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Research Article

Effects of deep exercise on pulmonary function, perceived stress and physical fitness among healthy smokers: A randomized clinical trail

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ABSTRACT

Background: smoking cessation is the most effective strategy to reduce smoking-related health risks, not all smokers are ready or able to quit immediately given the known benefits of deep breathing exercises on lung function, stress reduction, and physical fitness.

Objective: to evaluate the effects of deep breathing exercises on lung function, perceived stress, and physical fitness in healthy smokers.

Method: A randomized controlled trial was conducted from June 2023 to December 2023. Twenty-six male smokers (20–30 years) with at least 5 years of smoking history were randomly divided into an experimental group, which received pursed lip breathing, diaphragmatic breathing, and powered breathing exercises for 6 weeks, and a control group without any intervention. A spirometer was used for pulmonary function, a perceived stress scale for stress, a six-minute walk test for physical fitness, and chest expansion, and Pittsburgh sleep quality index (PSQI) for sleep quality. Assessment was done at baseline after the second, fourth, and sixth weeks.

Result: The mean age of participants was 22.77±0.46 years, smoking duration was 6.80±0.36 years, and BMI was 23.93 ± 1.23. Baseline comparisons revealed no significant differences ($p \geq 0.05$) in FEV1, FVC, FEV1/FVC, PSS, and CE between groups; however, significant differences were observed in PEF, 6MWT, and PSQI ($p<0.05$). Following intervention, significant improvements ($p<0.05$) were noted in FEV1 and FVC at the 2nd, 4th, and 6th weeks in the experimental group. MANCOVA analysis for controlling the baseline differences, showed significant group differences in PSQI ($p<0.001$), PEF ($p = 0.001$), and 6MWT ($p<0.001$).

Conclusion: Deep breathing exercises positively affected lung function, perceived stress, and physical fitness in healthy smokers.

Keywords: Smoking, deep breathing exercises, pulmonary function, perceived stress, and physical fitness

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INTRODUCTION

Smoking is a major global health concern, contributing to various respiratory, cardiovascular, and metabolic disorders[1]. Despite well-known facts of its harmful effects, many individuals continue to smoke, often struggling with addiction and associated stress[2]. Smoking adversely affects pulmonary functions by decreasing lung capacity, impairing airway resistance, and leading to chronic inflammation[3]. Furthermore, smokers commonly experience elevated stress levels and decreased physical fitness due to the physiological burden exerted on the cardiovascular and respiratory systems[4].

Among approaches to alleviate the negative effects of smoking, lifestyle interventions such as deep breathing exercises (DBE) have gained attention. DBE is a simple, non-invasive, and cost-effective technique that has been associated with improvements in lung function, stress reduction, and enhanced overall physical fitness[5]. Several studies have shown that DBE can increase lung volume, improve airway resistance, and strengthen oxygen saturation levels[6,7]. Studies have also indicated that controlled breathing techniques improve autonomic balance by enhancing parasympathetic activity and reducing sympathetic overactivity, leading to stress reduction[8,9]. A study demonstrated that deep breathing training over eight weeks significantly improved Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) among smokers[10]. Similarly, diaphragmatic breathing exercises led to an increase in peak expiratory flow rates, suggesting improved airway clearance and respiratory efficiency[11].

A systematic review by Hopper et al. (2019) indicated that individuals practicing deep breathing techniques reported lower cortisol levels and improved psychological well-being[12]. Additionally, stress management interventions that incorporate breathing exercises have shown promising results in improving mood, reducing anxiety, and enhancing overall quality of life[9]. Practicing deep breathing techniques exhibited improved cardiovascular endurance and reduced resting heart rates, indicating better cardiorespiratory efficiency[13].

While smoking cessation remains the most effective strategy to reduce smoking-related health risks, not all smokers are ready or able to quit immediately given the known benefits of deep breathing exercises on lung function, stress reduction, and physical fitness. This study aims to provide evidence supporting their role in promoting health among smokers who continue to smoke. By investigating the impact of deep breathing exercises on pulmonary function, perceived stress, and physical fitness among healthy smokers, this study's objective is to provide valuable insights for developing preventive and rehabilitative strategies in respiratory and public health domains.

METHODOLOGY

Design: This randomized controlled trial (RCT) (NCT06032793) was conducted at Riphah College of Rehabilitation Sciences from June 2023 to December 2023. Ethical approval (REC/MS-PT/01656) was obtained from the research ethics committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad.

Participants: Males aged 20–30 years who were healthy smokers with a smoking history of at least 5 years without any chronic pulmonary complication and willing to participate were included in the study. Smokers with any pulmonary disease, acute infections, other systemic disease chest deformity or any disability, history of any surgery, and not willing to participate were excluded from the study. Nonprobability convenience Sampling was used for data collection.

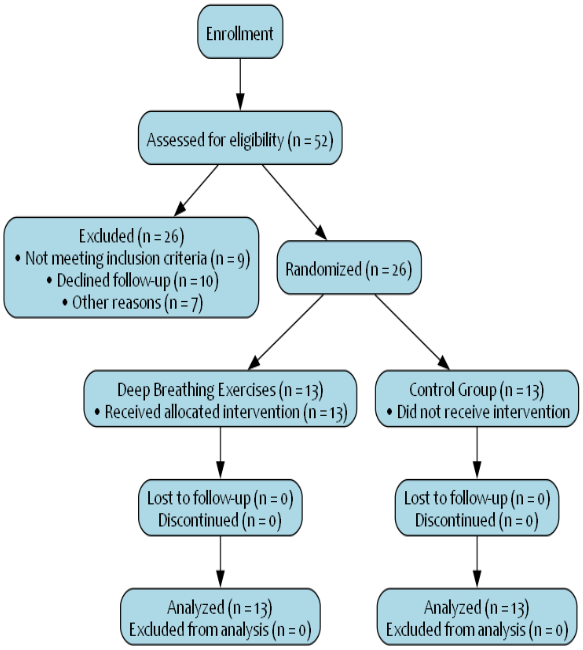

Figure 1 CONSORT diagram

Sample size: The sample size was n=26 calculated by the G power formula ANOVA with repeated measures used to evaluate associations within groups with a statistical power of 0.95, a chance of error of 0.05, and an effect size of 0.25. The calculated sample size is 13 per group. A total of n=52 participants were screened for eligibility, and n=26 were excluded due to a lack of fulfilment of the eligibility criteria. The n=26 participants were then randomly divided into control (n=13) and experimental (n=13) groups using the flip coin method. (Figure 1)

Outcome measures: Subjects were assessed at baseline after the second, fourth, and sixth weeks. Assessment is done by measuring lung capacity using a spirometer (ICC=0.75)[14], stress is measured using a Perceived Stress Scale[15], six-minute walk test (ICC=0.94 and 1.00) for physical fitness. The chest expansion was measured at the upper (under the armpits), middle (at the nipple line), and lower chest (near the bottom of the rib cage). The patient first took a few normal breaths, and then fully exhaled. After that, they took a deep breath in and held it briefly. The difference in chest size between full exhalation and full inhalation was measured using a measuring tape. Chest expansion at all three levels was within the normal range (2–5 cm), and the average of the three measurements was used for data analysis[16]. Sleep Quality Questionnaire (PSQI Questionnaire) The PSQI was developed to assess sleep quality all in the population (ICC=0.83) [17].

Randomization & blinding: The randomization was done by research coordinator using the sealed envelope method, number generator was also used to ensure random allocation. before the trial, sealed envelope containing cards indicating the intervention group were prepared. To administer the intervention, treating physical therapist opened envelope for each participant after obtaining written informed consent. The study was single blinded as the assessing physical therapists were blinded to the allocated intervention.

Intervention: Experiment group received pursed lip breathing (PLB), diaphragmatic breathing (DB), and powered breathing exercise (PBE) type of breathing exercise each treatment session usually consists of 10-15 consecutive breaths repeated 3-4 times a day, with a few seconds pause between each set for period of 6 weeks (table 1) and control group did not receive breathing exercise.

Table 1: Detail intervention protocol

	Pursed Lip Breathing	Diaphragmatic Breathing	Powered Breathing
Technique	Participants were instructed to inhale through the nose while keeping the lips closed, ensuring no air entered through the mouth. Exhalation was also done through the nose in a controlled manner.	Participants were guided to place one hand on the chest and the other just below the ribcage. They inhaled slowly through the nose, focusing on moving the stomach outward against the hand, followed by tightening the abdominal muscles during a slow exhalation through pursed lips.	Participants were taught to inhale forcefully while performing upward arm movements, followed by a forceful exhalation coordinated with downward arm movements.
Frequency/day	3-4 /day		
Repetition	10 -15		
Duration of Protocol	6 weeks		

Statistical analysis: The data analysis employed in this study utilized SPSS version 25. The $p<0.05$ indicated a significant interaction within groups at different time intervals. The effect size was estimated using partial Eta square (np^2), with values of <0.01, <0.06, and >0.15 representing small, medium, and large effect sizes, respectively. Following mixed ANOVA, within-group analysis utilized Repeated Measures ANOVA, and between-group comparison was done with an independent t-test. The MANCOVA was also applied to control the baseline differences in sleep quality (PSQI), PEF (%), and 6-MWT.

RESULTS

The average age of the subjects who received deep breathing exercises was 23.07±0.39 years and for those who did not receive breathing exercises; their mean age was 22.46±0.51 years. Smoking duration in the experimental group was 7.46±0.33 and in the control group, the mean was 6.15±0.38. The average BMI in the experimental group was 24.29±1.56 and in the control group it was 23.56±0.90.

In mixed ANOVA As the sphericity was not assumed, the Greenhouse-Geisser values showed that there is significant interaction effect between interventions and time factor assessment in all domains FEV {F=20.065 (2.4,57.8), p=.000, np^2=0.455}, FVC {F=11.793(2.14,51.4), p<0.001, np^2=0.329}, PEF{F=2.986(2.8,67.2), p=0.040, np^2=0.111}, FEV1/FVC{F=2.223(2.22,53.3), np^2=0.085}, PSS{6.68 (2.77,66.6), p=0.57, np^2=0.110}, 6MWT {F= 9.615(1.64.39.6), p=0.001, np^2=0.286}, chest expansion {F=11.90(1.47, 35.37), p<0.001, np^2=0.33}, and PSQI {F=74.308(2.35,56.53), p<0.001, np^2=0.756}.

The Repeated Measures ANOVA (RM ANOVA) results revealed that pulmonary function indicators, including FEV1, FVC, and PEF, showed marked improvement in the experimental group across all four time points. Notably, FEV1 improved significantly with a large effect size ($p<0.001$, $\eta p^2=0.67$) by the 4th and 6th weeks. Chest expansion also increased significantly ($p<0.001$, $\eta p^2=0.77$) at each time point with effect size. Physical fitness, assessed through the 6-Minute Walk Test (6MWT), demonstrated a significant increase by the 6th week ($p=0.01$), reflecting improved endurance. Additionally, perceived stress levels, measured using a perceived stress scale, significantly ($p<0.001$, $\eta p^2=0.94$) decreased at all post-baseline assessment levels, supported by a large effect size. In contrast, in the control group, most respiratory measures, such as FEV1, FVC, and PEF, remained unchanged ($p=1.00$). A significant decrease in FVC was observed by the 6th week ($p<0.001$, $\eta p^2<0.06$) with small to medium effect sizes in the control group reflecting negligible physiological changes. Pairwise comparisons confirmed early and progressive improvement in the experimental group FEV1 and perceived stress began to improve by the 2nd week ($p=0.06$ and $p<0.001$, respectively), with chest expansion also increasing significantly ($p<0.001$). These improvements became more pronounced from the 2nd to 4th week and peaked between the 4th and 6th week across most measures, including 6MWT ($p=0.01$) and chest expansion ($p<0.001$). Conversely, the control group experienced a decline in physical performance (6MWT, $p<0.001$) and pulmonary ratios like FEV1/FVC ($p<0.001$). (Table 2)

Table 2: Within group changes in study variables

		Experimental (n=13)					Control (n=13)				
		Mean	SD	p-value	F(df)	np^{2}	Mean	SD	p-value	F(df)	np^{2}
FEV1	Baseline	67.61	25.	0.06^{a}	24.94 (2.12,2.06)	0.67	56.15	23.83	1.00^{a}	0.614 (2.06,2.12)	0.04
	After 2nd Week	91.53	26.35	0.20^{b}			57.46	22.12	1.00^{b}		
	After 4th Week	114.53	22.51	0.00***^{c}			52.53	18.45	1.00^{c}		
	After 6th Week	139.53	20.91	0.00***^{d}			49.92	17.28	0.55^{d}		
FVC	Baseline	85.69	26.38	1.0^{a}	4.99 (1.43,1.63)	0.29	86.38	42.17	0.124^{a}	9.66 (1.63,1.43)	0.44
	After 2nd Week	90.61	23.92	0.23^{b}			53.30	23.66	1.00^{b}		
	After 4th Week	106.30	27.22	0.83^{c}			45.53	15.83	1.00^{c}		
	After 6th Week	128.40	49.95	0.**19**^{d}			41.61	14.56	0.00***^{d}		
PEF	Baseline	39.23	14.56	0.17^{a}	8.39 (2.77,2.59)	0.41	26.38	16.11	0.119^{a}	3.25 (2.59,2.77)	0.21
	After 2nd Week	56.69	24.30	1.00^{b}			41.15	20.25	1.00^{b}		
	After 4th Week	65.53	24.62	1.00^{c}			37.23	14.30	1.00^{c}		
	After 6th Week	73.76	19.74	0.00***^{d}			38.07	13.11	0.04*^{d}		
FEV1/FVC	Baseline	72.61	23.94	1.00^{a}	1.73 (2.20,1.85)	0.12	59.15	24.83	0.01**^{a}	16.66 (1.85,2.20)	0.58
	After 2nd Week	83.69	19.49	1.00^{b}			92.84	16.90	1.00^{b}		
	After 4th Week	87.46	20.51	1.00^{c}			94.69	9.84	1.00^{c}		
	After 6th Week	89.88	14.94	0.19^{d}			98.38	1.60	0.00***^{d}		
PSS	Baseline	2.00	0.00	0.00***^{a}	1.24 (1.58,2.40)	0.09	2.07	0.27	1.00^{a}	2.18 (2.40,1.58)	0.15
	After 2nd Week	2.00	0.00	0.99^{b}			2.15	0.37	0.99^{b}		
	After 4th Week	1.84	0.37	1.00^{c}			2.30	0.48	0.49^{c}		
	After 6th Week	1.92	0.277	0.30^{d}			2.07	0.49	0.12^{d}		
6MWT	Baseline	648.46	123.1	1.00^{a}	5.84 (1.44,2.24)	0.32	763.23	116.60	1.00^{a}	7.29 (2.24,1.44)	0.37
	After 2nd Week	597.76	192.9	0.34^{b}			746.15	116.87	1.00^{b}		
	After 4th Week	699.53	96.70	0.08^{c}			726.84	95.28	0.14^{c}		
	After 6th Week	752.84	94.56	0.01**^{d}			698.38	92.66	0.00***^{d}		
Chest Expansion	Baseline	3.42	0.62	1.00^{a}	41.03 (1.66,19.98)	0.77	3.30	0.61	1.00^{a}	0.44 (1.26,15.16)	0.08
	After 2nd Week	3.46	0.61	0.00***^{b}			3.28	0.62	0.79^{b}		
	After 4th Week	3.72	0.60	0.01**^{c}			3.21	0.54	1.00^{c}		
	After 6th Week	3.90	0.64	0.00***^{d}			3.26	0.54	0.55^{d}		
PSQI	Baseline	47.60	6.51	0.00***^{a}	187.65 (2.06,2.20)	0.94	40.73	9.38	1.00^{a}	0.28 (2.20,2.06)	0.02
	After 2nd Week	36.56	4.49	0.00***^{b}			38.86	7.19	1.00^{b}		
	After 4th Week	17.50	3.23	0.00***^{c}			40.02	8.15	1.00^{c}		
	After 6th Week	12.68	1.76	0.00***^{d}			40.25	7.87	0.77^{d}		

Significance Level: p<0.05, p<0.01**, p<0.001****

Baseline vs. week 1st; ^{b}week 1st vs. 2nd week; ^{c}2nd week vs. week 3rd; ^{d}3rd week vs. 4th week; ^{e}Baseline vs. 4th week; 6MWT- Six Minute Walk Test; FEV1-Forced Expiratory Volume; PEF-Peak Expiratory Flow; PSS-Perceived Stress Scale; PSQI-Pittsburgh Sleep Quality Index; ηp^{2}-partial eta-squared; SD-Standard Deviation

Between groups comparison showed that there was no statistically significant difference ($p≥0.05$) in the bassline measurements of the FEV1, FVC, FEV1/FVC, PSS, and CE. However, there was a statistically significant difference ($p<0.05$) in the baseline values of PEF, 6MWT and PSQI. After the deep breathing exercises, at 2nd, 4th and 6th weeks, there was a statistically significant difference ($p<0.05$), in all the measurements of only FEV1 and FVC. (table 3)

The Multivariate analysis of covariance showed significant group differences found PSQI (Pillai's Trace=.886, $p<0.001$, $\eta^2=0.886$), PEF (Pillai's Trace=0.516, $p=0.001$, $\eta^2=0.516$) and 6MWT (Pillai's Trace=0.612, $p<0.001$, $\eta^2=0.612$) indicating the experimental group improved more across all time points after adjusting for baseline values. The Univariate analysis showed that sleep quality was significantly improved in experimental group than control after each assessment level. While PEF showed significant ($p<0.05$) improvement after the 4th and 6th Week. The 6MWT only improved significantly ($p<0.001$) in experimental group after the 6th Week. (Table 4)

Table 3: Comparison between groups

		Experimental (n=13)		Control (n=13)			
		M	SD	M	SD	MD	p-Value
FEV1	Baseline	67.61	25.	56.15	23.83	11.46	0.243
	After 2nd Week	91.53	26.35	57.46	22.12	34.07	0.002***
	After 4th Week	114.53	22.51	52.53	18.45	62.00	0.000***
	After 6th Week	139.53	20.91	49.92	17.28	89.61	0.000***
FVC	Baseline	85.69	26.38	86.38	42.17	-0.69	0.960
	After 2nd Week	90.61	23.92	53.30	23.66	37.30	0.001***
	After 4th Week	106.30	27.22	45.53	15.83	60.76	0.000***
	After 6th Week	128.40	49.95	41.61	14.56	86.79	0.000***
FEV1/FVC	Baseline	72.61	23.94	59.15	24.83	13.46	0.172
	After 2nd Week	83.69	19.49	92.84	16.90	-9.15	0.213
	After 4th Week	87.46	20.51	94.69	9.84	-7.23	0.263
	After 6th Week	89.88	14.94	98.38	1.60	-8.50	0.053
PSS	Baseline	2.00	0.00	2.07	0.27	-1.76	0.063
	After 2nd Week	2.00	0.00	2.15	0.37	-3.23	0.050*
	After 4th Week	1.84	0.37	2.30	0.48	-7.38	0.000***
	After 6th Week	1.92	0.27735	2.07	0.49	-6.30	0.000***
CE	Baseline	3.42	0.62	3.30	0.62	0.14	0.62
	After 2nd Week	3.46	0.62	3.28	0.63	0.18	0.49
	After 4th Week	3.72	0.60	3.21	0.53	0.38	0.031*
	After 6th Week	3.90	0.64	3.27	0.54	0.56	0.012*

Significance Level: $p<0.05$, $p<0.01$**, $p<0.001$*

CE-Chest Expansion; FEV1-Forced Expiratory Volume in 1 second; FEV1/FVC-Forced Expiratory Volume in 1 second to Forced Vital Capacity ratio; FVC-Forced Vital Capacity; MD- Mean Difference; PSS-Perceived Stress Scale; ηp^2-partial eta-squared; SD-Standard Deviation

Table 4: Comparison between group while controlling baseline differences PSQI, PEF & 6MWT

	Descriptive Stats	2nd Week (M±SD)	4th Week (M±SD)	6th Week (M±SD)
Sleep Quality (PSQI)	Experimental Group	36.57 ± 4.49	17.51 ± 3.23	12.68 ± 1.76
	Control Group	38.87 ± 7.20	40.02 ± 8.15	40.25 ± 7.88
	Univariate Effects	-	-	-
	F	6.89	119.01	160.29
	p-value	0.015*	0.00***	0.00***
	ηp^2 (Effect Size)	0.231	0.838	0.875
Peak Expiratory Flow (%)	Experimental Group	56.69 ± 24.30	65.54 ± 24.63	73.77 ± 19.74
	Control Group	41.15 ± 20.25	37.23 ± 14.31	38.08 ± 13.11
	Univariate Effects	-	-	-
	F	1.09	8.22	23.78
	p-value	0.307	0.009**	0.00***
	ηp^2 (Effect Size)	0.045	0.263	0.508
6-Minute Walk Test	Experimental Group	597.77 ± 192.99	699.54 ± 96.71	752.85 ± 94.56
	Control Group	746.15 ± 116.87	726.85 ± 95.29	698.38 ± 92.67
	Univariate Effects	-	-	-
	F	1.26	3.75	30.96
	p-value	0.273	0.065	0.00***
	η^2	0.052	0.140	0.574

Significance Level: $p<0.05$, $p<0.01$**, $p<0.001$*

M-Mean; PSQI-Pittsburgh Sleep Quality Index; SD-Standard Deviation; η^2- Eta Squared

DISCUSSION

This study aimed to determine the effects of deep breathing exercises on pulmonary functions, perceived stress, physical fitness, and sleep quality in healthy smokers. The intervention was incorporated over six weeks. The results suggested that structurally incorporated deep breathing exercises induced significant physiological and psychological benefits, in contrast to the control group. These findings support the growing body of preventive evidence for the management of smoking's negative effects through non-pharmacological, mind-body interventions.

The significant improvements observed in forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF) in the experimental group highlight the restorative potential of deep breathing on lung function. These findings align with Choudhry et al. (2024), who reported improved pulmonary metrics in individuals practicing yogic breathing[18]. A study also demonstrated that diaphragmatic breathing enhances lung compliance and alveolar ventilation, even in asymptomatic smokers[19]. The mechanisms may include improved airway clearance, increased pulmonary surfactant activity, and strengthened respiratory musculature, especially the diaphragm and intercostal[20]. Furthermore, sustained breathing practice likely counteracts the Broncho-constrictive and inflammatory effects of nicotine, thus reversing early smoke-related respiratory compromise [21]. The lack of improvement in the FEV1/FVC ratio, despite significant gains in absolute volumes, reflects a proportional increase in both inspiratory and expiratory capacities. This ratio remains a stable diagnostic tool for identifying COPD, and since the study population consisted of healthy smokers. A study conducted by Abid et al. reported the same findings in healthy similar after two weeks intervention of similar intervention protocol[6].

The deep breathing group experienced a substantial reduction in Perceived Stress Scale (PSS) scores, consistent with prior studies highlighting the psychophysiological benefits of slow, deep[22,23, 24,25]. Deep breathing reduces stress through modulation of the hypothalamic-pituitary-adrenal (HPA) axis, reduction of sympathetic drive, and activation of baroreceptor reflex pathways that calm the brain's stress circuits[9,26]. Importantly, improvements were observed as early as the second week, suggesting that deep breathing induces a rapid change in the balance of the autonomic nervous system[27]. Chronic stress triggers smoking behaviour, and its reduction may contribute indirectly to efforts for smoking cessation[28]. So, incorporating the grating deep breathing into smoking cessation programs may provide dual benefits reducing nicotine dependence and alleviating stress[29].

Improvements in the 6-Minute Walk Test (6MWT) distance observed only in the experimental group suggest a clear enhancement in functional capacity and endurance [30]. Deep breathing may improve oxygen uptake efficiency, reduce the work of breathing, and enhance peripheral oxygen delivery, thereby enabling participants to walk longer distances[31,32]. The gradual increase in chest expansion, particularly evident by week four, supports the development of thoracic mobility and respiratory muscle efficiency. This is an important indicator of ventilator reserve capacity, especially in smokers, whose chest wall mechanics often become restricted over time due to chronic low-grade inflammation and postural changes [33]. In contrast, the control group showed a decline in 6MWT performance and chest expansion, likely to reflect the natural progression of deconditioning associated with continued smoking and sedentary lifestyles[34].

The significant improvements in Pittsburgh sleep quality index (PSQI) scores highlight the potent impact of deep breathing on sleep quality [35]. Poor sleep in smokers has been linked to nicotine's stimulating effects, nocturnal withdrawal symptoms, and increased oxidative stress [36]. Deep breathing exercises, especially before bedtime, likely promote parasympathetic dominance, reduce arousal levels, and lower sleep latency[37].

Similar outcomes have been documented in interventions using mindfulness meditation, yogic breathing, and progressive relaxation, has shown improvements in subjective and objective sleep parameters[38,39,40]. The consistency of our results with these studies emphasizes the therapeutic role of respiratory-based practices in sleep management, particularly in populations at risk of sleep disturbances.

Repeated measures and multivariate analysis revealed that most improvements were time-dependent and intervention-specific, with the experimental group consistently outperforming controls. Particularly, PSS and chest expansion showed significant changes as early as week two, while FEV1, FVC, and PSQI demonstrated greater improvements by weeks four and six, indicating cumulative and compounding benefits of consistent breathing practice[7,41].

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The absence of improvements or the deterioration in parameters among controls strengthens the attribution of observed effects to the breathing intervention itself, rather than external influences or the passage of time.

CONCLUSION

The deep breathing exercises significantly enhance respiratory function, reduce perceived stress, and improve overall physical fitness in healthy smokers. Clinically, incorporating structured breathing interventions as a preventive strategy for smokers to enhance lung function and manage stress levels effectively. Ongoing participation and follow-up are recommended to sustain these benefits long-term. These exercises could delay the onset of chronic obstructive pulmonary disease (COPD), cardiovascular conditions, and neuroendocrine dysregulation. The findings highlight the potential benefits of incorporating low-cost, easily accessible, non-pharmacological interventions exercises into smokers' rehabilitation, aimed at addressing both respiratory health and well-being. Further research is encouraged to examine the long-term effects and widespread use of these exercises.

DECLARATIONS & STATEMENTS

Author's Contribution

TN: substantial contributions to the conception and design of the study.
TN: acquisition of data for the study.
BA, FA and SS: interpretation of data for the study.
TN and FA: analysis of the data for the study.
TN, FA and SS: drafted the work.
TN, BA, FA and SS: revised it critically for important intellectual content.
TN, BA, FA and SS: final approval of the version to be published and agreement to be accountable for all aspects.
of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The study was conducted after the approval from the research and ethical committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad. Pakistan (REC/MS-PT/01656).

AI Use Statement

No AI was used for content generation, data analysis, or interpretation.

Consent Statement

Written informed consent was obtained from all participants of the study.

Data Availability Statement

Due to privacy the data presented in this study are available upon request from the corresponding author, as they are not publicly accessible.

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Conflicts of Interest

The authors declare no conflict of interest.

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No funding was involved in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Research Article

Effects of treadmill training on motor function balance and spasticity reduction in children with cerebral palsy: A randomized clinical trail

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ABSTRACT

Background: Cerebral palsy (CP) is the leading cause of childhood motor disability, often associated with impaired, poor balance and spasticity, which limits daily activities and reduces quality of life. Treadmill training has emerged as a promising therapeutic intervention aimed at enhancing these impairments.

Objective: To evaluate the effects of treadmill training on motor function, balance, and Spasticity in Spastic CP children

Methods: The randomized control trial was conducted at Helping Hand Comprehensive Physical Rehab Centre, Lower Dir, from June 2024 to January 2025. A total of n=36 children with spastic CP aged 4-12 with GMFCS levels I and II were included in the study. The GMFCS, pediatric balance scale (PBS), and modified Ashworth scale (MAS) were used to assess motor function, balance, and spasticity. Out of n=36 CP children, n=18 individuals received treadmill training along with conventional therapy, and n=18 received conventional therapy only. The assessments were done at the beginning, after 4 weeks, 8 weeks, and 12 weeks of training.

Results: The mean age of 8.17±2.21 years, having 42.6% male and 24.15% female. A non-significant interaction effect between intervention and time effect on spasticity {$F(3,102)=0.81$, $p=0.489$, $\eta p^2=0.02$} measured by modified Ashworth scale. While in PBS {$F(3,102)=36.41$, $p=0.489$, $\eta p^2=0.517$} significant interaction effect observed. Regarding motor functions, the Friedman test did not indicate overall significant ($p \geq 0.05$) change in GMFCS scores over time in both the experimental and control groups, and Wilcoxon signed-rank tests also confirmed insignificant ($p \geq 0.05$) changes between adjacent time points.

Conclusion: Progressive treadmill protocol when combined with conventional therapy, can produce clinically meaningful improvements in balance and spasticity in children with CP, even though it may not alter gross motor function classification in the short term.

Keywords: balance; cerebral palsy; motor function; spasticity; treadmill training.

Clinical Trail #: NCT06463301

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INTRODUCTION

Cerebral palsy (CP) is a non-progressive group of permanent movement disorders and the leading cause of childhood motor disability, often associated with impaired motor function, poor balance, and spasticity[1]. These impairments significantly limit a child's ability to perform daily activities and reduce their quality of life[2]. Cerebral palsy (CP) is attributed to factors such as birth asphyxia, maternal anemia, and pregnancy-induced hypertension[3]. The prevalence of Cerebral palsy affects approximately 1.7 million people globally. While with limited demographic data in Pakistan, A study in Karachi revealed a male-to-female ratio of 1.4:1, with prevalent cases of spastic tone (53.4%)[4].

There are several therapeutic approaches for treating spasticity in children with non-progressive chronic encephalopathy[5, 6]. Physiotherapy improves function, posture, balance, and gait in cerebral palsy and effective intervention requires careful assessment of impairments. The strategies should be focused on improving activity rather than solely reducing impairments[7, 8]. The combination of SPT and Partial Body Weight-Supported Treadmill Trainingrtial Body Weight-Supported Treadmill Training (PBWSTT improves gross motor function[9, 10].

Treadmill training has emerged as a promising therapeutic intervention aimed at enhancing motor function, improving balance, and reducing spasticity in children with CP[11]. The rhythmic, repetitive nature of treadmill walking stimulates neuroplasticity, encourages more normal gait patterns, and facilitates improvements in lower limb coordination and strength. Additionally, treadmill training can provide a safe, controlled environment to practice weight-bearing and stepping, which are critical for functional mobility[12]. While traditional physical therapy remains the cornerstone of CP management[13].

There is growing interest in treadmill training as a task-specific intervention, that can potentially offer greater functional improvements. Although previous studies have investigated treadmill training in children with cerebral palsy, most research has been limited by small sample sizes, and high-quality randomized clinical trial evidence specifically examining how training affects motor function, balance, and spasticity simultaneously. The current study to evaluate the effects of treadmill training on motor function, balance, and Spasticity in Spastic CP children

MATERIALS AND METHODS

Study Design: Participants: The approval obtained from the research and ethical committee of the Faculty of Rehabilitation and Allied Health Sciences Islamabad (RIPHAH/FR&AHS/letter-01826) and institutional head of Helping Hand Institute of Rehabilitation Sciences, in Lower Dir Talash from January to June 2024. The children diagnosed with cerebral palsy, aged between 04-12 years, having I or II levels of dependency on GMFCS with will cognitive abilities moreover the children misdiagnosis of CP, mental retardation, other neurological abnormalities, uncontrolled seizures, prior similar training, multiple contractures, significant respiratory issues, use of muscle relaxants, and hearing or communication problems were excluded from the study. A non-probability convenient sampling technique was used for sample collection.

Interventions: The eligible participants were randomly allocated in a 1:1 ratio into the treadmill training group (group A, n=18) and the conventional physical therapy group (group B, n=18). The participants received both intervention over 12 weeks, and outcomes assessment was done at baseline, week 4, week 8, and week 12.

Group A (Treadmill Training+Conventional Therapy): Participants in the experimental group received treadmill training in addition to conventional physical therapy. The treadmill intervention was based on the FITT principle, with progressive increases in speed, duration, and intensity across the 12 weeks. As a supportive harness system was not available, two trained physical therapists were present during each session to ensure safety. One therapist stood behind the child and the other at the side, assisting in balance, posture correction, and fall prevention. Participants were instructed to treadmill's parallel bars for added support. A mirror placed in front of the treadmill provided visual feedback to encourage upright posture and correct gait mechanics. Verbal cues were given throughout the sessions to guide and motivate the children.

Group B (Conventional Therapy Only): Group B received conventional physical therapy only, which included core stability exercises, sustained stretching, Weight-bearing exercises for upper and lower limbs, Balance and coordination training, strengthening exercises for upper and lower limbs, Gait training using parallel bars and standing frame

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activities. All therapy sessions were supervised by a physiotherapist, with reassessments conducted at four-week intervals for both groups.

Table 1. Detailed Intervention Protocol

Week	Group A (Treadmill Training)	Group A (Conventional Therapy)
Week 1–4	Frequency: 3 sessions/week Time: 10 min/session Intensity: 50–55% MHR Speed: 0.3 km/h	Core stability exercises: (supine bridging, 10 reps and 2 sets). Stretching: (hamstring and calf stretches (10 second hold, 10 reps) Weight-bearing exercises: (wall push-ups and standing balance (10 reps, 3 sets) Balance and coordination training: (cone stepping and single-leg stance with support (10 reps, 3 sets) Strengthening exercises: sit-to-stand and resistance band kicking (10 reps, 3 sets) Gait training: walking in parallel bars for 5 minutes/session Standing frame activities: (reaching for objects placed on a tray or table in front) to encourage upper limb engagement and trunk control 5 minutes/session.
Week 4–8	Frequency: 3 sessions/week Time: 20 min/session Intensity: 55–60% MHR Speed: 1.0 km/h	
Week 8–12	Frequency: 4 sessions/week Time: 20 min/session Intensity: 60–65% MHR Speed: 3.0 km/h	

Outcome Measures: In addition to demographic data age, BMI, and level of GMFCS were obtained. The GMFCS classified children with cerebral palsy based on their self-initiated movement abilities. Levels range from I (most functional) to V (most severe limitation). It is a validated and reliable tool (Kappa>0.90) as a global indicator of gross motor functions. The PBS is a valid and reliable tool (ICC>0.95) used to measure static and dynamic balance through 14 functional tasks. Each item is scored from 0 to 4 with scores ranging from 0 to 56 and higher scores indicating better balance. The MAS is a reliable tool (ICC=0.61–0.91) that was used to assess muscle tone and grade the level of spasticity during passive stretching. The scores range from 0 (no increase in tone) to 4 (rigid in flexion or extension) and lower scores indicate a reduction in spasticity.

Sample Size: n=36 samples were estimated using G power with a small effect size (0.2) and an α error margin of 0.05. To reduce β error probability, the power (1-β) was set to 0.95%. n=46 children with CP were screened for inclusion criteria; n=18 individuals did not meet the selection criteria and were therefore excluded from the study. A total of n=36 participants were randomly assigned to groups A (n=18) and B (n=18) respectively. (Figure 1)

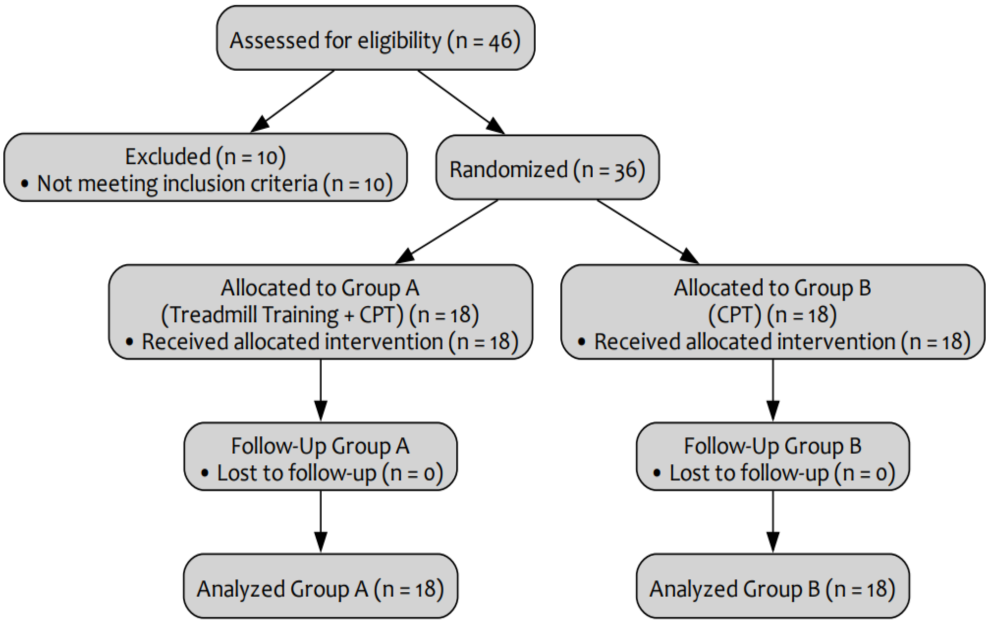


Figure 1: Consort Diagram

Randomization and blinding: Randomization was performed using the sealed enveloped method and a computerized random number generator. The random allocation was carried out by a biostatistician who was not involved in data collection. The random numbers were then written on index cards and sealed in a thick, opaque envelope before the investigation began. Following written informed consent, the physical therapist opened the envelope and administered the appropriate therapies to the patients. The assessing physical therapist was blinded to the intervention hence the trial was single-blind.

Statistical methods: The data analysis was done through the SPSS ver 26, and the significance level was set at $p<0.05$. A mixed-design ANOVA was applied to assess the interaction between Interventions and assessment time at baseline, 4th week, 8th week, and 12th week on motor function balance and spasticity. For the within main effects ANOVA with repeated measures and independent t-test for between the group comparison were applied.

RESULTS

The study sample comprised n=36 CP children ranging in age from 5 to 13 years, with a mean age of 8.17±2.21 years. In terms of Body Mass Index (BMI), values ranged from 18.29 to 51.22, with a mean BMI of 33.97±7.17 kg/m². A total of n=23(63.89%) males and the remaining n=13(36.11%) were female included in the study.

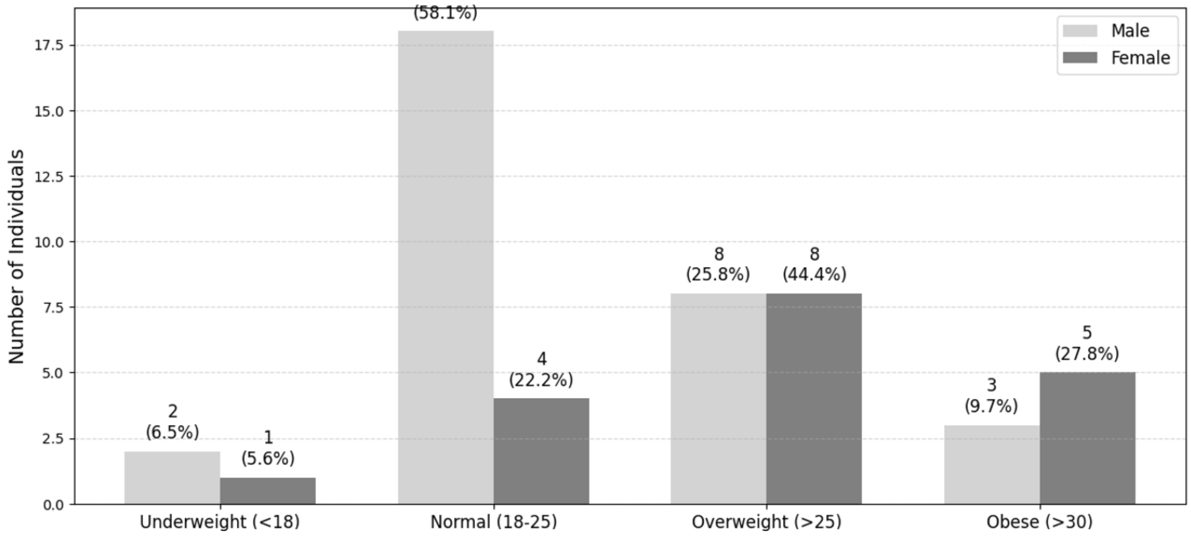
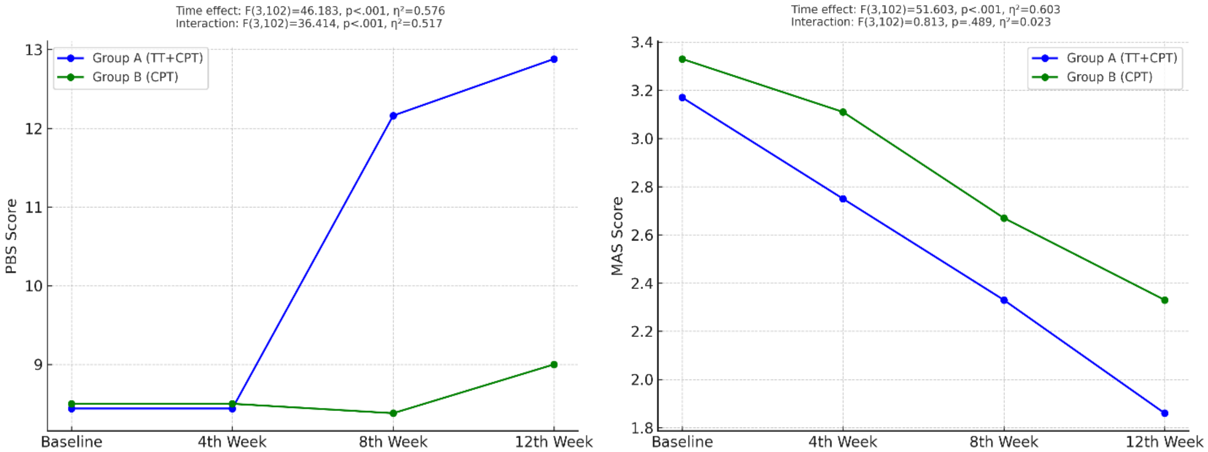


Figure 2: Gender based BMI distribution

The sphericity-assumed mixed ANOVA showed a non-significant interaction effect between intervention and time effect on spasticity{$F(3,102)=0.81$, $p=0.489$, $\eta p^2=0.02$} measured by modified Ashworth scale. While in PBS {$F(3,102)=36.41$, $p<0.001$, $\eta p^2=0.517$} significant interaction effect observed. (Figure 3)

Regarding motor function, the Friedman test indicated no overall statistically significant ($p\geq0.05$) change in GMFCS scores over time in both the experimental and control groups and Wilcoxon signed-rank tests also confirmed no statistically significant($p\geq0.05$) changes between adjacent time points.



Pediatric balance scale for balance

Modified ashworth scale for Spasticity

Figure 3: Interaction effect between intervention and time (PBS & Spasticity)

In group A (TT+CPT), the balance score on the Pediatric Balance Scale (PBS) and spasticity on MAS both showed significant improvements from baseline to the 12th week. The PBS score increased significantly with large effect size {8.44±5.19 to 12.88±5.68, $F(3,51)=42.67$, $p<0.001$, $\eta p^2=0.715$}, while spasticity reduces with moderate effect size {3.17±0.71 to 1.86±1.31, $F(3,51)=2.68$, $p<0.001$,

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ηp^2=0.636}. Further, the Pairwise comparisons show significant improvements ($p<0.05$) at each time interval from baseline to 4th week, 4th to 8th week, and 8th to 12th week in both variables.

While in group B (CPT), the results indicated a significant improvement from baseline to the 12th week in both the PBS {8.50±6.28 to 19±6.38, F(3,51)=12.04, $p<0.001$, ηp^2=0.415} and the MAS {3.33±0.49 to 2.33±0.59, F(3,51)=18.12, $p<0.001$, ηp^2=0.516}. The pairwise pattern suggests that no significant improvement from baseline to the 4th week and 4th week to 8th ($p\geq0.05$), but from the 8th to the 12th week, a statistically significant decline in PBS scores was observed (*p*=0.003), though the clinical relevance of this change is likely minimal. In contrast, after an initial non-significant (p=0.62) reduction from baseline to the 4th week, a significant (p=0.01) reduction in spasticity from the 8th week to the 12th week (table 2)

When comparing the both groups, no statistically significant differences were observed between the two groups at any time point for PBS and MAS. (table 3)

Table 2. With-in group (Main effects) changes in both groups

		Group A (TT+CPT) (n=18)					Group B (CPT) (n=18)				
		Mean±SD	**MD**	**F(3,51)**	**p-value**	**ηp^2**	**Mean±SD**	**MD**	**F(3,51)**	**p-value**	**ηp^2**
PBS	Baseline	8.44±5.19	0.00	42.6	1.00[a]	0.715	8.50±6.28	0.00	12.04	1.00[a]	0.415
	4th Week	8.44±5.19	-3.72		0.00***[b]		8.50±6.28	0.11		1.00[b]	
	8th Week	12.16±5.64	-0.72		0.263[c]		8.38±6.10	-0.61		0.003**[c]	
	12th week	12.88±5.68	4.44		0.00***[d]		9.00±6.38	0.50		0.00**[d]	
MAS	Baseline	3.17±0.71	0.42	36.71	0.008**[a]	0.68	3.33±0.49	-0.22	18.12	0.62[a]	0.516
	4th week	2.75±0.96	0.42		0.008**[b]		3.11±0.58	0.44		0.01*[b]	
	8th Week	2.33±1.03	0.47		0.013*[c]		2.67±0.49	0.33		0.17[c]	
	12th Week	1.86±1.03	1.31		0.00***[d]		2.33±0.59	1		0.00**[d]	

Significance Level; p<0.05, p<0.001**, p<0.001****

[a]Baseline to 4th week, [b]4th week to 8th week, [c]8th week to 12th week & [d]baseline to 12th week

MAS-Modified Ashworth scale; ηp^2-partial eta-squared; SD-Standard Deviation; PBS-Pediatric balance scale

Table 3: Group comparison on PBS & MAS

		Group A (TT+CPT) (n=18)	Group B (CPT) (n=18)		
		Mean±SD	**Mean±SD**	**MD**	**p-value**
PBS	Baseline	8.44±5.19	8.50±6.28	-0.05	0.97
	4th Week	8.44±5.19	8.50±6.28	-0.05	0.97
	8th Week	12.16±5.64	8.38±6.10	3.77	0.06
	12th week	12.88±5.68	9.00±6.38	3.88	0.06
MAS	Baseline	3.17±0.71	3.33±0.49	-0.16	0.42
	4th week	2.75±0.96	3.11±0.58	-0.36	0.18
	8th Week	2.33±1.03	2.67±0.49	-0.33	0.23
	12th Week	1.86±1.03	2.33±0.59	-0.47	0.10

Significance Level; p<0.05, p<0.001**, p<0.001****

PBS-Pediatric balance scale; MAS-Modified Ashworth scale; MD-Mean Difference; SD-Standard Deviation

DISCUSSION

The present study evaluated the effects of treadmill training along with conventional physical therapy (TT+CPT) compared to conventional physical therapy (CPT) alone on motor function, balance, and spasticity in cerebral palsy (CP).

In both groups, the most significant improvement in balance was measured on the Pediatric Balance Scale (PBS). However, the combination group (TT+CPT) demonstrated a large change with a large effect size. which suggests superior benefits of treadmill training among the study population. The progressive and task-specific nature of treadmill training may explain the enhanced gains observed in group A. Task-specific interventions that simulate gait patterns help reinforce motor learning principles and functional postural control, as proposed in dynamic systems theory [14]. The treadmill training improves functional balance by increasing postural alignment, reactive balance, and dynamic gait control[15]. Moreover, visual feedback using a mirror and verbal cues in the TT+CPT group could have motivated and facilitated proprioception and enhanced postural stability [16].

In within-group analysis, both groups showed significant improvement in balance. The TT+CPT group showed significant changes across all assessment levels from baseline to the 12th week.

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In contrast, the CPT group only showed significant changes from the 8th to the 12th week. This delayed response suggests that conventional therapy may take longer to produce clinically meaningful balance improvements. Treadmill-based interventions likely accelerate motor adaptation due to repetitive stepping and continuous sensory input[17, 18]. A systematic review by Sun et. al. concluded that treadmill training facilitates neural plasticity by enhancing corticospinal excitability and trunk control mechanisms [19]. Additionally, a study highlighted that gait-specific treadmill interventions promote symmetry and cadence, indirectly benefiting dynamic balance[20].

The spasticity measured by the Modified Ashworth Scale (MAS), was significantly reduced in both groups, but again, the TT+CPT group displayed earlier and greater reduction as compared to CPT alone. However, the interaction effect was non-significant, suggesting that while both interventions are effective, neither showed a statistically significant difference when compared directly. Despite this, within group, the large effect size observed in the TT+CPT group ($\eta p^2=0.636$) versus the moderate effect in the CPT group ($\eta p^2=0.516$) may show a trend towards better outcomes with treadmill training. Previous studies suggest that spasticity can be modulated through repetitive and rhythmic motion patterns, such as those provided by treadmill walking, which facilitate reciprocal inhibition and reduce hyperreflexia[21, 22].

Moreover, treadmill walking improves muscle elasticity and joint mobility, which could explain the notable reduction in MAS scores. [11].The consistent stretching and concentric-eccentric muscle activation during treadmill locomotion can reduce tonic muscle responses by engaging central pattern generators (CPGs) in the spinal cord[22, 23].

Supporting this hypothesis, Ribeirio et al found that treadmill-based gait training reduced lower limb spasticity and increased dorsiflexion range of motion[24]. Furthermore, progressively increasing intensity and duration may have enhanced descending motor control and dampened spastic neural circuits[22]. Interestingly, no significant changes were observed in motor function on Gross Motor Function Classification System (GMFCS) scores over the 12-week intervention period in either group. This outcome is not entirely surprising given that the GMFCS is a classification system rather than a responsive outcome measure. It is primarily designed to describe gross motor capacity rather than detect subtle functional changes over short-term interventions[25].

Additionally, in children older than four years, GMFCS levels are reported to be relatively stable over time, especially Hence, enhancements in dynamic skills like balance or reductions in spasticity may not necessarily translate into an immediate change in gross motor classification Instead, these gains might contribute to long-term improvements in functional independence and participation [26, 27]. A more sensitive tool such as the Gross Motor Function Measure (GMFM) may have provided better insight into motor performance improvements and responsive to changes in motor function induced by interventions in CP children[28].

Limitations Despite its strengths, including structured intervention protocols, this study has a low sample size and of short duration, as may not be sufficient to capture long-term functional changes or motor reclassification on GMFCS.GMFCS alone may not have been sensitive enough to detect functional motor improvements. Moreover, nutritional status, therapies at home, and cognitive engagement were not controlled, which may have affected the variability of responses.

CONCLUSION

The structured, progressive treadmill protocol when combined with conventional therapy, can produce clinically meaningful improvements in balance and spasticity in children with CP, even though it may not alter gross motor function classification in the short term. This combines protocol-enhanced postural stability and reduced muscle tone more effectively than conventional therapy alone, justifying its inclusion in comprehensive CP management programs. Based on current findings, future research should consider incorporating more sensitive outcome measures like GMFM, 10-meter walk test, or spatiotemporal gait parameters. Furthermore, evaluating long-term effects and maintenance achieved after stopping the treadmill training.

DECLARATIONS & STATEMENTS

Author's Contribution

RU: substantial contributions to the conception and design of the study.
RU, HA, and OF: acquisition of data for the study.
SNG, OF and SA: interpretation of data for the study.
RU and SA: analysis of the data for the study.
RU and SA: drafted the work.
RU, HA, SNG, WF, OF, and SA: revised it critically for important intellectual content.
RU, HA, SNG, WF, OF, and SA: final approval of the version to be published and agreement to be accountable for all aspects.
of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The approval obtained from the research and ethical committee of Faculty of Rehabilitation and Allied Health Sciences Islamabad (RIPHAH/FR&AHS/letter-01826) and institutional head of Helping Hand Institute of Rehabilitation Sciences, in Lower Dir Talash.

AI Use Statement

AI tools were used solely for formatting and language editing. No AI was used for content generation, data analysis, or interpretation.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Effects of Calisthenic exercises on physical fitness among school going children: a randomized control trial

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ABSTRACT

Background: With the rising trend of sedentary behaviour and decreased physical activity among school-aged children, there is a growing concern regarding their physical health and fitness. Calisthenic exercises, bodyweight-based movements, offer a cost-effective and accessible method to improve multiple components of physical fitness without the need for equipment.

Objective: To evaluate the effects of structured Calisthenic exercise program on physical fitness among school-going children.

Material and Methods: This two-arm, parallel-group randomized controlled trial was conducted over 10 months at a private school in Sargodha, Pakistan. Forty-eight male children were randomly allocated into two groups: Group A (intervention group) performed structured Calisthenic exercises thrice weekly for 8 weeks, while Group B (control group) continued routine school activities. Physical fitness was assessed using the Eurofit Physical Fitness Test Battery at baseline, week 4, and week 8. Repeated measures ANOVA and independent t-tests were used for statistical analysis.

Results: Significant within- and between-group improvements were observed in the intervention group across multiple fitness parameters including balance (Flamingo Balance Test, $p<0.001$), coordination (Plate Tapping Test, $p<0.001$), leg power (Standing Broad Jump, $p<0.001$), flexibility (Sit-and-Reach Test, $p=0.03$), muscular endurance (Sit-ups in 30 seconds and Bent Arm Hang, $p<0.001$), and aerobic capacity (20m Shuttle Run, $p=0.042$). Hand grip strength showed significant improvement in the intervention group over time ($p=0.002$), though not in comparison between groups. The control group showed minimal or no significant improvements.

Conclusion: Structured Calisthenic exercises significantly enhance physical fitness components including balance, flexibility, coordination, endurance, and strength in school-aged boys. Incorporating such programs into school routines offers a practical and scalable strategy to combat physical inactivity in children.

Keywords: Balance; endurance; exercise therapy; flexibility; motor skills; physical fitness

Clinical trial #: NCT05149794

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INTRODUCTION

Physical fitness plays a crucial role in the overall health and development of children. With increasing sedentary lifestyles and screen time, many children are experiencing declining physical fitness levels, which can negatively affect their physical, mental, and social well-being[1, 2]. Calisthenic exercises, which are body-weight movements such as push-ups, pull-ups, squats, and jumping jacks, offer a practical and accessible method to improve physical fitness without requiring specialized equipment[3]. These exercises enhance muscular strength, endurance, flexibility, coordination, and cardiovascular health[4]. Introducing Calisthenic routines in schools can promote healthy habits and improve the physical fitness of children, thereby contributing to their holistic development[5].

A study by Katsanis et al. (2021) demonstrated significant improvements in muscular strength and cardiovascular endurance after an 8-week Calisthenic training program in adolescents[6]. Similarly, regular Calisthenic activities improved flexibility and balance, which are critical for overall motor development[7]. Researches also highlight the role of physical fitness in enhancing academic performance, mental health, and social skills[8, 9].

However, there is limited research specifically targeting the Calisthenic exercises that can be effectively integrated into daily school routines to yield long-term benefits. The rationale behind studying the effects of Calisthenic exercises among school children stems from the need to identify cost-effective, easily implementable interventions that improve physical fitness and promote healthy lifestyles. Ideal settings for such interventions are the schools, due to their structured environment and access to large populations of children. Future health risks such as obesity, cardiovascular diseases, and mental health disorders can be prevented by physical fitness in children. This study's objective was to understand how Calisthenic exercises can be adapted and incorporated into school programs to enhance physical fitness and well-being.

MATERIALS AND METHODS

Study Design & Setting: This study was a two-arm, parallel-group randomized controlled trial, completed In ten months, from June 2020 to April 2021. The study was initiated after ethical approval from the research and ethical committee (RIU/FRAHS-ISB/REC/0766), Riphah International University Islamabad. The trial was conducted at the Sanai School System, Sargodha a private educational institution after approval from the Principal. Located in Sargodha, Pakistan. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Participants: The participants included in the study were male school-going children aged between 8-13 years, having a normal BMI as aged based BMI on WHO guidelines. Moreover, children were able to perform at least 10 repetitions of selected calisthenic exercises. While children having known physical or cognitive impairment or disability, or experiencing acute illness were excluded from the study. The recruitment of the participants was done using a non-probability purposive sampling method. After screening based on the selection criteria, written informed consent was obtained from the parents/guardians, and verbal assent was taken from the children. Participants were then randomly allocated to one of two groups.

Sample Size Calculation: The required sample size was calculated using G*Power software (ver. 3.1.9.7) based on medium effect size (f)=0.25, alpha (α)=0.05, power (1–β)=0.80 for two groups and with three measurement levels. The calculated sample size was n=48 participants, with n=24 participants per group.

Randomization and Allocation: N=48 participants were randomly assigned to Group A (Calisthenic) or Group B (Control group) using simple randomization generated through a random number generator for a customized random number table. Allocation concealment was ensured using sealed opaque envelopes. Due to the nature of the physical interventions, participants and trainers could not be blinded; however, outcome assessors were blinded to group allocation to minimize bias.

Intervention: Group A (Calisthenic Exercises) Participants in Group A underwent a structured calisthenic exercise program conducted three times a week for 8 weeks, under the supervision of Physical Therapist. Each session lasted approximately for 30 minutes and included a 3-minute warm-up followed by a progression of exercises mentioned in table 1.

Table 1: Calisthenic Exercises

Week	Exercises Performed
Week 1	Bunny Jumps (16×2 reps), Bear Crawls (8×3 reps), Crab Walks (8×3 reps)
Week 2	Bunny Jumps (15×2 reps), Bear Crawls (10×3 reps), Crab Walks (10×3 reps)
Week 3	Week 2 + Bird Dog (10 sec × 3 reps)
Week 4	Week 3 + Crouching Tiger (6×3 reps)
Weeks 5–8	Same protocol as Week 4 continued

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Group B (Routine Physical Activity): Participants in Group B continued their regular physical activities at school during recess. No additional structured exercises were introduced. All assessments were performed at the same intervals as the experimental group.

Outcome Measures: The Eurofit Physical Fitness Test Battery was used to evaluate physical fitness at baseline, week 4, and week 8. This battery includes Flamingo Balance Test (FBT), Plate Tapping (PT), Sit-and-Reach Test, Standing Broad Jump (SBJ), Hand Grip Strength Test (HG), Sit-Ups in 30 Seconds, Bent Arm Hang (BAH), 20m Endurance Shuttle Run (Bleep Test). All tests were administered by trained assessors (physical trainers) who were blinded to group allocation[10].

Data Analysis: Data were analyzed using SPSS version 20 with the level of significance set at $p<0.05$. The continuous variables were reported as mean ± standard deviation (SD), while categorical data were presented as frequencies and percentages. A Repeated Measures ANOVA was used to examine within-group changes over time (baseline, week 4, week 8). An independent samples t-test was used to compare between-group differences at each time point. Further, the post-hoc analyses with Bonferroni correction were used for pairwise comparisons when applicable.

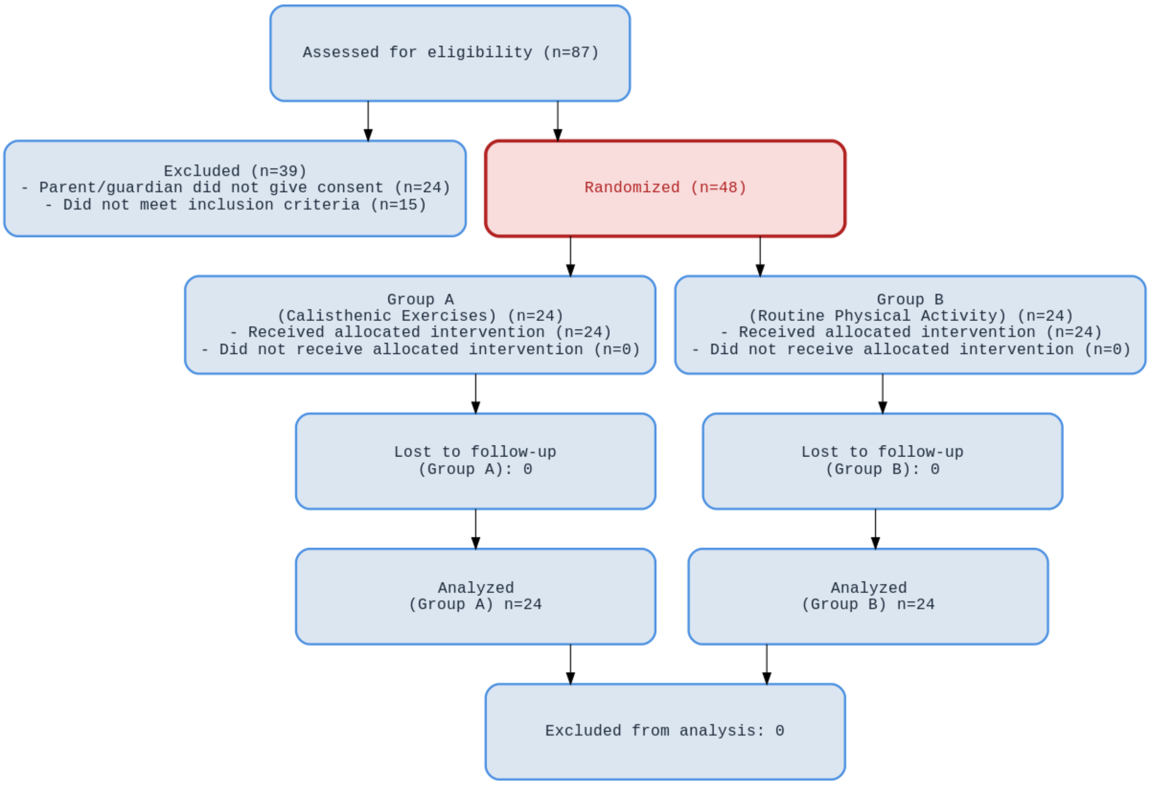

Figure 1: Study CONSORT diagram

RESULTS

The mean age of the study participants was 10.88±1.71 years and BMI was 20.15±2.06. The BMI category showed that n=15 participants were healthy, n=7 were at risk of overweight and the remaining n=3 participants were overweight.

With-in group analysis showed that the control group had no significant improvement ($p\geq0.05$) in all variables except the flamingo balance test, ($p=0.012$) which showed significant improvement with a large effect size in balancing after 8 weeks of treatment. The experimental group showed significant improvement in balance measured by the flamingo balance test ($p<0.05$), with a large effect size throughout the treatment. The upper body reaction time, hand-eye quickness, and coordination significantly improved after 8 weeks of treatment by plate tapping ($p<0.05$). As well as standing broad jump test $p<0.05$ showed significant improvement in leg power with a large effect size after the treatment duration. The sit-up 30 sec test showed significant improvement ($p<0.05$) with a large effect size throughout the treatment in the leg strength and stamina of participants. The bent arm hang test ($p<0.05$) showed significant improvement with a large effect size in muscular endurance of the arm and shoulder after treatment duration. While the stand reach test $p<0.05$ showed significant improvement with a large effect size in flexibility of standing and aerobic fitness 20m Bleep Test VO2 Max test ($p<0.05$) also showed significant improvement with a large effect size after 4 weeks of treatment. The hand grip test showed no significant improvement ($p\geq0.05$) throughout the treatment. (table 2)

Table 2: Within group changes

		Group A					Group B				
		$\bar{x}$	σ	MD/ F(df)	p-value	d/ ηp^2	$\bar{x}$	σ	MD/ F(df)	p-value	d/ ηp^2
Flamingo Balance Test	Pre	3.92	1.93	0.92	0.023*	0.89^{a}	4.25	1.29	0	1	0^{a}
	Post 4 Weeks	3.00	1.08	1.00	0.00***	1.73^{b}	4.25	1.29	0.333	0.12	0.68^{b}
	Post 8 Weeks	2.00	0.91	19.74(1.09,13.09)	0.00***	.622^{c}	3.92	1.08	5.5(2,22)	.012*	0.33^{c}
Plate Tapping Test	Pre	7.46	1.50	0.23	0.25	0.53^{a}	8.33	1.07	0.167	0.49	0.43^{a}
	Post 4 Weeks	7.23	1.16	0.61	0.003**	1.22^{b}	8.16	.83	0	1	0^{b}
	Post 8 Weeks	6.61	1.12	16.16(2,24)	0.00***	0.57^{c}	8.16	.83	2.20(2,22)	0.13	0.16^{c}
Standing Broad Jump	Pre	144.76	36.76	2.0	0.00***	2.45^{a}	139.08	25.56	0.75	1.00	0.29^{a}
	Post 4 Weeks	146.76	36.86	2.46	0.00***	1.63^{b}	138.33	24.72	0.33	0.11	0.68^{b}
	Post 8 Weeks	149.23	37.12	62.77(1.30, 15.61)	0.00***	0.84^{c}	138.66	24.58	0.70(1.04,11.51)	0.42	0.06^{c}
Sit and Reach Test	Pre	0.76	4.83	0	1.00	0^{a}	1.58	3.23	0	1	0^{a}
	Post 4 Weeks	0.76	5.16	2.38	0.1	0.62^{b}	1.58	3.23	0	1	0^{b}
	Post 8 Weeks	3.15	1.62	(5.47.02,12.28)	0.03*	0.31^{c}	1.58	3.23	0. (2,22)	1	0^{c}
Hand Grip Test	Pre	16.23	2.68	0	1	0^{a}	13.66	2.60	0.667	1.00	0.29^{a}
	Post 4 Weeks	16.23	2.68	.031	1.00	0.28^{b}	13.00	1.70	0	1	0^{b}
	Post 8 Weeks	16.26	2.66	1.00(2,24)	0.38	0.07^{c}	13.00	1.70	1.00(2,22)	0.38^{c}	0.08^{c}
Sit-up 30 sec	Pre	8.53	4.09	0.53	0.008**	1.04^{a}	9.75	4.51	0	1	0^{a}
	Post 4 Weeks	9.07	3.86	1.0	0.00***	0^{b}	9.75	4.51	0	1	0^{b}
	Post 8 Weeks	10.07	3.75	34.65(2,24)	0.00***	0.74^{c}	9.75	4.51	0.(2,22)	1	0^{c}
Bent Arm Hang	Pre	43.46	30.69	2.00	0.00***	2^{a}	59.66	21.05	0.50	1.00	0.24^{a}
	Post 4 Weeks	45.46	30.89	2.84	0.00***	2.66^{b}	59.16	20.52		1	0^{b}
	Post 8 Weeks	48.30	31.15	103.98(2,24)	0.00***	0.89^{c}	59.16	20.52	0.70(2,22)	0.51	0.06^{c}
20m Bleep Test (VO$_2$ Max)	Pre	49.12	2.61	0.86	0.140	0.62^{a}	49.22	1.97	0.025	1.00	0.29^{a}
	Post 4 Weeks	49.99	2.56	0.13	1.00	0.28^{b}	49.25	2.00		1	0^{b}
	Post 8 Weeks	49.86	2.43	4.82(1.13, 13.60)	0.04*	0.28^{c}	49.25	2.00	1.00(2,22)	0.38	0.08^{c}

^{a} pre to 4th week, ^{b} 4th week to 8th week and ^{c} pre to 8th week.

Significance Level: $p<0.05$, $p<0.01$**, $p<0.001$****

d- Cohens'd; df-Degree of Freedom; F-Statics; ηp^2-partial eta-squared; $\bar{x}$-Mean Difference; σ -Standard Deviation

Table 3: Comparison between the groups

		Group A		Group B				
		$\bar{x}$	σ	$\bar{x}$	σ	MD	p-value	d
Flamingo Balance Test	Pre	3.92	1.93	4.25	1.29	0.33	0.02*	0.20
	Post 4 Weeks	3.00	1.08	4.25	1.29	1.25	0.00***	1.05
	Post 8 Weeks	2.00	0.91	3.92	1.08	1.92	0.00***	1.92
Plate Tapping Test	Pre	7.46	1.50	8.33	1.07	0.87	*-0.27	0.67
	Post 4 Weeks	7.23	1.16	8.16	.83	0.93	0.03*	0.92
	Post 8 Weeks	6.61	1.12	8.16	.83	1.55	0.00***	1.57
Standing Broad Jump	Pre	144.76	36.76	139.08	25.56	-5.68	0.16	-0.18
	Post 4 Weeks	146.76	36.86	138.33	24.72	-8.43	0.33	-0.27
	Post 8 Weeks	149.23	37.12	138.66	24.58	-10.57	0.18	-0.34
Sit and Reach Test	Pre	.76	4.83	1.58	3.23	0.82	0.03*	0.20
	Post 4 Weeks	.76	5.16	1.58	3.23	0.82	0.13	0.19
	Post 8 Weeks	3.15	1.62	1.58	3.23	-1.57	0.00***	-0.61
Hand Grip Test	Pre	16.23	2.68	13.66	2.60	-2.57	0.00**	-0.97
	Post 4 Weeks	16.23	2.68	13.00	1.70	-3.23	0.00***	-1.44
	Post 8 Weeks	16.26	2.66	13.00	1.70	-3.26	0.00***	-1.46
Sit-up 30 sec	Pre	8.53	4.09	9.75	4.51	1.22	0.67	0.28
	Post 4 Weeks	9.07	3.86	9.75	4.51	0.68	0.93	0.16
	Post 8 Weeks	10.07	3.75	9.75	4.51	-0.32	0.84	-0.08
Bent Arm Hang	Pre	43.46	30.69	59.66	21.05	16.20	0.00***	0.62
	Post 4 Weeks	45.46	30.89	59.16	20.52	13.70	0.11	0.52
	Post 8 Weeks	48.30	31.15	59.16	20.52	10.86	0.02*	0.41
20m Bleep Test (VO$_2$ Max)	Pre	49.12	2.61	49.22	1.97	0.10	0.97	0.04
	Post 4 Weeks	49.99	2.56	49.25	2.00	-0.74	0.03*	-0.32
	Post 8 Weeks	49.86	2.43	49.25	2.00	-0.61	0.08	-0.27

Significance Level: $p<0.05$, $p<0.01$**, $p<0.001$****

d- Cohens'd; $\bar{x}$-Mean Difference; σ -Standard Deviation

A statistically significant difference was found in the mean change of the Hand Grip Test, with the experimental group (16.24±2.68) showing greater hand grip strength compared to the control group (13.22±1.74), p=0.002, with a large effect size (Cohen's d=-1.39). This indicates a substantial improvement in grip strength in the experimental group. While no significant (p≥0.05) difference regarding Sit and Reach Test, and Bent Arm Hang Test. (Figure 2)

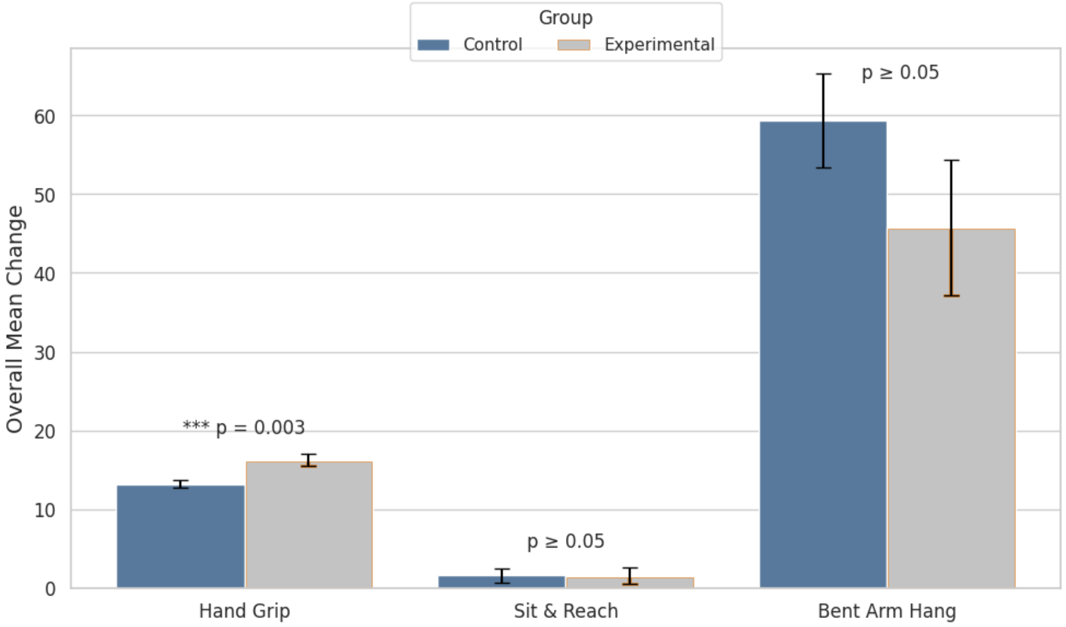

Figure 2: Comparison of Mean Change of groups from baseline to 12th week

DISCUSSION

This study determined the effects of an 8-week structured Calisthenic exercise program on various physical fitness parameters in school-going boys. The findings demonstrate that Calisthenic training produced significant improvements in multiple fitness parameters compared to routine activity at school, particularly in balance, coordination, flexibility, muscular endurance, and aerobic capacity. These results are consistent with and add to the growing body of literature supporting the role of body-weight exercises in paediatric fitness promotion.

The improvement observed in balance, as measured by the Flamingo Balance Test, is supported by previous findings, that enhanced postural control in children may be improved by calisthenic training[11]. This may be attributed to the neuromuscular adaptations[12] resulting from dynamic and static body control during exercises like bear crawls and crab walks, which challenge the vestibular and proprioceptive systems.

Significant enhancement in hand-eye coordination and upper limb reaction time, reflected in Plate Tapping Test results, aligns with Kojic (2024), who highlighted improvements in motor coordination through regular structured physical activity[13]. Mechanistically, these changes may be driven by increased cortical stimulation and synaptic plasticity[14] from repeated, rhythm-based movements integral to calisthenics.

The Standing Broad Jump and Sit-Ups in 30 Seconds test results indicate improved lower limb explosive strength and core muscular endurance respectively. These findings are in agreement with Sort well et al. (2021), who demonstrated that plyometric and bodyweight circuits enhance muscle fibre recruitment and anaerobic endurance in children[15]. Exercises such as bunny jumps and crouching tigers likely activated fast-twitch muscle fibres and increased neuromuscular efficiency[16].

Improvement in the 20-meter Shuttle Run (VO_2 max) confirms the aerobic benefits of calisthenic exercise. Consistent with Jovanović et al. (2024), who reported improved cardiovascular endurance in children undergoing high-repetition bodyweight exercise regimes[17], our results suggest that calisthenics, although non-equipment based, sufficiently stimulate the cardiorespiratory system due to their circuit style implementation and minimal rest periods[18].

Flexibility, as assessed by the Sit-and-Reach Test, also improved significantly. This is observed to improve hamstring and lower back flexibility in children undergoing a general dynamic warm-up followed by full-body movement exercises[19, 20]. In calisthenics, movements involving multiple joints like bird-dog and crouching tiger contribute to an increased range of motion and reduced muscle tightness.

The Hand Grip Strength showed a statistically significant mean improvement in the experimental group over time. This may be explained by the nature of calisthenic movements, which emphasize functional and dynamic muscular endurance over isolated static strength. Repetitive body weight increases oxidative capacity in the forearm muscles, improving their endurance and resistance to fatigue[21]. Exercises involving sustained positions, including crab walks and crouching tigers, promote isometric strength gains through prolonged time under tension of the forearm and intrinsic hand muscles[22]. Additionally, these dynamic and stabilizing movements enhance motor unit recruitment, synchronization, and coordination, all of which contribute to improvements in functional grip strength[23, 24]. The lack of substantial improvements in the control group across most parameters underscores the limited effectiveness of unstructured or recess-based physical activity. An study by Tanveer et al supports the findings that school-based interventions must be intentional, guided, and consistent to elicit measurable benefits[25].

The nutritional factors were not controlled or recorded, which may potentially influence the fitness outcomes. Moreover, the study was conducted in one private school, so the findings may not reflect the diversity of socioeconomic or geographic school settings. Though improved fitness is often associated with better cognition and mood, these variables were also not assessed.

CONCLUSION

The findings reinforce that structured Calisthenic exercise programs can significantly improve balance, coordination, endurance, strength, and flexibility among school-aged boys. These results support the integration of bodyweight-based fitness modules in school curricula as a cost-effective, accessible, and impactful approach to combat sedentary lifestyles in children. Future studies should include diverse populations, compare different types of physical activity, and explore the cognitive and psychosocial effects of such interventions while controlling the confounder which may affect the effects. Although physical education departments are in the majority of schools, there is a decreased trend of structured activity in schools. This study may guide to incorporate the structured exercise program as a routine activity to enhance physical fitness and may avoid future risks of diseases.

DECLARATIONS & STATEMENTS

Author's Contribution

FZ: substantial contributions to the conception and design of the study.
FZ, MK, and LZ: acquisition of data for the study.
FZ, LZ and BF: interpretation of data for the study.
FZ: analysis of the data for the study.
FZ: drafted the work.
FZ, MK, LZ, and BF: revised it critically for important intellectual content.
FZ, MK, LZ, and BF: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The study was initiated after ethical approval from the research and ethical committee (RIU/FRAHS-ISB/REC/0766), Riphah International University Islamabad. The trial was conducted at the Sanai School System, Sargodha institution after approval from the Principal. Located in Sargodha, Pakistan

AI Use Statement

No AI was used for content generation, data analysis, or interpretation.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Acknowledgments

None to declare.

Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Dose response of neural mobilization on hamstring flexibility in patients with non-specific low back pain: a randomized control trial

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ABSTRACT

Background: Non-specific low back pain (NSLBP) often correlates with reduced hamstring flexibility, contributing to altered biomechanics and recurrent symptoms. Neural mobilization (NM) techniques are increasingly integrated into management strategies to address neurogenic inflammation and neural tissue mobility. However, the dose-response relationship of NM for hamstring flexibility remains unclear, with limited studies isolating dosage effects amid multimodal interventions.

Objectives: to determine the dose-response effect of NM on hamstring flexibility, pain, and disability in NSLBP patients, comparing high-dose versus low-dose protocols over a 4-week intervention. Methodology: A single-blinded randomized controlled trial allocated 34 NSLBP patients (aged 18–40) to Group A (High-dose NM) and Group B (Low-dose NM. The outcomes (NPRS for pain, ODI for disability, AKE test for flexibility) were assessed at baseline, 2 weeks, and 4 weeks.

Results: Group A showed a significantly greater reduction at 2 weeks ($p=0.007$, $d=0.58$), though differences became non-significant by week 4. At the same time, Group A demonstrated superior reductions at both 2 weeks ($p=0.0316$, $d=1.06$) and 4 weeks ($p<0.001$, $d=2.01$). Finally, both groups improved equally in AKE ($p\geq0.05$ between groups).

Conclusion: High-dose NM provides acute advantages for pain and disability reduction, However, equivalent hamstring flexibility gains across doses suggest that concurrent stretching dominates flexibility outcomes, overshadowing NM's dose-dependent effects.

Keywords: disability; hamstring; knee extension; low back pain; lumbar flexion; neural mobilization

Clinical trial #: NCT05101200

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INTRODUCTION

Low back pain (LBP) is a complex clinical condition that is common in over 80% of adults, and it is experienced at some point in their lives[1]. Among these cases, non-specific LBP covers a substantial proportion without any definitive underlying pathology[2]. In NSLBP, reduced hamstring flexibility has been frequently observed, which may contribute to altered lumbar pelvic mechanics, compensatory movements, and recurrent pain episodes[3, 4]. Conventional management strategies include thermal therapy[5], stretching[6, 7], and strengthening exercises[8]. Recent advances have emphasized the inclusion of neural mobilization techniques, especially for restoring neural tissue mobility and reducing neurogenic inflammation[9, 10].

Neural mobilization (NM), including techniques such as slump stretching and sciatic nerve gliding, has shown promise in enhancing flexibility, reducing pain, and improving functional outcomes[11, 12]. However, the therapeutic efficacy of NM may vary depending on the dosage, intensity, and frequency of application. Despite growing clinical usage, there is limited clarity regarding the optimal dose-response relationship of neural mobilization for improving hamstring flexibility in NSLBP populations.

Several studies have explored the impact of neural mobilization in individuals with LBP. For instance, Lin et al. have demonstrated the effectiveness of NM in improving nerve mobility and reducing pain sensitivity[12]. Similarly, clinical trials have reported improvements in hamstring flexibility following sciatic and slump nerve glides[11, 13]. Moreover, integrating NM with therapeutic exercises and heat therapy has yielded promising outcomes for symptom reduction and flexibility enhancement[14]. A recent study tested dosage response through neural mobilization on acute athletic performance. It was inferred that the five-minute neural gliding protocol is a more effective post-test than dynamic stretching [15].

However, lack of well-controlled, randomized trials that explicitly compare the dose-response effect of neural mobilization on hamstring flexibility in patients with NSLBP. Most available research examines NM as a singular intervention or in conjunction with exercises but does not systematically investigate how differing intensities influence outcomes. Furthermore, limited studies explored how neural mobilization dosage affects the interplay between flexibility improvement and pain reduction over time. So the purpose of the study was to determine the dose-response of neural mobilization on hamstring flexibility in patients with non-specific low back pain.

METHODOLOGY

Study Design and setting: A single-blinded Randomized control trial was conducted at Darul Sehat Hospital; Karachi completed prior official conduct of the study ethical approval was obtained from the Riphah Ethical Committee for the duration of one year (2021 to 2022). The individuals were told of the study's objectives, and they provided their written informed permission in line with the Declaration of Helsinki [16].

Selection Criteria: In the study, both males and females of age between 18 to 40 years were recruited with nonspecific low back pain in sub-acute and chronic phases. Individuals with specific low back pain cause, central or peripheral neurologic signs, systemic illness, psychiatric deficits, any surgical procedure was done 6 months past, and mental deficits were excluded from the study.

Intervention: Group A received high-dose neural mobilization consisting of; a neural mobilization technique (slump, sciatic), hot pack for 15 minutes, and strengthening exercises for quadriceps, hamstring, and erector spinae with 10-12 rep/2 sets [17]. Group B received low-dose neural mobilization with minimal intensity which consisted of; a hot pack: 15 minutes, strengthening exercises with 5-7 rep/1 set, strengthening exercises for quadriceps and erector spinae 5-7 rep/1 set, and static stretching exercises for hamstring 5-7 rep/1 set of AKE. Both groups were given sessions of 30 min/day, 2 days/week for 4 weeks, assessment was done at baseline, 2nd week & the end of 4th week [18] (Table 1)

Table 1: Intervention protocol.

Description	Group A (n=17) High Dose of NM	Group B (n=17) Low Dose of NM
Neural mobilization (slump, sciatic)	Knee extension, ankle dorsiflexion, and head extension in a slumped posture followed by ankle plantar flexion together with knee and head flexion	
Dosage	10-12 reps / 2 sets	5-7 reps / 1 set
Hot pack	15 minutes	15 minutes
Strengthening exercises (Erector spinae, quadriceps)	10-12 reps / 2 sets	10-12 reps / 2 sets
Hamstring stretching	10-12 reps / 2 sets	10-12 reps / 2 sets
Frequency and Duration	40 min/session, 2 days/week for 4 weeks; assessments at baseline, 2nd, and 4th week	

Back pain intensity was measured via the 11-point Numeric Pain Rating Scale (NPRS) which is a known valid and reliable tool in the back pain population [19]. The disability associated with low back pain was assessed by the validated Oswestry Disability Index (ODI) the final score/index ranges from 0-100 [20]. Hamstring flexibility was measured via the active knee extension test AKE and is a valid and reliable tool [21]. The lumbar flexion range was assessed via the Schober test; a distance of less than 4 cm is indicated for compromised lumbar flexibility [22].

Sample Size: The required sample size was estimated a priori using G*Power 3.1.9.7 with medium effect size f=0.24, alpha error probability α=0.05, and desired statistical power (1-β)=0.85. So, the total required sample size was calculated as n=34 participants. A total of n=50 potential individuals were approached among which n=10 didn't meet the eligibility criteria and n=6 declined to participate. There was no loss of follow-up, and all participants completed the intervention completely. The final analysis was done on n=34 participants who were then randomly divided into Group A (n=17) and Group B (n=17). (Figure 1).

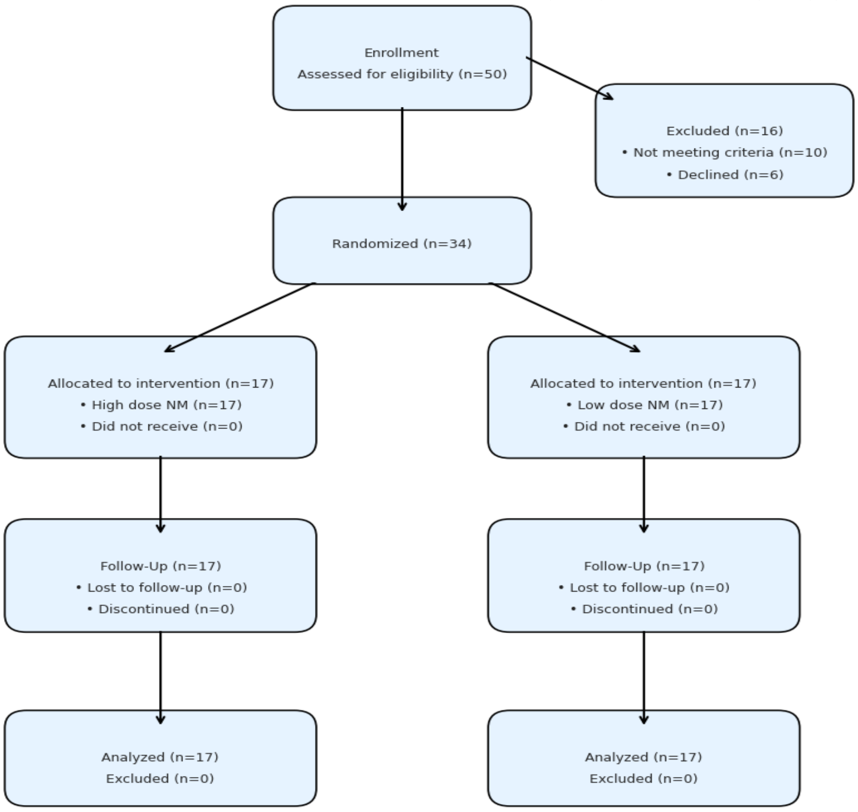

Figure 1: Consort Diagram

Individuals were equally allocated into two treatment groups based on randomization via the sealed envelope method. Group A (high-dose neural mobilization) and Group B (low-dose neural mobilization) were the titles of the two sealed envelopes that were blinded to the patients. When a participant agreed to participate in the study and was ready for allocation, they were asked to blindly draw one of the sealed envelopes, without knowing its contents. This process ensured that participants had an equal and unpredictable chance of being assigned to either intervention group. Once one group was selected, the next participant was automatically allocated to the remaining group to maintain balanced group sizes. This procedure prevented selection bias and maintained allocation concealment until the intervention assignment was revealed.

The statistical values were analyzed using SPSS version 23. Based on the normality testing between groups, analysis was performed via Independent sample t-test. While within-group analysis was performed via RMANOVA with pairwise comparison. The significance value was determined as p<0.05.

RESULTS

Total 34 individuals participated in the study including 4 (23.5 %) males and 13 (76.5 %) females in Group A and 6 (35.5 %) males and 11 (64.7 %) females were in Group B. Among the participants the mean age in group A was 33.69 ± 6.06 and in group B mean was 33.12 ± 6.70 years.

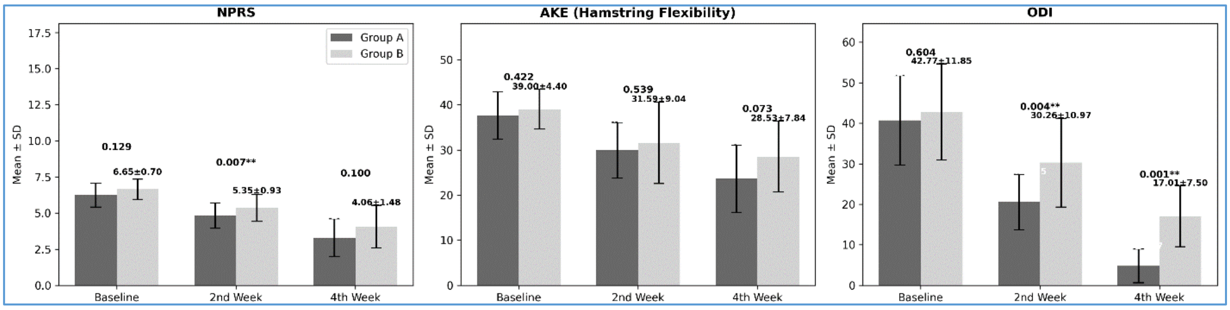

Figure 2: Between group comparison of outcomes

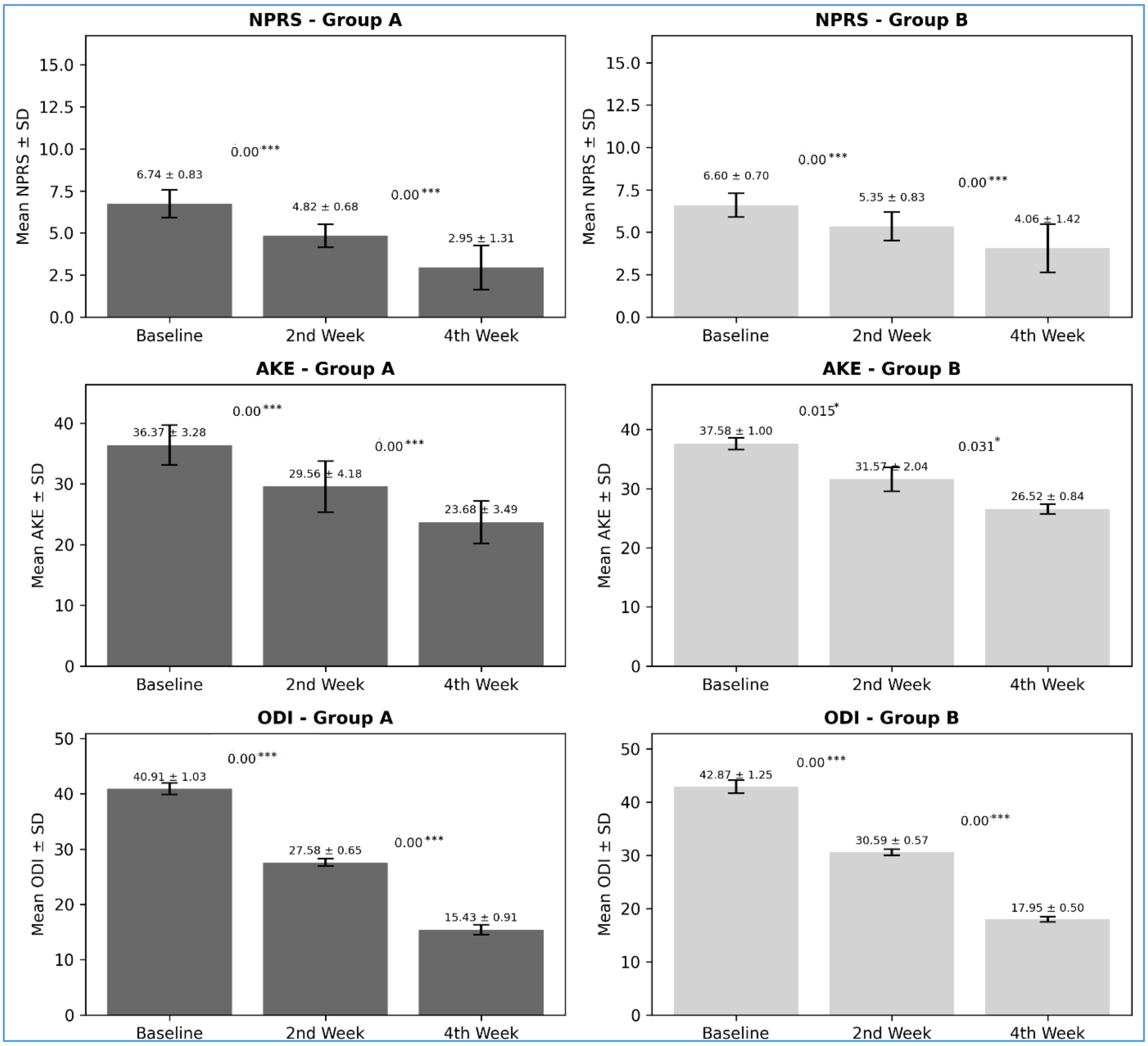

Figure 3: Within Group Analysis (Repeated Measure ANOVA-Pairwise Comparison)

At baseline, the two groups showed comparable scores across all outcome measures. The pain intensity, measured by the 2nd week Group A reported significantly (p=0.007, Cohen's d-0.58) lower pain scores than Group B). This trend continued but the difference was not statistically (p0.100) significant at the 4th week. For hamstring flexibility on active knee extension (AKE), both groups demonstrated similar improvements over time; however, differences between groups at all time points were small and not statistically (p≥0.05) significant. Finally, disability scores assessed with the Oswestry Disability Index (ODI) by the 2nd and 4th weeks Group A showed significantly greater reductions in disability than Group B 2nd week (p=0.004) and 4th week (p=0.001). These findings indicate that the intervention was effective in reducing pain and disability, with large effect sizes favoring Group A, while improvements in hamstring

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flexibility were modest and not significantly different between groups. (Figure 2)

The pain intensity was significantly ($p<0.001$) improved in both group at each assessment till 4th week with large effect size. It was observed that, in Group A (High Dose), there was a significant improvement in Active Knee Extension (AKE) over time {F=53.59 (1.29, 20.68), $p=0.003$, $\eta p^2=0.77$} with a large effect. The mean AKE scores improved significantly ($p<0.001$) from 37.65±5.25 degrees at baseline to 29.94±6.17 degrees at the 2nd week and further to 23.65±7.49 degrees at the 4th week. Similarly, Group B (Low Dose) also showed a significant improvement in AKE {F=13.165(1.54, 24.69), $p=0.015$, $\eta p^2=0.45$}, with a moderately large effect size. The Mean AKE decreased significantly ($p<0.001$) from 39.00±4.40 degrees at baseline to 31.59±9.03 degrees at the 2nd week and 28.53±7.83 degrees at the 4th week. For ODI Total Scores, Group A demonstrated a highly significant improvement across time points {F=13.165 (1.54, 24.69), $p=0.001$, $\eta p^2=0.92$}, with a very large effect size. The mean ODI score reduced significantly from 40.70±11.03 at baseline to 20.53±6.85 in the 2nd week and 4.78±4.16 in the 4th week. While in Group B, there was also a significant decrease {F=194.86 (1.71, 27.43), $p=0.005$, $\eta p^2=0.92$} in ODI scores across the time points ($p=0.005$), with a similarly large effect size ($\eta p^2=0.92$). The ODI scores decreased from 42.76±11.85 at baseline to 30.26±10.97 at the 2nd week and17.00±7.50 at the 4th week. (Figure 3)

DISCUSSION

The current study aimed to compare the dose-response of neural mobilization on hamstring flexibility in nonspecific LBP on outcomes including pain, active knee extension, lumbar flexion, and disability.

Regarding the pain intensity within-group analysis showed that high and low-dose neural mobilization both significantly reduced the low back pain. while the group difference was observed between groups at the end of the intervention. However, Group A's significant pain reduction after 2nd week reflects NM's dose-dependent neurophysiological impact. Higher repetitions (10–12 reps/set) may enhance mechano-transduction in neural tissues, optimizing ion channel function and reducing ectopic firing[23]. Earlier research lends evidence to the present study's claim by Balcı A et al. (2020) stated that the neural mobilization with 3 sets was found significantly effective in lowering the pain intensity in the wrestlers' population ($P<0.05$) [18]. Similarly, a study by Krishna H et al. (2019) conducted to examine the efficacy of neural mobilization on pain found similar findings as; a significant immediate reduction of pain ($P<0.05$) on the visual analogue scale in young adult athletes after the application of hamstring neural mobilization [24].

However, these findings contradict the finding of a study conducted by Jin-yong et al. (2021) to determine the immediate effectiveness of the neural slider technique with hamstring tightness; where no significant improvement was observed in lumbar flexion at within-group analysis ($p=0.27$) as well as between group analysis ($p=0.33$) [25]. The difference might be due to the concern that Jin-yong et al. (2021) studied only immediate effects, while in our study comparison was done till 4th week. This extended duration allowed for the cumulative effects of the interventions, leading to significant improvements in the lumbar flexion range. While Jin-yong et al. only focused on the immediate effects of the neural slider technique on hamstring tightness and lumbar flexion, immediate assessments might not capture the full therapeutic benefits of neural mobilization, which can accrue over time with repeated sessions.

The results of this study in the AKE Test within-group analysis showed that the groups with high and low dose neural mobilization were significantly effective with a large effect size. However, no significant group difference was found between group analyses showing that both doses are equally effective. Previous studies have also declared similar findings such as a study conducted by Balcı A et al. (2020) reported significant improvement ($P<0.05$) in the AKE test after the application of low-dose neural mobilization in wrestlers with back pain. [18]. Furthermore, Jin-yong Limet al. (2021) also found a significant increase in hamstring flexibility with low-dose mobilization of the nerve [26]. The observed findings in knee extension match the physiological goal of neural sliding which can improve nervous system function and facilitate better flexibility irrespective of the dosage [27]. Moreover, previous literature is consistent with current findings thus further aiding the physiological reasoning of the current study. The similar results observed with high-dose interventions might be explained by a ceiling effect, where a certain threshold of neural mobilization achieves the maximum possible benefit, beyond which additional improvements are minimal. Both low and high doses might have exceeded this threshold, leading to similar findings.

Oswestry Disability Index (ODI) analysis shows both groups were found significantly effective in reducing the disability level with moderate to large effect size when compared in pairwise comparison analysis. While significant group difference was observed with more disability reduction in Group A than in Group B explaining the fact that high-dose neural mobilization is more effective in reducing the disability in variables related to physical functioning. The result of this study is in coherence with a meta-analysis showing larger effect sizes were discovered for NM's impact on pain relief and disability improvement [28]. This could be justified by the physiological response of high-dose neural mobilization explained by Romero-Morales et al. (2022) that the intensity of the nerve gliding and sliding during stretching is correlated to improved functional status of muscle locally and overall limb functional status [29].

The use of co-interventions (hot packs and strengthening exercises) in both groups confounds the isolated effects of neural mobilization (NM), making it difficult to establish a clear dose-response relationship. Furthermore, the lack of a true control group receiving no NM prevents meaningful comparisons to standard care or placebo effects.

CONCLUSION

High-dose neural mobilization (NM) demonstrates acute neurophysiological benefits for pain and disability in NSLBP, mediated through anti-inflammatory and descending modulatory pathways. However, its limited dose-response effect on flexibility highlights the dominance of concurrent stretching. Future studies should integrate biomarker assays, isolate NM dosage, and extend follow-up to elucidate long-term neuroadaptation.

DECLARATIONS & STATEMENTS

Author's Contribution

RL: substantial contributions to the conception and design of the study.
AZ: acquisition of data for the study.
AZ: interpretation of data for the study.
RL: analysis of the data for the study.
RL and AZ: drafted the work.
RL and AZ: revised it critically for important intellectual content.
RL and AZ: final approval of the version to be published and agreement to be accountable for all aspects.
of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The study was conducted in accordance with the Declaration of Helsinki. Prior to conduction of study the approval was obtained from ethical committee of Riphah International University (RIPHAH/RCRS/REC/Letter-01058).

AI Use Statement

No AI was used for content generation, data analysis, or interpretation.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

This study does not involve the creation or analysis of new data, and therefore, data sharing is not applicable to this article

Conflicts of Interest

The authors declare no conflict of interest.

Funding

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Research Article

Effectiveness of scapular clock exercises in scapular dyskinesia in post-operative cardiac patients: A randomized clinical trial

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Abstract

Background: Scapular dyskinesia is a frequent complication after cardiac surgery due to thoracic immobility, pectoral tightness, and muscle imbalances, contributing to persistent shoulder pain and functional deficits.

Objective: To evaluate the effectiveness of scapular clock exercises combined with conventional physiotherapy versus conventional physiotherapy alone in reducing pain, improving range of motion (ROM), and enhancing shoulder function in post-operative cardiac patients.

Material and Methods: This randomized clinical trial included n=28 post-cardiac surgery patients with scapular dyskinesia, who were allocated to either Group A (scapular clock exercises plus conventional physiotherapy) or Group B (conventional physiotherapy). Both groups were treated thrice weekly for 4 weeks. The primary outcome was the Numeric Pain Rating Scale (NPRS), and secondary outcomes included QuickDASH and shoulder ROM. Statistical analysis was conducted using RM-ANOVA and independent t-tests.

Results: The mean age of n=17(60%) male and n=11(40%) female subjects were 55.21±7 years. Both groups significantly improved pain, disability, and ROM over 4 weeks ($p<0.05$). Group A demonstrated markedly greater improvements in NPRS, QuickDASH, and all ROM directions at 2- and 4-week follow-ups compared to Group B, with large effect sizes.

Conclusion: Scapular clock exercises combined with conventional physiotherapy offer superior outcomes for pain, disability, and mobility compared to conventional physiotherapy alone. These findings highlight the importance of incorporating targeted scapular exercises into cardiac rehabilitation to address under-recognized musculoskeletal deficits.

Keywords: scapular clock exercises; postoperative rehabilitation; numeric pain rating scale (NPRS); quickdash; resistance training; post-sternotomy complications; physiotherapy; upper limb function.

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INTRODUCTION

Scapular dyskinesia is a condition that can significantly affect shoulder function, leading to pain, reduced range of motion, and impaired neuromuscular control [1]. Sternotomy can cause an alteration in thoracic mobility, pectoral muscle tightness, and weakening of scapular stabilizers such as the serratus anterior and lower trapezius. These factors contribute to abnormal scapular mechanics, potentially leading to secondary shoulder pain and movement limitations. Post-cardiac surgery, particularly following median sternotomy, patients often develop shoulder dysfunction due to prolonged immobility, protective postures, and muscle imbalances [2]. About 47% of patients report shoulder aches post-cardiac surgery and 91% remain symptomatic even after 14.6 months of operation.

Management of scapular dyskinesia involves various rehabilitation strategies aimed at improving muscle function and reducing disability [3]. Manual therapy combined with conventional physiotherapy has better results in post-surgical cancer patients, improving shoulder range of motion, pain levels, and muscle strength compared to scapular-focused exercises alone[4]. Furthermore, suspension-type exercises have demonstrated benefits in scapular muscle strength, although they did not significantly outperform traditional methods in pain relief or functional improvement[5].

The rehabilitation of post-cardiac surgery patients primarily focuses on cardiovascular recovery, often neglecting musculoskeletal complications such as scapular dyskinesia. Scapular clock exercises can strengthen the affected trapezius muscle and stretch the shortened pectoralis minor muscle which plays a vital role in normal positioning and function of the scapula[6]. The addition of this exercise regime in cardiac rehabilitation, it can reduce the incidence of scapular dyskinesia. It was hypothesized that scapular clock exercises are significantly effective in shoulder problems in postoperative cardiac patients. The aim of this research was to determine the effectiveness of scapular clock exercises for the management of scapular dyskinesia in postoperative cardiac patients.

METHODOLOGY

Study design and setting: This randomized clinical trial (NCT05426694) was carried out from May 2024 up to August 2024 in the Faisalabad Institute of Cardiology (FIC), Faisalabad, Pakistan, after the approval (Tuf/IRB/314/24) from institute's review board of The University of Faisalabad (TUF). The competent FIC authority signed the IRB to allow data collection from the institute. The protocols were conforming to the Helsinki Declaration and informed consent was taken from each subject prior to the commencement of treatment.

Participants: The inclusion criteria consisted of male and female subjects 35 to 65 years of age, post-cardiac surgery individuals with a minimum 6 weeks gap after surgery, a history of shoulder pain, and complaints of scapular region pain with ≤50% reduction of active range of motion (ROM) of shoulder abduction, external rotation, and flexion. Affirmative findings of Scapular assistance test (SAT) and Scapular retraction test. The prominence of any border of scapula on observation. The exclusion criteria included; the bilateral problem of the shoulder, account of prior operation or facture of the shoulder, neuromuscular disorders, Type-III dyskinesia of scapula, glenohumeral or acromioclavicular arthritis, and subject not willing to participate in the study.

Sample Size: The study design involves 2 groups and 3 repeated measurements. The sample size n=30 was calculated to achieve 82% power (1-β) to detect a medium effect size (f=0.25) at a significance level of α=0.05. The sample was collected by using a nonprobability purposive sampling technique. They were randomly and equally divided into two groups (n=15 each) Group A (scapular clock exercises with baseline exercises) and Group B (baseline exercises only). A total of n=39 individuals were assessed for eligibility. Of these, n=9 was excluded, n=7 did not meet inclusion criteria, and n=2 declined participation. So, the remaining n=30 participants randomized into Group A (n=15) received separate clock exercises combined with stretching and strengthening, while Group B (n=15) only focused on stretching and strengthening exercises for shoulder muscles. During follow-up, both groups experienced one participant loss each due to missed sessions at the 2nd and 4th weeks, resulting in n=14 participants analyzed per group. Ultimately, 28 participants (14 in each group) were included in the final analysis. (Figure 1)

Randomization: For this study, participant randomization was conducted using an online randomization generator to ensure impartial group allocation and internal validity. The process involved uploading a list of participant identification numbers (IDs 1–30) into the tool, which then allocated each ID to a group via a computer-generated random sequence with equal probability. This method guaranteed allocation concealment, preventing selection bias by ensuring researchers.

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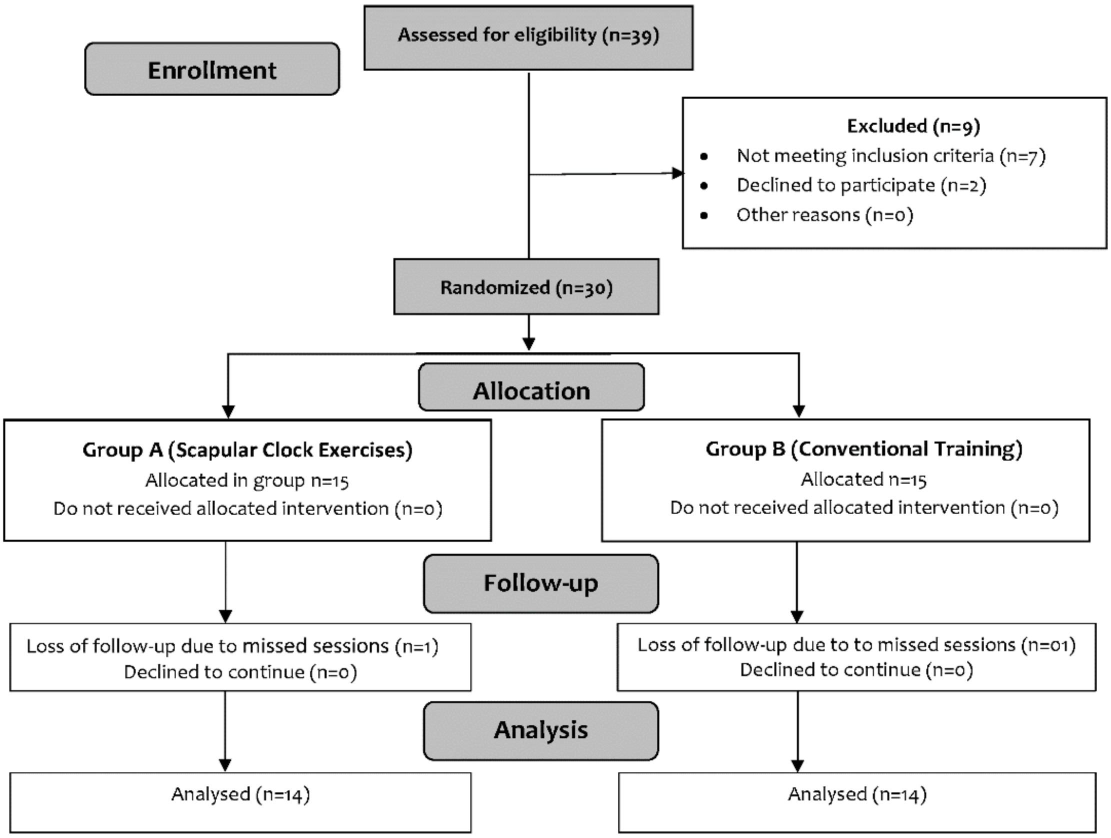

Figure 1: Consort diagram

Blinding: The outcome assessor was blinded to group allocation to minimize detection bias. Treating therapists administering the interventions could not be blinded due to the nature of the exercise-based interventions. These measures ensured that assessments were conducted without knowledge of group allocation, preserving the integrity of the results.

Intervention: Each session followed a structured protocol, ensuring progression based on individual tolerance and recovery status. All participants received conventional physical therapy (CPT) including infrared therapy for 10–15 minutes before engaging in therapeutic exercises. Patients were seated 60 cm away from the infrared source, ensuring optimal heat penetration for muscle relaxation and pain relief. The therapy was conducted under the supervision of a qualified therapist to ensure proper technique and prevent complications. Following infrared therapy, all patients performed stretching and strengthening exercises to enhance scapular mobility and shoulder function. These included wall washes, corner stretch, pectorals stretching, and sleeper stretch. Each stretch was held for 15-30 seconds and repeated up to 10 times. The treatment was given for three days per week for four weeks for both groups.

Group A was given scapular clock exercises along with CPT. The scapular clock exercises were progressed according to each week. For the scapular clock exercises, the therapist stood beside the patient, the patient placed their hand on the wall at shoulder level with the elbow extended, and performed scapular elevation as well as depression with fingers pointing toward 12 and 6 o'clock positions. After that participant performed scapular protraction and retraction with fingers at 3 o'clock and finally repeated scapular protraction and retraction with fingers at 9 o'clock. The hold time for each movement was 10 seconds. These exercises were performed in the initial two weeks and continued for four weeks with adding resistance with TheraBand. Group B only received CPT. (Figure 2)

Outcome measures: The primary outcome measure was the Numeric Pain Rating Scale (NPRS) used to record the level of pain described by patients. This scale has numerical values from 0 to 10, where 0 shows no pain, 5 is moderate pain and 10 is very severe pain. The reliability of this scale is 84% [7]. The secondary outcome measures were *Quick*DASH and shoulder ROM. *Quick*DASH questionnaire assessed the level of shoulder disability. Its total score varies from 0 to 100, smaller value means lesser disability of arms, shoulders, and hands while a greater value means moderate to severe disability. The reliability and validity of *Quick*Dash are 90% and 70%, respectively [8]. A goniometer was used to measure shoulder ROM and it is a reliable tool with about 91-98% reliability recorded in a study [9].

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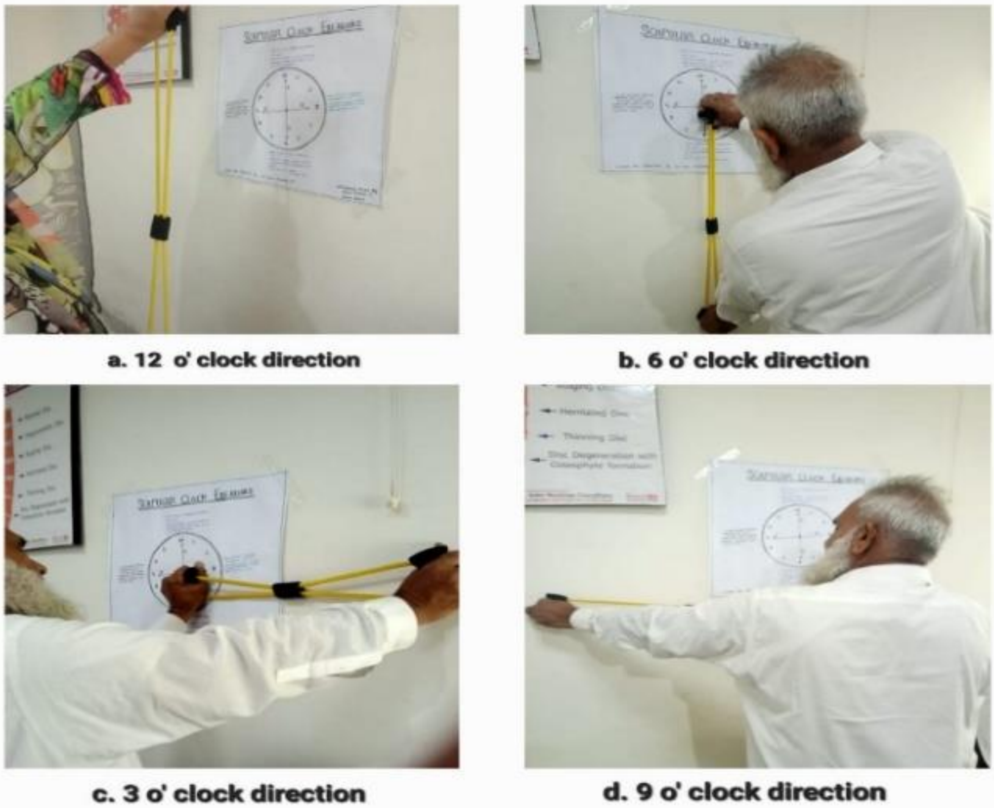
a. 12 o' clock direction
b. 6 o' clock direction
c. 3 o' clock direction
d. 9 o' clock direction

Figure 2: Patient is performing scapular clock exercise holding TheraBand in all directions

Data was analyzed by SPSS version 27 and a ($p<0.05$) was taken as significant. The assumptions of the parametric test were assumed. So, repeated measure ANOVA with pairwise comparison was used for within-group changes. For comparison between the groups, an Independent t-test was applied along with Cohen's d for effect size.

RESULTS

There were n=28 subjects analyzed with a mean age of 55.21±7.28 years. There was n=17(60%) male subjects and n=11(40%) female subjects. the majority of involved side of the patients in n=21(75%) were the left side, whereas only n=7(25%) were affected on the right side.

The RMANOVA with pairwise comparisons demonstrated that Group A (Scapular Clock Exercise) and Group B, showed significant improvements ($p<0.05$) in pain, disability, and shoulder ROM over four weeks at each assessment within both groups. (Table 1)

Table 1: Within-group comparison for pain, shoulder disability and ROMs

		Group A (Scapular Clock Exercise +CPT)			Group B (CPT)		
		Mean±SD	MD/F (2,26)	p-value	Mean±SD	MD/F (2,26)	p-value
NPRS	Baseline	7.36±.63	1.35a	0.001**	7.29±.46	.71a	0.011*
	After 2nd week	6.00±.392	1.78b	0.003**	6.57±.51	.42b	0.015*
	After 4rth week	4.21±.579	95.12c	0.00***	6.14±.36	45.67c	0.004**
QuickDASH	Baseline	38.57±5.94	14.85a	0.00***	40.07±8.22	7.42a	0.002**
	After 2nd week	23.71±5.49	13.78b	0.00***	32.64±9.03	6.42b	0.012*
	After 4rth week	9.93±2.52	132.67c	0.00***	26.21±9.42	88.49c	0.00***
Shoulder Flexion ROM	Baseline	84.50± 8.53	-15.42a	0.002**	85.71±17.98	-5.14a	0.041*
	After 2nd week	99.93±12.06	-18.00b	0.005**	90.86±17.93	-4.78b	0.026*
	After 4rth week	117.93±13.19	107.85c	0.00***	95.64±17.76	12.22c	0.019*
Abduction ROM	Baseline	79.57±10.72	-12.35a	0.003**	76.14±9.63	-4.57a	0.037*
	After 2nd week	91.93±8.53	-16.57b	0.002**	80.71±9.42	-4.64b	0.034*
	After 4rth week	108.50±9.49	12.22c	0.00***	85.36±7.99	15.33c	0.015*
External Rotation	Baseline	36.71±9.63	-7.35a	0.004**	37.57±4.66	-3.21a	0.046*
	After 2nd week	44.07±8.81	-8.85b	0.006**	40.79±4.28	-3.28b	0.031*
	After 4rth week	52.93±7.77	81.94c	0.00***	44.07±3.85	18.79c	0.021*

Significance level: $p<0.05$, $p<0.01$** & $p<0.001$****

S.D- Standard deviation; NPRS- Numeric-Pain Rating Scale; QuickDASH- Disability of arms, shoulder and hands questionnaire Quick form/short version; ROM- Range of Motion, MD- Mean Difference

Table 2: Between-group comparison of outcome measures

		Group A (SCE+CPT)	Group B (CPT)			
Outcome measure		Mean±SD	Mean±SD	p-value	MD	Cohen's d
NPRS	Baseline	7.36±.63	7.29±.46	.737	0.07	0.13
	After 2 weeks	6.00±.392	6.57±.51	.003**	-0.57	-1.25
	After 4 weeks	4.21±.579	6.14±.36	.001**	-1.93	-4.00
Quick DASH	Baseline	38.57±5.94	40.07±8.22	.585	-1.5	-0.21
	After 2 weeks	23.71±5.49	32.64±9.03	.004**	-8.93	-1.20
	After 4 weeks	9.93±2.52	26.21±9.42	.001**	-16.28	-2.36
Shoulder Flexion ROM	Baseline	84.50± 8.53	85.71±17.98	.821	-1.21	-0.09
	After 2 weeks	99.93±12.06	90.86±17.93	.128	9.07	0.59
	After 4 weeks	117.93±13.19	95.64±17.76	.001**	22.29	1.42
Abduction ROM	Baseline	79.57±10.72	76.14±9.63	.382	3.43	0.34
	After 2 weeks	91.93±8.53	80.71±9.42	.003**	11.22	1.25
	After 4 weeks	108.50±9.49	85.36±7.99	.001**	23.14	2.64
External Rotation	Baseline	36.71±9.63	37.57±4.66	.767	-0.86	-0.11
	After 2 weeks	44.07±8.81	40.79±4.28	.221	3.28	0.47
	After 4 weeks	52.93±7.77	44.07±3.85	.001**	8.86	1.44

Significance level: p<0.05, p<0.01** & p<0.001****

SD- Standard deviation; NPRS- Numeric-Pain Rating Scale; QuickDASH- Disability of arms, shoulder and hands questionnaire Quick form/short version; ROM- Range of Motion; n- number of subjects in that group, MD- Mean Difference

As the group was comparable at the baseline, Group A achieved statistically (p<0.05) and clinically superior outcomes in pain relief, functional improvement, and all aspects of shoulder range of motion compared to Group B at every assessment, except for flexion ROM and external ROM which were only significant after 4th week, suggesting the greater effectiveness of Scapular Clock Exercises over conventional baseline exercises. (Table 2)

DISCUSSION

The current RCT evaluated the effectiveness of scapular clock exercises combined with conventional physical therapy (CPT) versus CPT alone in reducing pain, improving functional disability, and enhancing shoulder range of motion (ROM) in postoperative cardiac patients with scapular dyskinesia. The results revealed that both groups demonstrated significant improvements across all outcome measures over the 4-week intervention period. However, Group A, which received the scapular clock exercises, showed markedly greater improvements in the Numeric Pain Rating Scale (NPRS), Quick DASH, and all shoulder ROM directions compared to Group B. The between-group differences were especially evident in the 4th week of intervention, with a large effect size for pain relief, functional disability, and ROM.

Our findings are in line with prior research demonstrating the effectiveness of scapular-specific exercises in shoulder rehabilitation[10]. Scapular dyskinesia has been identified as a major contributor to pain and restricted ROM following thoracic surgery due to muscle weakness and poor scapular control [11]. Previous interventions using closed-chain scapular exercises and targeted strengthening of periscapular muscles have shown superior outcomes in restoring scapular kinematics, reducing pain, and improving shoulder function, which supports the greater improvements observed in our experimental group[12, 13]. Moreover, recent research has highlighted that progressive resistance exercises using TheraBands can improve muscle endurance and neuromuscular control, ultimately resulting in greater functional recovery[14,15,16]. Despite this, most existing rehabilitation protocols for post-cardiac surgery focus on general upper-limb mobility and strength without specifically targeting scapular kinematics. Our findings extend this evidence base by demonstrating that structured clock exercises can further enhance scapular stability and facilitate active movement in all three planes of motion.

The observed clinical benefits can be attributed to several mechanisms. Scapular clock exercises promote rhythmic and controlled protraction, retraction, elevation, and depression across multiple directions, which restores normal scapulohumeral rhythm and neuromuscular control[17]. Specifically, the exercises stretch shortened pectoral muscles and activate key stabilizers like the lower trapezius and serratus anterior, improving postural alignment and reducing abnormal scapular winging that often accompanies post-cardiac surgery rehabilitation[18, 19].

The progressive use of theraband in the latter two weeks increased the load, which led to the adaptive strengthening of scapulothoracic musculature, contributing to enhanced active ROM and greater functional gains measured on the QuickDASH[20]. Reduction in pain can be explained by the decrease in soft-tissue stiffness, restoration of joint mechanics, and modulation of pain-processing pathways through active movement and sensory input[15]. The resultant improvements in motor control and stability not only relieved pain but also enabled participants to perform daily arm and shoulder tasks more efficiently.

Despite these encouraging results, the relatively small sample size limits the generalizability of the findings, and future multicenter trials with larger samples are needed to confirm these results. Further, the study was short-term (4 weeks), so the sustainability of the improvements beyond this period is unknown.

CONCLUSION

The study supports the use of scapular clock exercises in conjunction with baseline exercises as a safe, practical, and effective rehabilitation strategy for reducing shoulder pain, disability, and ROM restrictions in post-operative cardiac patients with scapular dyskinesia. By demonstrating these exercises for this underserved group, this research holds significant implications for both clinical practice and future guideline development in cardiac rehabilitation. Future research with longer follow-ups and larger, more diverse cohorts will help establish the sustained efficacy of this intervention and its feasibility as a routine component of post-cardiac rehabilitation programs.

DECLARATIONS & STATEMENTS

Author's Contribution

IA, SZ and AS: substantial contributions to the conception and design of the study.
IA, SZ and AS: acquisition of data for the study.
SZ and AS: interpretation of data for the study.
IA, RAB and AM: analysis of the data for the study.
IA, SZ, AS, RAB and AM: drafted the work.
IA, SZ, AS, RAB and AM: revised it critically for important intellectual content.
IA, SZ, AS and RAB: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

This RCT was carried out in the Faisalabad Institute of Cardiology (FIC), Faisalabad, Pakistan, after the approval (Tuf/IRB/314/24) from institute's review board of The University of Faisalabad (TUF).

AI Use Statement

No AI was used for content generation, data analysis, or interpretation.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Due to privacy or ethical considerations, the data presented in this study are available upon request from the corresponding author, as they are not publicly accessible.

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Conflicts of Interest

The authors declare no conflict of interest.

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