Kinesiology in Higher Education, 7(1), 76–85.
10. Kyriakidou G, Tsalis G, Evaggelinou C. Impact of a Three-Month Training Break on Swimming Performance in Athletes with Intellectual Disability. Sports. 2024 Dec 2;12(12):330.
11. Zannotti CM, Bohannon RW, Tiberio D, Dewberry MJ, Murray R. Kinematics of the double-leg-lowering test for abdominal muscle strength. Journal of Orthopaedic & Sports Physical Therapy. 2002 Sep;32(9):432-6.
12. Sannicandro, I., Cofano, G., Rosa, R. "Core Stability in Swimming Performance: An Analysis Using the Double-Leg-Lowering Test." J Hum Kinet, 2014.
13. Moradi, M., Hadadnezhad, M., Letafatkar, A. et al. Efficacy of throwing exercise with TheraBand in male volleyball players with shoulder internal rotation deficit: a randomized controlled trial. BMC Musculoskelet Disord 21, 376 (2020).
14. Shei RJ. Respiratory muscle training and exercise performance. *Sports Medicine*. 2018.
15. Barbosa TM et al. Energetics and biomechanics as determinants of swimming performance. *Journal of Science and Medicine in Sport*. 2010.
16. Cordain L, Stager J. Pulmonary structure and function in swimmers. *Sports Medicine*. 1988.

17. Hibbs AE et al. Optimizing performance by improving core stability and core strength. *Sports Medicine*. 2008.
18. Reed CA et al. The effects of core stability training on athletic performance. *Journal of Strength and Conditioning Research*. 2012.
19. Maglischo EW. *Swimming Fastest*. Human Kinetics. 2003.
20. Hodges PW, Gandevia SC. Activation of the human diaphragm during a repetitive postural task. *J Physiol.* 2000;522(Pt 1):165–75.
21. Kolar P, Neuwirth J, Sanda J, Suchanek V, Svata Z, Pivec M, et al. Analysis of diaphragm movement during tidal breathing and during its activation while breath holding. *J Appl Physiol (1985).* 2009;107(4):1065–72.
22. Janssens L, McConnell AK, Pijnenburg M, Claeys K, Brumagne S. Inspiratory muscle training affects proprioceptive use and low back pain. *Med Sci Sports Exerc.* 2015;47(1):12–9.
23. West JB. *Respiratory Physiology: The Essentials.* 10th ed. Philadelphia: Wolters Kluwer; 2016.
24. McGill SM. *Low Back Disorders: Evidence-Based Prevention and Rehabilitation.* 3rd ed. Champaign (IL): Human Kinetics; 2016.
25. Illi SK, Held U, Frank I, Spengler CM. Effect of respiratory muscle training on exercise performance in healthy individuals: a systematic review and meta-analysis. *Sports Med.* 2012;42(8):707–24.