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The intersection of artificial intelligence and rehabilitation sciences: promoting originality and integrity in research

Abdul Haseeb Bhutta[1,2*]

Keywords: Artificial intelligence; integrity; rehabilitation sciences

Artificial Intelligence (AI) as a scientific discipline is an exciting opportunity for the development of a new direction in rehabilitation sciences and the improvement of patient care and research approaches [1]. Nevertheless, this integration brings a lot of problems to the issue of credibility and novelty around the processes of researching practices. Thus, this editorial is devoted to these questions, stressing the importance of a strong ethic compared to the standards for research in this shifting context.

AI technologies have started influencing Rehabilitation sciences by offering individualized intervention, patient tracking, and optimization of the results by using big data analytics [2, 3]. For example, the machine learning approach may retrieve an avalanche of data to predict rehabilitation strategies that may be effective for patients with particular characteristics [4]. Nonetheless, as more developments are created through the utilization of artificial intelligence, the likelihood of ethical concerns and questions regarding originality in research rises as well [5].

Scientific practice requires creativity and any utilization of AI needs to hold to this regulated element of advancement. Investigators should implement specific precautions to avoid plagiarism or the unauthorized borrowing of concepts through the use of AI tools [6]. This requires policies and procedures that define how the use of AI in production can be realized without compromising the research process domain [7]. AI practice must be brought into the open through mandatory reporting obligations that compel institutions to declare the use of AI throughout research processes.

It is equally important in all fields especially those which have the potential to endanger the lives of patients. As noted in various studies, the principles of ethical practice like candor, accountability, and transparency are critical in developing public confidence in science [8]. That means the rehabilitation sciences community must embrace the operational and best use of AI and ensure that researchers learn the ethics of using them and the importance of following the set standards. There is a need to ensure institutional commitment to the training of consciousness on responsible conduct of research and the use of AI [7]. Key factors touched upon here include bias that exists in the AI systems they develop and the kind of data they produce [9, 10].

To this end, researchers should be compelled to specify the strategies they have applied AI in their research; the database they have utilized; the algorithm they have employed; and the reasons as to why they selected such choices [11]. This transparency is necessary to make methods reproducible and trustworthy [12]. There was a proposal that enhancing the elements of interdisciplinary interaction would increase the yield of their work [13]. There is also the concern that the ethical standards followed should not be overlooked in the peer review processes thus the

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procedures should be changed to allow for the review of the implementation of AI [6].

Universities and research centers need to develop strong guidelines to prevent researchers from engaging in wrongdoing; this can involve developing and providing procedures for reporting research misconduct [14-16].

AI in the domain of rehabilitation sciences has the potential to take the specialty to the next level. However, this potential has to be controlled and balanced by the goals of novelty, as well as the ethical course of the research. By keeping the emphasis on ethical behavior and core principles of the rehabilitation sciences the community can embrace the attributes of AI while at the same time preserving the integrity of science. It will increase the quality of work done while also making new technologies in rehabilitation it is useful and beneficial for society.

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Research Article

Effects of Low-impact elliptical training on knee osteoarthritis outcomes and knee joint space: a randomized clinical trail

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ABSTRACT

Background: Different physical therapy treatment strategies are used to decrease the symptoms and reduce the severity of knee Osteoarthritis (OA). Low-impact elliptical training is like mobilizations, which increase nourishment and contribute to increased joint space. Objective: To determine the effects of low-impact elliptical training on knee osteoarthritis (OA) outcomes and knee joint space.

Methods: Data for the randomized controlled trial (NCT05977374) was collected from 28 participants through a non-probability convenience sampling technique and randomized into group A: which received low-impact elliptical training along with conventional therapy, and group B: which received traditional physical therapy for 12 weeks. The outcomes were checked through a knee injury and Osteoarthritis Outcome Score (KOOS) pre and post-treatment at the 6th and 12th week and knee space was measured by X-rays pre and post-treatment at the 12th week only.

Results: the mean age of group A study participants was 51.92±9.106 years, and 50.29±5.483 years for group B, respectively. Within-group analysis, all domains of the KOOS for the low-impact elliptical training group showed significant improvement ($p \leq 0.005$). Between-group analyses, all the domains of the KOOS showed a non-significant difference with $p \geq 0.05$. In the between-group analysis of the knee joint width of the medial and lateral spaces in pre- and post-observation, there was no significant difference noted, but within the group, significant improvement ($p=0.007$) was observed in the medial space for the LIET group only

Conclusions: Elliptical training can be used to intervene in individuals with grade 1 and 2 knee osteoarthritis compared to conventional physical therapy for the alleviation of pain, stiffness, ADLs, sports, and QOL. Moreover, it may improve knee joint space.

Keywords: elliptical training; knee OA; knee outcome; pian

Clinical Trials # NCT05977374

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INTRODUCTION

Knee osteoarthritis (OA) is a chronic degenerative disease affecting millions of people worldwide, particularly those above 60 years of age[1, 2]. Different factors, including trauma or joint injury, repetitive actions like squatting and kneeling, mechanical stressors, obesity, old age, sex, lifestyle, calcium deficiency, metabolic diseases like diabetes, and genetic factors, can contribute to knee OA[3]. Knee osteoarthritis can result from the degradation of cartilage, the formation of osteophytes, and the reconstruction of the subchondral bone[4]. Generally, knee OA is diagnosed by physical examination, X-ray images, MRI scans, and arthroscopy[5].

To decrease the symptoms and severity level of knee osteoarthritis, physical therapy is one of the treatment strategies that can be employed [6]. Grade 1 and 2 mobilization can reduce pain and improve joint function by promoting blood flow, improving nutrient delivery, increasing joint lubrication, and reducing stress on the joint surfaces. Additionally, by increasing the range of motion and promoting joint flexibility, they may help decrease the compressive forces on the joint, hence helping to improve joint space. Low-impact exercises such as swimming, cycling, or elliptical machines can facilitate the maintenance of knee homeostasis. These exercises initiate a cycle of optimally promoting knee chondrocyte production and regenerating knee cartilage through the cyclic compression loading technique, which enhances blood flow, oxygen, and nutrient supply[7].

Elliptical training is a popular fitness tool due to its ease of use and low risk of injury, which simulates the motion of walking or running while reducing the impact on joints [8] [9]. It has been found to have positive effects on knee osteoarthritis by decreasing knee varus and improving physical function and walking ability in individuals after total hip arthroplasty [10]. Off-axis elliptical training also reduces pain, improves knee function, and enhances lower extremity neuromuscular control in older adults [11]. Modified elliptical trainers with a converging footpath and reduced inter-pedal distance have different impacts on knee joint kinematics depending on the direction and incline of the exercise. Elliptical training puts less strain on the joints than high-impact exercises and protects knees from stressful impact [12].

As elliptical training employs the same cyclic process of compressive loading as manual knee joint mobilizations, the mobilizations are mostly performed manually, and active participation of the patient is limited. Elliptical training, on the other hand, would allow the patient to engage actively and support cartilage recovery in knee osteoarthritis. Until now, limited information has been available on the effects of elliptical training on knee space changes in knee OA, so this study assessed the effects of elliptical training on knee joint space and knee OA outcomes.

MATERIAL AND METHODS

Study Design & Setting: It was a single-blinded, randomized clinical trial (NCT05977374) conducted at the Islamabad Physical Therapy and Rehabilitation Centre (IPRC-21-01-2022-23), Rawalpindi, Pakistan. The study was completed within 1 year from January 2022-Feburary 2023 and approval was taken from the research and ethical committee (REC) of the Faculty of Rehabilitation and Allied Health Sciences (RIPHAH/RCRS/REC/Letter-01238) Riphah International University.

Participants: Selected participants were between the ages of 40 and 65, both male and female, with knee osteoarthritis (OA) of grades 1 and 2. Participants were ineligible if they had any recent musculoskeletal ailments, such as trauma or fractures of the lower limb. Individuals suffering from low back discomfort, sciatica, acute infections, or fever were excluded. Participants who were using supplements or drugs that might potentially interact with the findings from the research were also eliminated. Finally, the existence of any knee joint abnormalities was a significant determinant of exclusion.

Sample Size: Using G-Power, keeping the effect size small (0.24), α error margin at 0.05 and to avoid β error probability, the power (1- β) was set at 0.95%, and the sample size calculated was n = 28. A total of n=100 patients were assessed for eligibility through the non-probability convenience sampling technique and 28 participants fulfilled the inclusion criteria.

Randomization: The envelop sealed method using a computerized random number generator was used for randomization. An individual who was not directly involved in the study did the random allocation. The random numbers were then written on the index cards and placed in a thick and opaque sealed envelope before the start of the study. After obtaining written informed consent, the physical therapist opened the envelope and provided the respective interventions to the patients. As the assessed patient was blinded to the intervention so the study was single-blinded.

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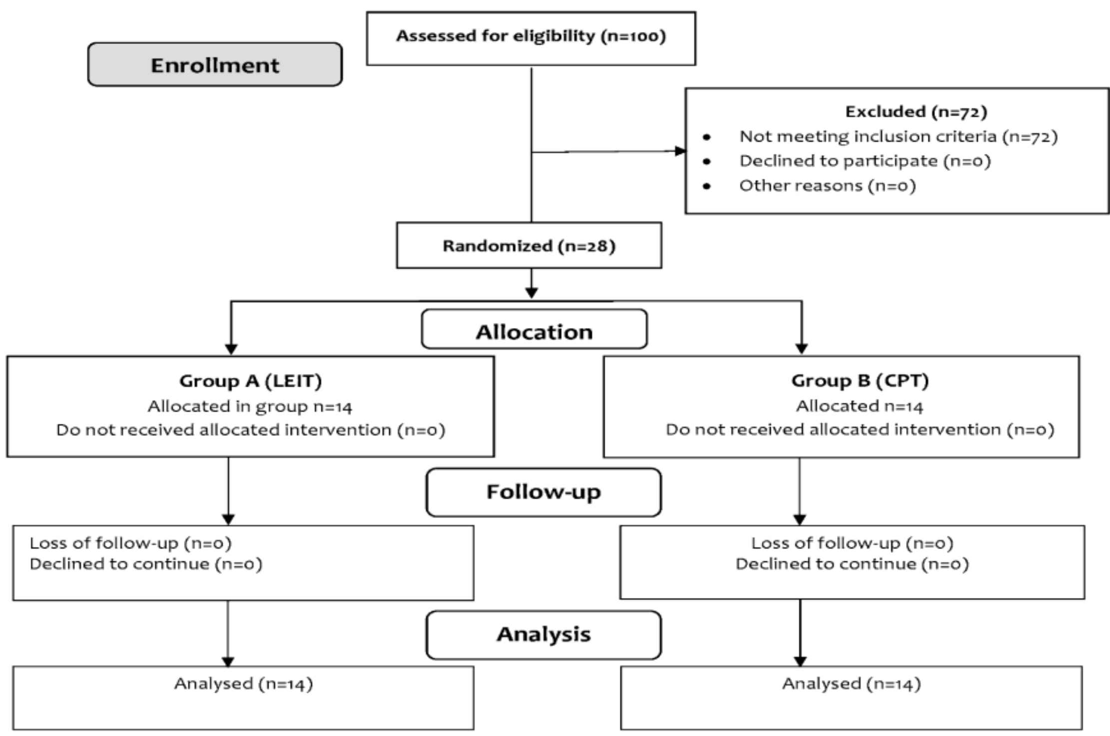

Figure 1: CONSORT diagram

Intervention: 60-minute session was given to each patient 3 times per week and was given for 12 weeks. Data was collected at baseline, after 6 weeks, and then after 12 weeks for KOOS, but knee joint space was measured by X-ray at baseline and after 12 weeks.

Treatment Group A (Conventional Physical Therapy and low impact Elliptical Training): received electrotherapy sessions (Ultrasound (f) 1 MHz, intensity 1.5W/cm2, 7 mins), isometric exercises (10 reps, 5 sec hold, 3 sets), and open chain activities for 40–50 minutes, 3 times per week. Before and following elliptical training, each participant undertook static stretching exercises. Static muscle stretching included calf muscle, quadriceps muscle, iliotibial band, and hamstring stretching with10 repetitions and 10-second hold for each leg.

Table 1: Description of intervention

	Group A (LIET)	Group B (CPT)
	Ultrasound (f) 1MHz, intensity 1.5W/cm2 7 mins. Knee isometrics 10 reps 5 sec hold, 3 sets. Knee open chain activities, 3 times/week. Static muscle stretching included calf muscle, quadriceps muscle, iliotibial band, and hamstring stretching with10 repetitions and 10-second hold was given. The anterior-posterior Maitland mobilization of grades 1-2 was performed for 3 minutes for 6 weeks Home Care Plan was also given. This protocol was repeated during each session and occurred three times per week for 12 weeks	
Week 1 & 6	The individual did a 5-minute warm-up on the elliptical machine at their own speed. This protocol was repeated during each session, which lasted between 30 minutes and 1 hour and occurred three times per week for 12 weeks 3 mins of elliptical training with 120 strides/min followed for the enhancement of results	-
Week 7 & 12	Training progressed to 5 mins of elliptical training when results showed positive response with 120 strides/min	-

The individual did a 5-minute warm-up on the elliptical machine at their own speed. Once the individual was acquainted with the equipment, the 3-minute elliptical training began at a predetermined rate. This protocol was repeated during each session, which lasted between 30 minutes and 1 hour and occurred three times per week for 12 weeks. For weeks 1–6, 3 minutes of elliptical training with 120 strides per minute were followed for the enhancement of results. For weeks 7–12, training progressed to 5 minutes of elliptical training with 120 strides per minute.

Treatment Group B (Conventional Physical therapy): The conventional group received the

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electrotherapy (Ultrasound (f) 1MHz, intensity 1.5W/cm2, 7 mins) and isometric exercises (10 reps, 5 sec hold, 3 sets), knee open chain activities 3 times/week, and stretching exercises were performed. The anterior-posterior Maitland mobilization of grades 1-2 were performed for 3 minutes for 6 weeks, then after that, the oscillation time was increased to 5 minutes, and a home plan was given.

Assessments: The researchers considered the ethical, legal and regulatory norms and standards for this research according to the Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data. For data collection, a demographic questionnaire with KOOS was used. Additionally, x-rays were used as a third method to check the existence of knee OA grades and post-treatment improvements in the knee joint space with radiant software. The five patient-relevant aspects of the KOOS were graded separately: pain (9 things); symptoms (7 items); ADL function (17 items); sport and recreation function (5 items); and quality of life (4 items). All items have five possible answers being rated from 0 to 4.The random effects intraclass correlation coefficients for pain, 0.93 for symptoms, 0.75 for activities of daily living, 0.81 for sport and recreation function, and 0.86 for knee-related quality of life were all considered high [13].

Radiant DICOM (Digital Imaging and Communications in Medicine) Viewer is a medical image processing and display application that uses the DICOM protocol [14]. DICOM software are used to examine a variety of imaging techniques, including digital radiography (CR, DX), magnetic resonance (MRI), digital angiography (XA), computed tomography (CT),), and ultrasound (US, IVUS) etc.[15] Radiant software is designed to analyze a wide range of digital data formats, including 2D and 3D images. The ability to view CR, CT & MRI studies on your PC using VR would allow medical practitioners to better evaluate a disorder along its 3D morphology and also help in determining a treatment plan[16]. We use Radiant DICOM for viewing digital X-rays of the knee joint and have found it, an excellent tool for analysing knee osteoarthritis. The radiographs of the anterior-posterior and lateral views of the knee joint were taken [17]. Then these images were transferred to DVD and different dimensions of knee joint space width (KJSW) were measured from digital X-ray film with the help of computer image measuring software at baseline and after 12 weeks.

Statistical methods: Descriptive statistics were used to summarize the study findings and were subsequently presented in tables and graphs. A mixed ANOVA with partial eta squared (ηp2) as the effect size was used to examine the interaction between interventions and the level of assessment because non-parametric tests were appropriate for the data. A one-way ANOVA test was used to analyze changes over time for between-group comparisons. The RM-ANOVA test was used for within-group comparisons. The data was analyzed using SPSS (v-20) with $p<0.05$ as a significant level.

RESULTS

The mean age of study participants of Group A was 51.92±9.106 years, whereas Group B had 50.29±5.483 years. The gender (p=0.12) and the BMI (p=0.54) are normally distributed in both groups. (Figure 2 & 3)

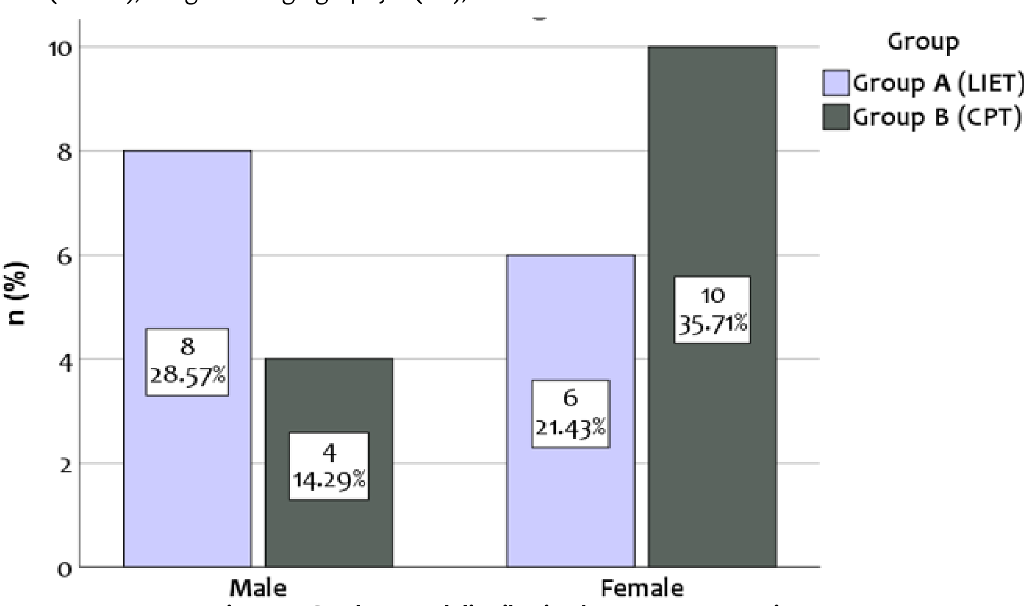

Figure 2: Gender Based distribution between Interventions

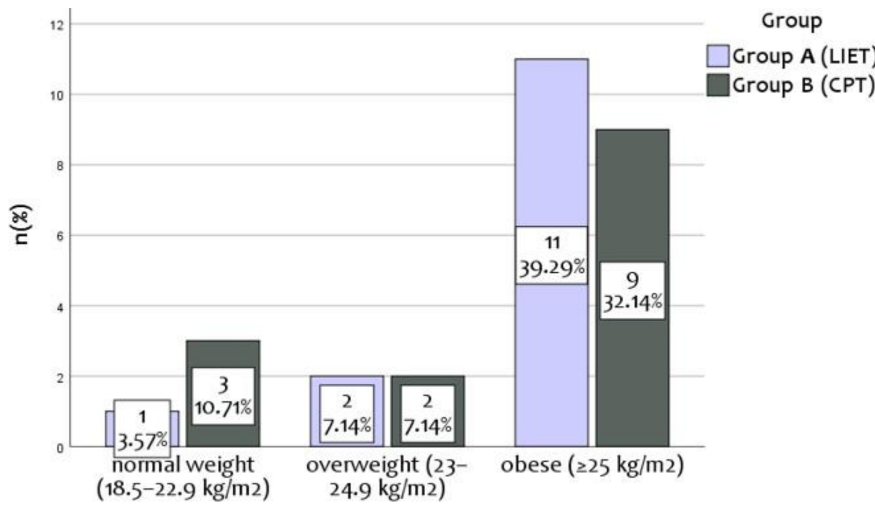

Figure 3: BMI distribution between interventions

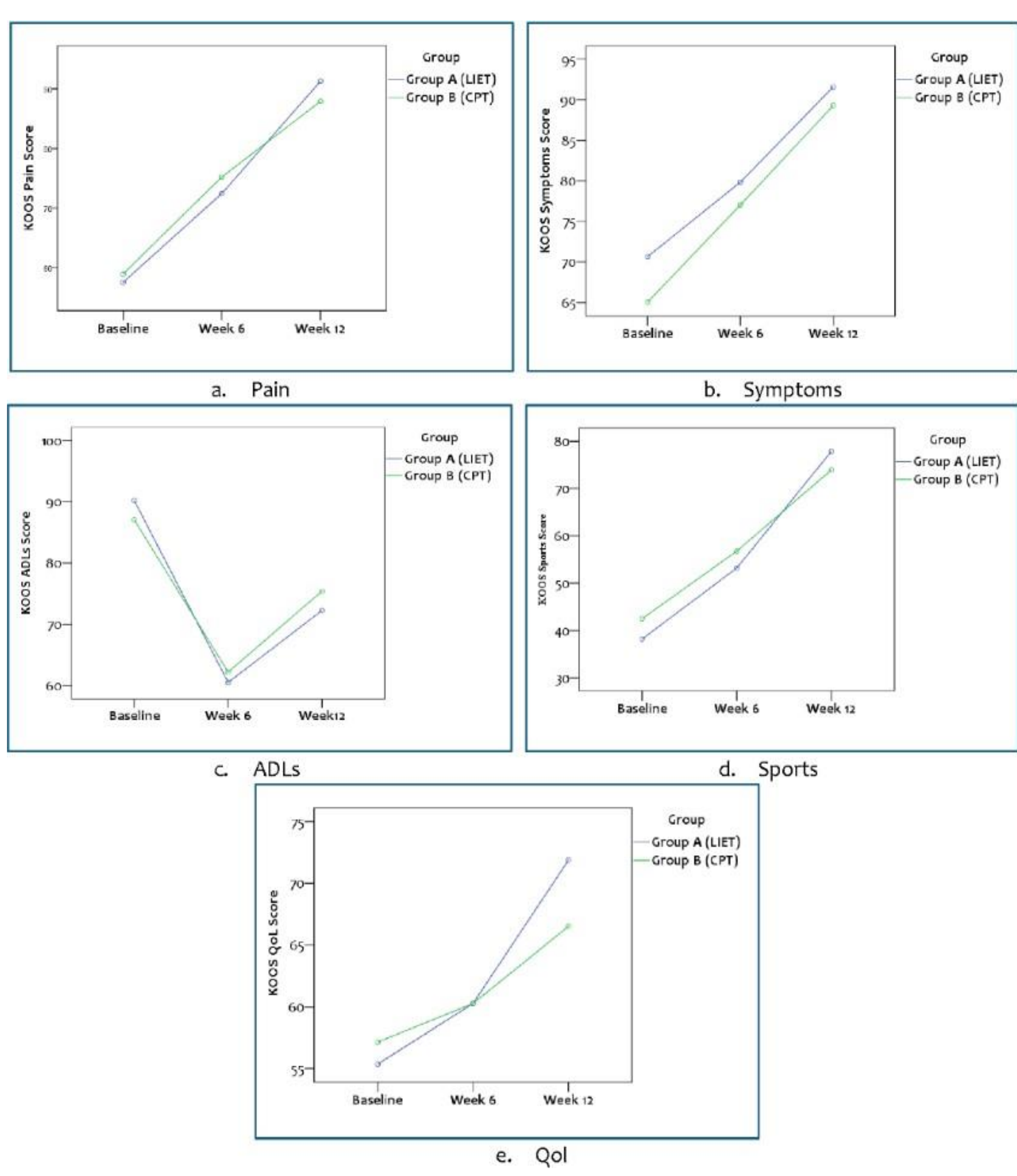

Figure 4: Interaction effects of intervention with level of assessment

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While assuming the sphericity, there is no homogeneity in the variance, whether the sphericity was assumed or not, there is no significant difference in the individual in the domain of KOOS with the level of assessments. There is no significant interaction effect regarding KOOS, pain {F= 1.058(2, 52), p-value 0.346}, symptoms {F= 0.053 (2, 52), p-value 0.608}, ADLs {F= 1.379 (2, 52), p-value 0.261}, sports {F= 2.394 (2, 52), p-value 0.101} and QOL {F= 1.177 (2, 52), p-value 0.316}. (Figure 5)

Within-group analysis, the domains of the KOOS for Low Impact Elliptical training there is no significant difference within the groups in all its variables, pain, stiffness, ADLs, Sports, (p> 0.005) except QOL of Conventional Physical therapy training initially there was a no improvement from baseline to week 6 then from 6th week to 12th week, but generalized improvement has been seen from baseline to 12 week {F= 10.855(1.427, 18.55), p-value 0.002, ηp2=0.455}. However, an overall improvement has been observed within the group of CT. (Table 3).

Between-group analysis performed by one-way ANOVA which is explained in detail in Table 3, shows that in all the domains of the KOOS, there is no significant difference observed regarding pain, stiffness, ADLs, sports, and QOL with p≥0.05. From the baseline to the 6th week till the 12th week, better results have been documented from both groups. The between group analysis of the Knee joint width of the medial and lateral spaces in pre and post observation, in which there was no significant difference noted but with-in the group significant improvement was observed. Illustration showed in Table 4 & 5.

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

		Group A (LIET)					Group B (CPT)				
		Mean	SD	MD/F (df)	p-value	ηp²	Mean	SD	MD/F (df)	p-value	ηp²
Pain	Baseline	57.54	17.85	-14	0.001* [a]		58.93	14.42	-16	0.001* [a]	-
	After 6th week	72.42	20.48	-18	0.00*** [b]		75.20	5.49	-12	0.00*** [b]	-
	After 12th week	91.27	12.74	59.88(2,26)	0.00*** [c]	0.82	87.90	7.02	43.71(2,26)	0.00*** [c]	0.77
Symptoms &Stiffness	Baseline	70.66	16.99	-9	0.011** [a]		65.05	11.56	-11	0.00*** [a]	-
	After 6th week	79.85	16.96	-11	0.001* [b]		77.04	9.57	-12	0.00*** [b]	-
	After 12th week	91.58	9.66	27.202(2,26)	0.00*** [c]	0.67	89.29	3.96	63.81(2,26)	0.00*** [c]	0.83
Function	Baseline	60.50	20.03	29	0.00*** [a]		62.18	14.04	24	0.00*** [a]	-
	After 6th week	72.27	23.24	-11	0.007* [b]		75.42	10.58	-13	0.00*** [b]	-
	After 12th week	90.23	14.97		35.138(2,26)	0.730	87.08	7.54	103.09(1.36)	0.00*** [c]	0.88
Sports	Baseline	38.21	20.24	-15	0.006* [a]		42.50	11.72	-14	0.00*** [a]	-
	After 6th week	53.21	25.00	-24	0.00*** [b]		56.79	9.11	-17	0.00*** [b]	-
	After 12th week	77.86	20.44	74.83(2,26)	0.00*** [c]	0.852	73.93	10.77	75.11(1.13,14.81)	0.00*** [c]	0.85
Quality of life	Baseline	55.36	20.04	-4	0.566 [a]		57.14	14.05	-3	0.75 [a]	-
	After 6th week	60.27	17.09	-11	0.002*** [b]		60.27	8.70	-6	0.073** [b]	-
	After 12th week	71.88	12.44	10.85(1.42,18.5)	0.002*** [c]	0.455	66.52	6.30	4.45(1.27,16.59)	0.042* [c]	0.25

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

[a]Baseline to 6th week, [b]6th week to 12th week & [c]baseline to 12th week; df-Degree of Freedom; ηp²-Partial eta square; MD-Mean Difference; SD-Standard Deviation

Table 3: One way ANOVA for between group analyses at three different points

		Group A (LIET)		Group B (CPT)			
		Mean	SD	Mean	SD	F (1,26)	p-value
Pain	Baseline	57.54	17.85	58.93	14.42	1.04	0.31
	After 6th week	72.42	20.48	75.20	5.49	0.29	0.59
	After 12th week	91.27	12.74	87.90	7.02	0.67	0.41
Symptoms &Stiffness	Baseline	70.66	16.94	65.05	11.56	0.05	0.82
	After 6th week	79.85	16.96	77.04	9.57	0.24	0.62
	After 12th week	91.58	9.66	89.29	3.96	0.75	0.39
Function	Baseline	60.50	20.03	62.18	14.04	0.06	0.79
	After 6th week	72.27	23.24	75.42	10.58	0.21	0.64
	After 12th week	90.23	14.97	87.08	7.54	0.49	0.48
Sports	Baseline	38.21	20.24	42.50	11.72	0.47	0.49
	After 6th week	53.21	25.00	56.79	9.11	0.25	0.62
	After 12th week	77.86	20.44	73.93	10.77	0.40	0.53
Quality of life	Baseline	55.36	20.04	57.14	14.05	0.07	0.78
	After 6th week	60.27	17.09	60.27	8.70	0.00	1.00
	After 12th week	71.88	12.44	66.52	6.30	2.06	0.16

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

LIET- Low Impact Elliptical Training; CPT- Conventional Physical Therapy; SD-Standard Deviation; MD-Mean Difference.

Table 4: Between the group changes in both groups.

		Group	Mean	SD	p-value
Lateral Knee Joint Space (mm)	Pre	LIET	5.15	0.78	0.86
		CPT	5.20		
	Post	LIET	5.40	0.57	0.80
		CPT	5.34	0.70	
Medial Knee Joint Space (mm)	Pre	LIET	4.36	0.58	0.39
		CPT	4.58		
	Post	LIET	4.51	0.56	0.31
		CPT	4.76	0.72	

Significance Level: p<0.05, p<0.01**, p<0.001****
LIET- Low Impact Elliptical Training; CPT- Conventional Physical Therapy; SD-Standard Deviation; ηp²-Partial eta square; MD-Mean Difference.

Table 5: With-in group changes in both groups.

Group			Mean	SD	MD	p-value	ηp²
Low Impact Elliptical Training (LIET)	Lateral Knee Joint Space (mm)	Pre	5.15	0.78	0.25	0.07	0.48
		Post	5.40	0.57			
	Medial Knee Joint Space (mm)	Pre	4.36	0.58	0.15	0.007**	0.17
		Post	4.51	0.56			
Conventional Physical Therapy (CPT)	Lateral Knee Joint Space (mm)	Pre	5.20	0.86	0.13	0.15	0.33
		Post	5.34	0.70			
	Medial Knee Joint Space (mm)	Pre	4.58	0.76	0.17	0.06	0.32
		Post	4.76	0.72			

Significance Level: p<0.05, p<0.01**, p<0.001****
LIET- Low Impact Elliptical Training; CPT- Conventional Physical Therapy; SD-Standard Deviation; MD-Mean Difference; ηp²-Partial eta square

DISCUSSION

The primary goal of the present study was to assess the effects of Low-impact elliptical training on knee joint space and the outcomes of Knee OA. According to the results of the present study, the mean age of participants was 51 years. Pain, stiffness, ADLs, sports, and QOL were significantly improved for the LIET group and the conventional treatment group, with no significant difference between the two groups, but the knee joint space showed significant improvement in the LIET group only. Hence, standard elliptical training generates peak knee valgus angle difference, impacting knee kinematics.

A study conducted on patella femoral pain patients using an off-axis elliptical training programmer showed a significant decrease in foot plate pivoting angle and sliding distance. It also showed improvement in lower limb off-axis control and single-leg hop distance by 0.2 meters.[18] With an elliptical machine, peak tibial forces are reduced as compared to running, which indicates a low loading rate and further enhancement on the medial side can be done by employing a larger step width on a regular elliptical machine[19]. In a recent study elliptical training showed the same positive outcomes in knee osteoarthritis. The possible reason behind that increased proprioception with minor weight-bearing slows the progression of cartilage abnormalities reduced pain, and improved knee function.

Different studies assessed the effects of different exercise interventions on knee cartilage health and related biomarkers. Bricca et al. evaluated the impact of exercise on articular cartilage health through systemic review in people with OA of the knee and found that loading interventions can lead to positive cartilage modifications and also have positive effects on glycosaminoglycan in knee cartilage [20]. Similar findings were also obtained in a recent trial in which knee outcomes and knee joint space were significantly improved in the elliptical training group. Knee ROM is also markedly improved in the elliptical training group. Cyclic compression puts less stress on the knee joint than high-impact exercises. During compression, fluid is taken from the synovial membrane, and during decompression, cartilage resorbs various nutrients and oxygen. This fluid then enters the extracellular matrix (ECM), where it circulates to chondrocytes at diverse tissue depths and facilitates cartilage development in OA patients[21, 22].

A 48-month cohort research indicated that people who used elliptical training generated more cartilage than those who did physical exercise [12]. Certain studies also showed promising outcomes and improved quality of life with minimal loading of joints by improving the health of knee joint cartilage[23]. In the present study, medial knee joint space in the elliptical group improved significantly. Recent studies also align with the results of previous studies showing peak knee valgus angle difference and reduction in knee osteoarthritis symptoms. Elliptical training involves a low-impact, weight-bearing exercise providing more space for the joint to move without excess

compression or friction. Elliptical training has positive effects on joint biomechanics. It strengthens the muscles, such as the quadriceps and hamstrings, improving the blood circulation of the muscles around the knee joint to provide necessary oxygen and nutrients to the joint, enhancing tissue repair and reducing inflammation, which can contribute to increased joint space [24].

A systematic review reported positive effects of exercises on the outcomes of knee osteoarthritis patients[25]. A systematic review reported positive effects of resistance exercise on activities of daily living and knee outcomes [26]. In the present study, the conventional group, received electrotherapy, isometrics, open-chain exercises, and mobilizations and showed significant positive effects on knee outcomes. Exercise and Mobilization techniques can reduce pain and improve joint function by promoting blood flow and nutrient supply to cartilage. It helps in reducing inflammation and increasing flexibility of the knee joint [27].

Primorac et al. reviewed the pathogenesis of knee osteoarthritis and non-operative therapeutic considerations and found that exercise therapy results in significant improvements in KOOS and WOMAC, indicating the positive impact of exercise therapy Similarly, an RCT compared the effectiveness of manual therapy versus neuromuscular training by using VAS, WOMAC, and goniometry and concluded that manual therapy is more effective to decrease pain and physical disability as compared to neuromuscular treatment. A systematic review reported that manual therapy, when combined with exercises can be effective in reducing knee-specific impairments and improving overall QoL in knee osteoarthritis persons [28]. In a recent trial, grade I and II mobilizations were applied to the conventional group and resulted in positive effects on knee outcomes [29]. Grade 1 and 2 mobilization techniques may help to decrease the compressive forces on the joints and promote better alignment of the knee joint surface [30].

Romanowski et al. found that manual therapy(post-isometric relaxation and joint mobilization) interventions led to clinical benefits for knee pain reduction and improved function [31]. The effects of Kinesio Tape and endurance training in improving the quality of life of knee OA were compared for participants between the ages of 40-70 years, and both interventions were equally effective in improving the quality of life [32].Meta-analysis recruited participants of knee OA and found that conventional therapy and circuit training showed improvement in knee stiffness, activities of daily living, and quality of life [33]. Similar findings are also achieved in our study in which elliptical training and conventional therapy showed significant improvement in knee outcomes. Knee Joint Mobilization generates rhythmic oscillatory movements within the normal joint range. Joint mobilization reduced pro-inflammatory gene activation (e.g., IL-1β, cyclooxygenase, etc), leading to improved local inflammation, reduction in pain, and improvement in knee ROM.

Due to the limited resources this study was done at a low-cost budget. Follow-up was of a short period with a small sample size that may limit the generalizability of results. To provide a comprehensive understanding of the lasting effects, a longitudinal follow-up study should be conducted beyond 12 weeks. Future studies should investigate the use of sophisticated imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) scans to have precise information regarding joint structures, cartilage integrity, and knee spacing, providing a full assessment of the course of knee osteoarthritis (OA) by including diverse participants with large sample size to apply findings on the broader population. Future studies should compare elliptical training with other types of interventions as well to determine relative effectiveness as well.

CONCLUSION

As both groups improved in terms of the KOOS variables, elliptical exercise was found to be good for the relief of pain, stiffness, ADLs, sports, and QOL. Furthermore, post-x-rays of medial knee joint space width (JSW) showed favourable outcomes, indicating that elliptical training can be employed for interventional purposes in persons with grades 1 and 2 of osteoarthritis of the knee.

DECLARATIONS & STATEMENTS

Author's Contribution

SSKB, AA and SR: substantial contributions to the conception and design of the study.
SSKB, SR: acquisition of data for the study.
SSKB, AA and ZA: analysis of the data for the study.
SSKB, ZA, SR: interpretation of data for the study.
SSKB: drafted the work.
SSKB, AA, SM, ZA and SR: revised it critically for important intellectual content.
SSKB, AA, SM, ZA and SR: 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 at the Islamabad Physical Therapy and Rehabilitation Centre (IPRC-21-01-2022-23), Rawalpindi, Pakistan after approval was taken from the research and ethical committee (REC) of the Faculty of Rehabilitation and Allied Health Sciences (RIPHAH/RCRS/REC/Letter-01238) Riphah International University.

Consent Statement

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

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

None to declare.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

None to declare.

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Research Article

Effects of 8 weeks plyometric training on injury prevention of domestic cricket players: A randomized clinical trail

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ABSTRACT

Background: plyometric training enhances muscle function, improves dynamic strength, and potentially reduces injury risk by increasing the stiffness of the muscle-tendon complex.

Objective: To determine the effects of 8-week plyometric exercises on injury prevention of domestic cricket players.

Methods: A randomized clinical trial was conducted at the sports club PAF base in Murid, Chakwal. A total of n=34 domestic cricket players were included in the study through a non-probability purposive sampling technique. Male players between the age gap of 18-25 years and having no history of trauma/injury in the past month were included in this study. They were randomly allocated into the plyometric group (n=18) and a conventional group (n=18). Group A received plyometric training whereas group B received conventional training. The Nine Test Battery Screening was used for assessment. The assessment was done at baseline and after the 8th week.

Results: The mean age of cricketers in this study was 22.56±2.427. After 8 weeks of intervention, a significant difference was found in the plyometric group as compared to the conventional group for injury prevention using nine test battery screening with p-value ($p<0.05$)

Conclusion: Plyometric training is effective in improving physical fitness and thus prevents injury in cricket players.

Keywords: plyometric training; nine test battery screening; conventional training; physical fitness; injury prevention.

Clinical Trail #: NCT06212843

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INTRODUCTION

Cricket, is a completely non-contact sport, although injuries can happen in different ways [1]. Overuse injuries are widespread in elite cricket and are a result of the physical demands of the game, especially while delivering the ball [2]. There was a range of 5.4% to 25% of injuries to the head, neck, and face, and 19.8% to 34.1% of injuries to the upper limbs. Lower limb injuries often made up 22.8% to 50.0% of all injuries, whereas back and trunk injuries typically made up 18.0% to 33.3% of all injuries.[1] Injuries from cricket are most frequently strains, sprains, fractures, bruises, and open wounds [3].

Among the various injuries that cricket players face, rotator cuff injuries are most recurrent [4]. This results in an overexerted shoulder from movements like hitting, fielding, and bowling. Fielders and bowlers are particularly susceptible to rotator cuff problems due to their heavy shoulder use and repetitive movements which bring the muscles and tendons under stress [3] [5].

Other common injuries in cricket include meniscus tears caused by applying lateral stress to the flexed knee while the foot is placed on the ground and the femur rotates internally. 10. Shoulder dislocations are commonly seen amongst bowlers and fielders which may result from forceful shoulder movements. [9]. Moreover, due to the quick acceleration and deceleration involved in bowling and batting, trunk-side train injuries are another common occurrence among cricket players, particularly fast bowlers [11]. Ankles suffer a great deal of strain during cricket. This usually occurs when the ankle twists inwards, but it can also happen when batsmen turn from running or when bowlers land in old footmarks at the bowling crease [6].

Enhancing or maintaining physical fitness is the ultimate or intermediate goal of exercise. Measuring physical fitness is widespread and useful before preventative and rehabilitative treatments since it is directly linked to illness prevention and health promotion [7]. Strength, muscular endurance, cardiorespiratory power, mobility, balance, coordination, and body composition were all recognized as crucial elements of fitness in these investigations. Research has unequivocally demonstrated that increased fitness reduces the risk of injury and that people with lesser muscular or cardiorespiratory endurance are more likely to sustain an injury [8]. In order to improve the performance of the athlete and in return prevent injury, three major exercise approaches are taken which include firstly the traditional weight training, secondly plyometric training, and thirdly dynamic weight training [9].

Plyometric training is a fast-paced, explosive exercise that helps athletes perform better by developing their power, speed, and agility using the principle of the stretch-shortening cycle [10]. Plyometric training, when done regularly, can help prevent injuries and improve strength, power, agility, and coordination over time [11]. Additionally, when plyometrics was contrasted with other training modalities (weight training, eccentric training, and isometric training), several authors found that PT had a significant positive impact on maximal strength [12].

Plyometric training, a popular type of physical conditioning, uses jumping exercises because the muscular action of the stretch-shortening cycle functions as a potentiating neurophysiological mechanism. Plyometric workouts provide both technical and physical advantages, but they can also help athletes avoid injuries. Plyometric training has been shown to be beneficial in lowering upper and lower limb injuries in a variety of sports, including cricket, according to a systematic study. The results indicated that by enhancing neuromuscular control, proprioception, and landing mechanics, well-executed plyometric training regimens can reduce the incidence of lower body injuries.

METHODOLOGY

This single-blinded randomized controlled trial was conducted at PAF base Murid, Chakwal from 1st September 2023 to 30th November 2023 after approval from the coach of the PAF cricket team. Ethical approval was taken from the Research Ethical Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Riphah/RCRAHS-ISB/REC/MS-PT/01667).

Male cricketers aged 18-25 years were included in the study. The cricket having a less than 3-month history of any musculoskeletal injury was excluded.

The sample size calculated for this study was n=36 participants and was calculated with G*power while we kept the effect size small (0.25) and the α error margin 0.05. To keep the β error probability out of the equation, the power (1- β) was kept at 0.90%. A total of n=36 participants were then randomly allocated into two groups, n=18 were in the plyometric group (Group A) while n=18 of them were included in the conventional group (Group B). From Group B n=2 participants did not follow the intervention plan and did not complete the study, so excluded from the analysis. (Figure 1).

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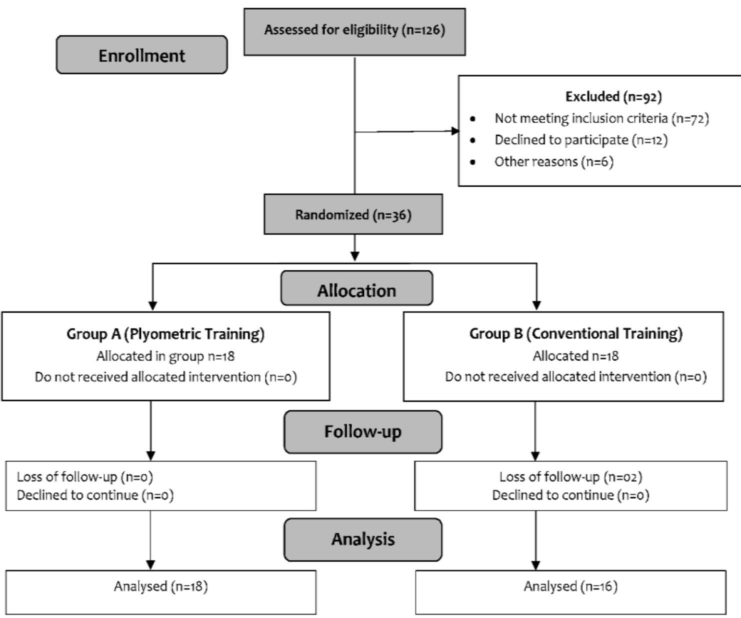

Figure 1: CONSORT diagram

Intervention: Both Groups received 8 8-week assigned training programs thrice a week for a 60-minute session with 1 1-minute rest period between each set of exercises. Group A received 8-week plyometric training, while Group B received conventional training protocol as routine. The details of exercises in both groups have been presented in Tables 1 and 2.

Subjects were evaluated at baseline, after the 2nd, 4th, 6th, and 8th weeks. The assessments were made through nine test battery screenings. Nine functional movement tests make up the nine-test battery screening, which is primarily used to screen athletes for movement competency in Deep squats, one-legged squats, inline lunges, Active hip flexion, SLR, Push Diagonal lift, seated rotation, and functional shoulder mobility. It also detects pain during movements and musculoskeletal side-to-side imbalances, allowing for correction that lowers the risk of injury and improves performance and quality of life [7]. An earlier examination of the 9TSB's intra- and inter-rater reliability yielded an ICC of 0.80.

The data was analysed with SPSS Ver 25. The descriptive statistics mean, standard deviations, frequency, and percentages were used for data presentation. The mixed-ANOVA was used to determine the interaction effects between training protocol and level of assessment. For the main effect, One-way ANOVA was used for between-group comparison, and RM-ANOVA was used for with-in-group changes.

Table 1: Plyometric Protocol

Weeks	Foot contacts	Exercise	Sets Reps	Intensity
1	90	Plyo pushup	3x5	Low
		Chest pass		
		Med ball drop		
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		
2	100	Plyo pushup	2x10	Intermediate
		Chest pass		
		Med ball drop	3x5	Low
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		
3	120	Plyo pushup	2x10	Intermediate
		Chest pass		
		Med ball drop		
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		
4	140	Plyo pushup	3x10	Intermediate
		Chest pass		
		Med ball drop	4x5	
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		
5	160	Plyo pushup	3x10	Intermediate
		Med ball drop		
		Overhead throw		
		Squat jump		
		Plyo setup	4x5	Low
		Lateral jump over hurdle		
6	180	Plyo pushup	5x6	High
		Med ball drop		
		Overhead throw		
		Squat jump		
		Plyo setup		
		Lateral jump over hurdle		
7	200	Under head throw	5x6	High
		Dynamic rotational chest pass		
		Overhead throw with step		
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		
8	220	Under head throw	5x8	High
		Dynamic rotational chest pass		
		Overhead throw with step		
		Kneeling squat jump		
		Lateral jump over hurdle		
		Cone jumps		

Table 2: Conventional Protocol

Exercises	Frequency/ Day/Week	No. of Sets	Intensity
Hamstring Stretch	1 Time A Day And 3 Times A Week.	10 reps x 1 set x 20 seconds hold	High To Low in Every week
Quadricep stretch			
Piriformis stretch			
Adductor Stretch			
Side bending bilateral			
Biceps stretch			
Triceps stretch			
Oblique stretch			
Jumping jacks		30 reps x 1 set	
Push ups			
Russian twists			
Lunges			

RESULTS

The mean age of the athletes was 22.56±2.427 (R=18-25) years. Most of the players were batsmen (n=16), While n=10 were fast bowlers, n=6 were spinners and n=2 were all-rounders. (figure 2)

The results of RMANOVA showed that both groups were significantly improved ($p<0.05$) from baseline to the end of 8 weeks of training in all outcome measures in the 9-test battery and its total score. While pairwise comparison of Deep squats ($p=0.013$) and one-legged squats ($p=0.013$) also improved significantly from 2nd to 4th week. While straight leg raise ($p<0.001$) was improved from the 6th – 8th week the total score of the 9-test battery was also significantly improved ($p<0.01$) from the 2nd week to the 6th week respectively. In the conventional training group the pairwise result showed significant improvement in In-line Lunges ($p=0.03$) and 9 test battery screening score $p=0.004$) from the 4th to 6th week, and active hip flexion ($p<0.001$) from the 6th -8th weeks, respectively.

Some variables like diagonal rotation ($p=0.03$) and seated rotation ($p=0.04$) were comparable at the baseline and found significantly improved scores after 8-week plyometric training as compared to conventional training, while active hip flexion and push-ups were not significantly ($p≥0.05$) different. (table 3)

Moreover, deep squats, one-legged squats, straight leg raises, Functional Shoulder Mobility, and 9TBS were not comparable at baseline, so the mean of the mean differences was compared. The result showed that functional shoulder mobility was significantly improved ($p=0.027$) in a plyometric group than conventional training group. While other outcome measures showed no significant ($p≥0.05$) difference between groups. (Table 4)

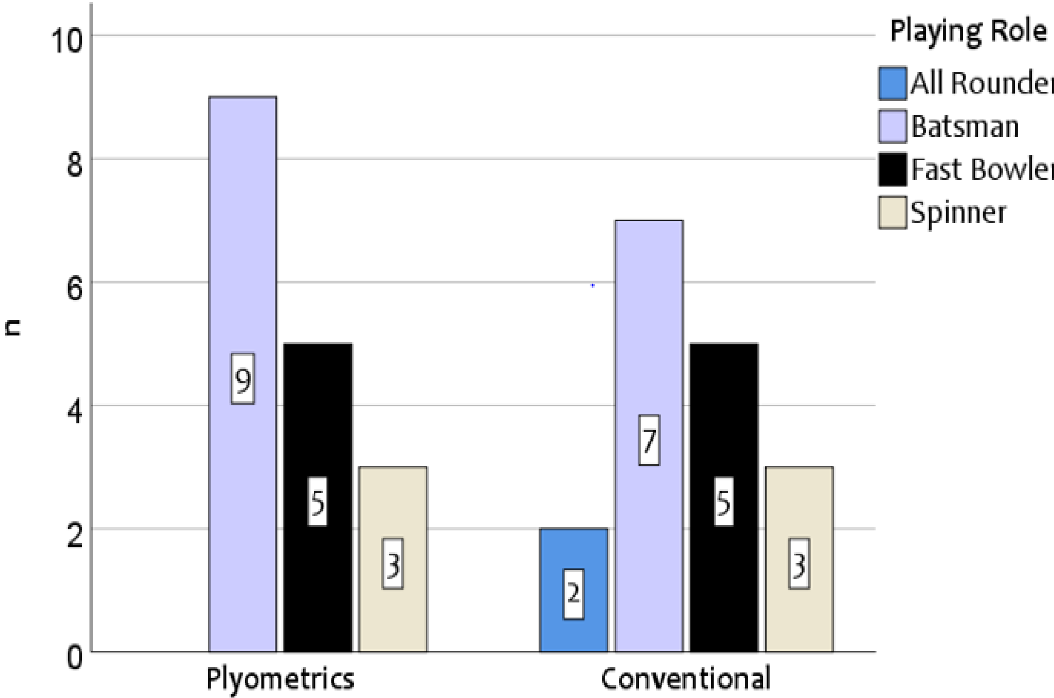

Figure 2: Playing role of participant

Table 3: With-in group changes from baseline to 8th week in Group A and B

		Group A Plyometrics (n=18)				Group B Conventional (n=16)			
		x̄	σ	MD/F(df)	p-value	x̄	σ	MD/F(df)	p-value
Deep Squat	Baseline	1.66	1.13	0.22	1[a]	0.75	1.12	0.18	1[a]
	After 2nd Week	1.88	1.02	0.55	0.01[b]*	0.93	1.06	0.62	0.12[b]
	After 4th Week	2.44	0.78	.27	0.20[c]	1.56	0.89	0.43	0.14[c]
	After 6th Week	2.72	0.57	0.16	0.82[d]	2.0	1.03	0.25	0.41[d]
	After 8th Week	2.88	0.47	16.41(1.96,33.33)	0.00[e]	2.25	0.93	16.35(1.96,43.47)	0.00[e]
One Legged Squat	Baseline	1.11	0.96	0.22	1[a]	0.31	0.70	0.18	1[a]
	After 2nd Week	1.16	0.70	0.55	0.01[b]*	0.37	0.71	0.62	0.12[b]
	After 4th Week	1.55	0.78	0.27	0.20[c]	0.62	0.72	0.43	0.14[c]
	After 6th Week	1.94	0.63	0.16	0.827[d]	0.62	0.72	0.25	0.41[d]
	After 8th Week	2.38	0.84	17.95(2.63,44.71)	0.000[e]	0.93	1.06	5.41(1.84,27.66)	0.000[e]
In-Line Lunges	Baseline	1.77	1.26	0.44	0.160[a]	1.43	1.21	0.12	1[a]
	After 2nd Week	2.22	1.06	0.16	1[b]	1.31	1.14	0.37	0.54[b]
	After 4th Week	2.38	0.91	0.33	1[c]	1.68	0.95	0.43	0.038[c]*
	After 6th Week	2.72	0.57	0.11	0.293[d]	2.12	0.88	0.00	1[d]
	After 8th Week	2.83	0.51	9.51(2.08,34.65)	0.000[e]***	2.12	1.15	6.61(1.92,28.88)	0.005[e]**
Active Hip Flexion	Baseline	1.88	0.96	0.11	1[a]	1.37	1.02	0.62	0.19[a]
	After 2nd Week	2.00	0.97	0.50	0.081[b]*	2.00	0.82	0.06	1[b]
	After 4th Week	2.50	0.78	0.11	1[c]	2.06	0.68	0.43	0.68[c]
	After 6th Week	2.61	0.69	0.11	1[d]	2.50	0.89	0.00	0.00[d]
	After 8th Week	2.72	0.82	8.52(1.98,33.68)	0.001[e]***	2.50	0.89	9.56 (2.33,34.9)	0.000[e]
Straight Leg Raise	Baseline	2.33	0.68	0.05	1[a]	1.56	1.26	0.56	0.45[a]
	After 2nd Week	2.27	0.75	0.44	0.41[b]	2.12	0.88	0.31	0.55[b]
	After 4th Week	2.72	0.46	0.11	1[c]	2.43	0.51	0.25	1[c]
	After 6th Week	2.83	0.51	0.00	0[d]	2.18	0.83	0.25	0.41[d]
	After 8th Week	2.83	0.51	4.70(2.47,42.07)	0.010[e]*	2.43	0.89	4.13(2.19,32.96)	0.022[e]*
Push Up	Baseline	2.22	1.17	0.11	1[a]	2.06	1.06	0.12	1[a]
	After 2nd Week	2.33	0.90	0.22	1[b]	1.93	1.06	0.56	0.33[b]
	After 4th Week	2.55	0.85	0.33	0.29[c]	2.50	0.81	0.06	1[c]
	After 6th Week	2.88	0.32	0.00	1[d]	2.43	0.89	0.00	1[d]
	After 8th Week	2.88	0.32	4.94(2.30,39.09)	0.009[e]**	2.43	1.03	3.24(2.42,36.31)	0.042[e]*
Diagonal Lift	Baseline	1.61	0.84	0.27	1[a]	1.43	1.20	0.00	1[a]
	After 2nd Week	1.88	0.83	0.27	0.96[b]	1.43	1.15	0.43	0.89[b]
	After 4th Week	2.16	0.92	0.33	1[c]	1.87	1.02	0.50	0.27[c]
	After 6th Week	2.50	0.61	0.27	0.96[d]	2.37	0.61	0.50	1[d]
	After 8th Week	2.77	0.42	10.38(3.17,53.96)	0.00[e]	2.18	1.04	5.28(2.52,37.89)	0.006[e]**
Seated Rotation	Baseline	1.83	1.15	0.33	1[a]	1.56	1.15	0.18	1[a]
	After 2nd Week	2.16	0.92	0.38	0.3[b]	1.75	1.18	0.31	0.19[b]
	After 4th Week	2.55	0.85	0.16	1[c]	2.06	0.99	0.12	1[c]
	After 6th Week	2.72	0.57	0.05	1[d]	2.18	0.98	0.06	1[d]
	After 8th Week	2.77	0.54	9.32(2.37,40.40)	0.000[e]	2.25	0.93	7.45(1.95,29.25)	0.003[e]**
Functional Shoulder Mobility	Baseline	1.38	1.24	0.66	0.096[a]	2.25	0.85	0.12	1[a]
	After 2nd Week	2.05	1.05	0.22	1[b]	2.37	0.80	0.12	1[b]
	After 4th Week	2.27	1.07	0.05	1[c]	2.50	0.81	0.12	1[c]
	After 6th Week	2.33	1.08	0.33	0.29[d]	2.62	0.80	0.06	1[d]
	After 8th Week	2.66	0.59	12.52(2.37,40.30)	0.000[e]	2.68	0.79	5.97(2.54,38.17)	0.003[e]**
9 Test Battery Screening	Baseline	15.83	3.91	2.16	0.57[a]	12.75	3.78	1.50	0.13[a]
	After 2nd Week	18.00	3.48	3.16	0.005[b]**	14.25	3.56	3.06	0.004[b]**
	After 4th Week	21.16	3.80	2.11	0.004[c]**	17.31	2.33	1.75	0.05[c]*
	After 6th Week	23.27	3.30	1.50	0.062[d]*	19.06	3.51	0.75	0.82[d]
	After 8th Week	24.777	3.57	34.78(2.65,45.15)	0.00[e]	19.81	4.47	29.63(2.0,3.07)	0.00[e]

*Significance level-p<0.05*p<0.01**, p<0.001****

[a]Baseline to 2nd week, [b]2nd week to 4th week, [c]4th week to 6th week, [d]6th to 8th week , [e]Baseline to 8th week; M-Median; IQR-Inter Quartile Range; x̄-Mean; σ-Standard deviation; MD-Mean difference

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Table 4: Between Group Comparison group A and group B (9TSB)

		Plyometrics(n=18)		Conventional(n=16)		F(df)	p-value	ηp²
		x̄	σ	x̄	σ			
Deep Squat	Baseline	1.66	1.13	0.75	1.12	5.55	0.025*	0.15
	After 2nd Week	1.88	1.02	0.93	1.06	7.06	0.012*	0.18
	After 4th Week	2.44	0.78	1.56	0.89	9.42	0.004*	0.23
	After 6th Week	2.72	0.57	2.00	1.03	6.54	0.015*	0.17
	After 8th Week	2.88	0.47	2.25	0.93	6.59	0.015*	0.17
One Legged Squat	Baseline	1.11	0.96	0.31	0.70	7.44	0.010*	0.18
	After 2nd Week	1.16	0.70	0.37	0.71	10.45	0.003**	0.25
	After 4th Week	1.55	0.78	0.62	0.71	12.90	0.001**	0.28
	After 6th Week	1.94	0.63	0.62	0.71	32.11	0.000***	0.50
	After 8th Week	2.38	0.84	0.93	1.06	19.54	0.000***	0.37
In-Line Lunges	Baseline	1.77	1.26	1.43	1.20	0.64	0.430	0.02
	After 2nd Week	2.22	1.06	1.31	1.13	5.82	0.022*	0.15
	After 4th Week	2.38	0.91	1.68	0.94	4.81	0.036	0.13
	After 6th Week	2.72	0.57	2.12	0.88	5.57	0.025	0.15
	After 8th Week	2.83	0.51	2.12	1.14	5.61	0.024	0.15
Active Hip Flexion	Baseline	1.88	0.96	1.37	1.02	2.27	0.142	0.06
	After 2nd Week	2.00	0.97	2.00	0.81	0.00	1.000	0.00
	After 4th Week	2.50	0.78	2.06	0.68	2.97	0.094	0.08
	After 6th Week	2.61	0.69	2.50	0.89	0.16	0.687	0.00
	After 8th Week	2.72	0.82	2.50	0.89	0.56	0.457	0.01
Straight Leg Raise	Baseline	2.33	0.68	1.56	1.26	5.04	0.032*	0.13
	After 2nd Week	2.27	0.75	2.12	0.88	0.29	0.590	0.01
	After 4th Week	2.72	0.46	2.43	0.51	2.91	0.098*	0.08
	After 6th Week	2.83	0.51	2.18	0.83	7.56	0.010*	0.19
	After 8th Week	2.83	0.51	2.43	0.89	2.58	0.118	0.07
Push Up	Baseline	2.22	1.16	2.06	1.06	0.17	0.681	0.01
	After 2nd Week	2.33	0.90	1.93	1.06	1.37	0.250	0.04
	After 4th Week	2.55	0.85	2.50	0.81	0.03	0.848	0.00
	After 6th Week	2.88	0.32	2.43	0.89	4.02	0.053	0.11
	After 8th Week	2.88	0.32	2.43	1.03	3.11	0.087	0.08
Diagonal Lift	Baseline	1.61	0.84	1.43	1.20	0.23	0.628	0.01
	After 2nd Week	1.88	0.83	1.43	1.15	1.74	0.196	0.05
	After 4th Week	2.16	0.92	1.87	1.02	0.76	0.389	0.02
	After 6th Week	2.50	0.61	2.37	0.61	0.34	0.561	0.01
	After 8th Week	2.77	0.42	2.18	1.04	4.83	0.035*	0.13
Seated Rotation	Baseline	1.83	1.15	1.56	1.15	0.46	0.499	0.01
	After 2nd Week	2.16	0.92	1.75	1.18	1.32	0.258	0.04
	After 4th Week	2.55	0.85	2.06	0.99	2.41	0.131	0.07
	After 6th Week	2.72	0.57	2.18	0.98	3.86	0.058*	0.11
	After 8th Week	2.77	0.54	2.25	0.93	4.16	0.049*	0.11
Functional Shoulder Mobility	Baseline	1.38	1.24	2.25	0.85	5.39	0.027*	0.14
	After 2nd Week	2.05	1.05	2.37	0.80	0.96	0.334	0.03
	After 4th Week	2.27	1.07	2.50	0.81	0.45	0.506	0.01
	After 6th Week	2.33	1.08	2.62	0.80	0.77	0.385	0.02
	After 8th Week	2.66	.594	2.68	0.79	0.01	0.931	0.00
9 test battery screening	Baseline	15.83	3.91	12.75	3.78	5.42	0.026*	0.14
	After 2nd Week	18.00	3.48	14.25	3.56	9.60	0.004**	0.23
	After 4th Week	21.16	3.80	17.31	2.33	12.27	0.001**	0.27
	After 6th Week	23.27	3.30	19.06	3.51	12.99	0.001**	0.28
	After 8th Week	24.77	3.57	19.81	4.47	12.91	0.001**	0.28

*Significance level: p<0.05*p<0.01**, p<0.001***; ηp² Partial ETA; Md-Median; IQR-Inter Quartile Range; x̄-Mean; σ-Standard deviation; MD-Mean difference*

Table 5: Average mean Comparison between Groups

	Group	N	x̄	σ	p-value
Deep Squats (Mean)	Plyometrics	18	2.32	57511	0.52
	Conventional	16	1.50	63267	
One legged squat (Mean)	Plyometrics	18	1.63	63338	0.06
	Conventional	16	0.57	70000	
Straight Leg Raise (Mean)	Plyometrics	18	2.60	35645	0.41
	Conventional	16	2.15	65524	
Functional Shoulder Mobility (Mean)	Plyometrics	18	-1.23	1.09	0.027*
	Conventional	16	-.53	.624	
9-Test Battery (Mean)	Plyometrics	18	20.61	2.73	0.17
	Conventional	16	16.63	2.99	

*Significance level: p<0.05*p<0.01**, p<0.001***; x̄-Mean; σ-Standard deviation; MD-Mean difference*

DISCUSSION

The purpose of this study was to determine the effects of plyometric exercise on injury prevention in domestic cricket players. In the plyometric group, all variables of the 9-test battery were improved in the 8-week intervention.

Plyometric training serves as an injury prevention tool, ensuring players can sustain the physical demands of cricket while improving their field performance[13]. This structured approach gives them an edge in competitive cricket while prolonging their careers. These exercises are effective methods for improving joint stability, addressing muscle imbalances, and enhancing balance and coordination, which in turn optimizes performance and aids in injury prevention[14, 15]. Plyometric training stimulates proprioceptors, improving the body's awareness of joint position and movement, contract together, creating a stabilizing effect and improves the tensile strength of ligaments and tendons, which enhances their ability to resist abnormal joint movement during activities[16, 17].

Early improvements in deep squat test scores in the 2nd to 4th week are likely due to rapid neural adaptations and enhanced motor coordination[18]. Delayed straight leg raise test improvement in the 6th to 8th week indicates improved muscle-tendon elasticity[19]. The total score of the 9-test battery improvement from the 2nd to 6th week highlights the cumulative effect of enhanced strength, stability, and coordination across multiple functional tests[20].

In the conventional training group, significant improvements were observed in In-Line Lunges ($p=0.03$) and the 9-Test Battery Total Score ($p=0.004$) from the 4th to the 6th week, while Active Hip Flexion showed notable gains ($p<0.001$) from the 6th to the 8th week. These results highlight the gradual strength and flexibility enhancements achieved through controlled, repetitive movements targeting specific muscle groups[21]. Conventional training likely emphasized core and lower-limb strength, contributing to better balance and stability in tasks like lunges[22]. Additionally, stretching and isolated strength exercises improved flexibility and range of motion, particularly in the hip flexors, resulting in late-phase improvements. This training approach effectively builds strength and ROM over time, aligning with its progressive nature[23, 24].

The comparison between plyometric and conventional training reveals distinct advantages in specific outcome measures. Plyometric training demonstrated significantly greater improvements in Diagonal Rotation ($p=0.03$) and Seated Rotation ($p=0.04$) after 8 weeks, attributed to its emphasis on explosive, multidirectional movements that enhance core stability and rotational power through the stretch-shortening cycle (SSC)[25]. Additionally, Functional Shoulder Mobility significantly improved ($p=0.027$) in the plyometric group, likely due to dynamic exercises like medicine ball throws and plyometric push-ups, which enhance neuromuscular efficiency and joint proprioception[26]. However, outcomes such as Active Hip Flexion and Push-Up performance showed no significant differences ($p\geq0.05$) between groups, suggesting that both training modalities effectively target these areas through distinct mechanisms of plyometric training through dynamic strength and neural adaptations, and conventional training through controlled, isolated exercises[27]. Furthermore, variables such as Deep Squat, One-Legged Squat, Straight Leg Raise, and 9-Test Battery Score (9TBS) showed no significant differences between groups, likely due to baseline disparities and the complementary nature of the training approaches[28]. While plyometric training yielded early gains in dynamic tasks, conventional training exhibited gradual improvements, indicating both methods effectively enhance functional movement patterns through different pathways[29]. These results highlight the unique and synergistic benefits of each training modality, underscoring the potential for integrating both to optimize performance and functional outcomes.

One key limitation is the short 8-week training duration, which captures only the short-term effects of the interventions. Furthermore, potential injury risks associated with plyometric training, particularly for less experienced athletes, were not considered, raising concerns about the practicality and safety of implementing such programs broadly. Addressing these limitations in future studies would enhance the validity and applicability of the findings.

CONCLUSION

The cumulative improvements of the 9-Test Battery underscore the overall efficacy of both approaches in enhancing functional movement patterns and reducing injury risk. While plyometric training provides quicker gains in explosive and rotational tasks, conventional training contributes to steady improvements in balance, strength, and flexibility. However, the findings are limited by the short 8-week training period, which does not capture long-term effects or potential injury risks associated with plyometric exercises. Future research with longer intervention durations and diverse athlete populations is recommended to validate and expand these findings.

DECLARATIONS & STATEMENTS

Author's Contribution

AS and AR: substantial contributions to the conception and design of the study.
AS, SR and HMABR: acquisition of data for the study.
AS, AA and ZA: analysis of the data for the study.
AS, ZA, SR: interpretation of data for the study.
AS: drafted the work.
AS, FA, AA, AR and HMABR: revised it critically for important intellectual content.
AS, FA, AA, AR and HMABR: 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 conducted in PAF base Murid, Chakwal from 1st September 2023 to 30th October 2023. Ethical approval was taken from Research Ethical Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Riphah/RCRAHS-ISB/REC/MS-PT/01667)

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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None to declare.

Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Effects of high intensity interval training on mobility and fitness outcomes in stroke: a randomized clinical trail

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ABSTRACT

Background: Stroke causes severe impairments in mobility, balance, and quality of life, making it the leading cause of disability globally. New research indicates that high-intensity interval training (HIIT) may benefit stroke patients more.

Objective: To determine the effects of high-intensity interval training on mobility and fitness outcomes in stroke.

Methods: A single-blinded, randomized controlled study was carried out on n=44 ambulatory stroke survivors between the ages of 45 and 65 years. The participants were randomly assigned to group A (n=22) received conventional physiotherapy (CPT). While Group B received HIIT in addition to conventional physiotherapy. The Berg Balance Scale (BBS), Heart Rate Recovery (HRR), Functional Ambulation Categories (FAC), Stroke-Specific Quality of Life (SS-QOL), Timed Up and Go (TUG) test, and the 6-Minute Walk Test (6MWT) were the outcome measures. At baseline, six weeks, and twelve weeks, assessments were carried out.

Results: The HIIT group had significantly improved mobility, balance, and cardiovascular fitness. In the 6MWT ($p<0.001$), BBS ($p<0.001$), FAC ($p=0.002$,), insignificant p-value in HRR ($p=0.93$, $\eta p^2=0.00$), SS-QOL ($p=0.01$, $\eta p^2=0.16$), and TUG tests ($p=0.01$, $\eta p^2=0.16$), and hence was better ($p < 0.05$) in all variables except FAC (0.48).

Conclusion: High-intensity interval Training significantly improves walking capacity, balance, cardiovascular recovery, and quality of life in stroke survivors when combined with conventional standard physiotherapy interventions, as compared to conventional physiotherapy alone.

Keywords: Fitness; HR reserve; high-intensity interval training; mobility; quality of life; stroke rehabilitation; six-minute walk test.

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INTRODUCTION

Stroke is a neurological condition caused lack of oxygen reaching the brain's areas leading to disability [1, 2]. Stroke ranks third in terms of contributing more to disability and is thought to be the second leading cause of death globally [3]. An ischemic stroke occurs when blood flow to the brain diminishes due to obstructions in vessels.[4].

Following a stroke, many patients face major physical impairments, such as walking, balance, coordination, and movement. These limitations can make simple chores like dressing, cooking, or moving across a room seem overwhelming and challenging [5]. Physical rehabilitation is critical to improve these abilities and recover independence, but for some survivors, these deficits might last for a long time, depending on the severity of the stroke and the parts of the brain affected[6, 7]. However, compared to healthy people, stroke survivors have half the cardiorespiratory fitness and nearly twice the energy costs for locomotion, which significantly increases their inactivity [8].

Systematic reviews indicate that focused interventions, including aerobic and strength training, can alleviate these challenges, improve functional capabilities, and elevate overall quality of life [9-11]. Generally, to increase cardiorespiratory fitness after a stroke moderate-intensity continuous cardiovascular exercise is advised [12]. Recent systematic reviews suggest that higher-intensity training, with a heart rate reserve of 60% or more, may be more effective for enhancing walking capacity and overall recovery [4]. High-intensity interval training has surfaced as a beneficial method for individuals experiencing neurological gait impairments, including those caused by conditions such as cerebral palsy or stroke [5]. The HIIT training method consists of alternating intervals of maximum speed walking followed by recovery periods, enabling patients to maintain elevated aerobic intensities in comparison to traditional continuous training [13].

The high-intensity exercises improve CRF, gait, and balance among stroke survivors; however, further research is needed to standardize protocols for long-term rehabilitation effects [14]. The rationale for incorporating HIIT into stroke rehabilitation stems from its potential to enhance cardiorespiratory fitness, improve mobility, and support cognitive recovery. As research continues to evolve, HIIT may become a cornerstone of rehabilitation protocols for stroke survivors, offering a time-efficient and effective approach to improving overall health outcomes. So, the objective was to evaluate the Effects of high-intensity interval training on mobility and fitness outcomes in stroke.

METHODOLOGY

Study Design and Setting: Single-blinded parallel two-group randomized controlled trial. Protocols were followed 3-5 days a week and 10-12 sets were performed one time a day for 12 weeks. The study was conducted with ethical approval (RIRAHS-ISB/REC/MS-PT/01745) and permission (RIPHAH/FR&AHS/Letter 014310) at Capital Hospital Islamabad, Grace Medical Centre, and IAT Aesthetic and Therapy.

Selection Criteria: The sample was collected through a nonprobability convenient sampling technique. This study comprised adult stroke survivors (aged 45–65) who were ambulatory and able to walk without help. This participant with co-morbid conditions such as cardiovascular disease, asthma/COPD, uncontrolled hypertension, and uncontrolled diabetes, as well as those with impaired cognition with a Mini-Mental State Examination (MMSE) score of more than 24, were excluded.

Sample size: the sample size of n=44 subjects was calculated Using G*Power, the sample size was determined with an alpha error probability of (α=0.05), an effect size of 0.25, and a power (1 – β) of 0.95. After the allocation into groups A and B. A total of n=49 subjects were evaluated for eligibility criteria, and n=5 declined participation due to not meeting the selection criteria (n=2) and accessibility issues (n=3). The remaining n=44 was randomly allocated equally to Groups A (n=22) and B (n=22). During the follow up there was n=08 loss of follow-up in groups A (n=4) and B (n=4). So in the data analysis, n= 36 participants were included. (Figure 1)

Randomization & Blinding: Sequentially numbered, opaque, sealed envelopes were used to hide the allocation of people into HIIT and conventional physical therapy groups. After recruiting and baseline evaluation, the envelopes were unsealed, and the treating therapists were given the information about randomization. This study is single-blinded because only the examiner knows about the intervention and group allocation the participants are not aware of groups.

The participants were randomly assigned to group A and received conventional physiotherapy (CPT). While Group B received HIIT in addition to CPT. Both interventions aimed at improving mobility and fitness in individuals with chronic stroke. HIIT Protocol: The HIIT protocol focuses on improving cardiovascular fitness, balance, and functional mobility through short, high-intensity exercises with rest intervals. Exercises included seated and standing balance, dynamic tasks, walking, and stationary cycling. Intensity ranged from 50-70% HR max, with progressive increases in

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duration (4–6 minutes) and complexity over 12 weeks, performed 5 days per week.

CPT Protocol: The CPT protocol followed traditional stroke rehabilitation, emphasizing balance, mobility, and strength. It included passive/active ROM exercises, sitting/standing balance, resistance training, and gait tasks. Sessions progressed in intensity (low to high) and duration (30–60 minutes) over 12 weeks, conducted 3–5 days per week. Further week-wise detail of the intervention in both groups has been presented in table 1.

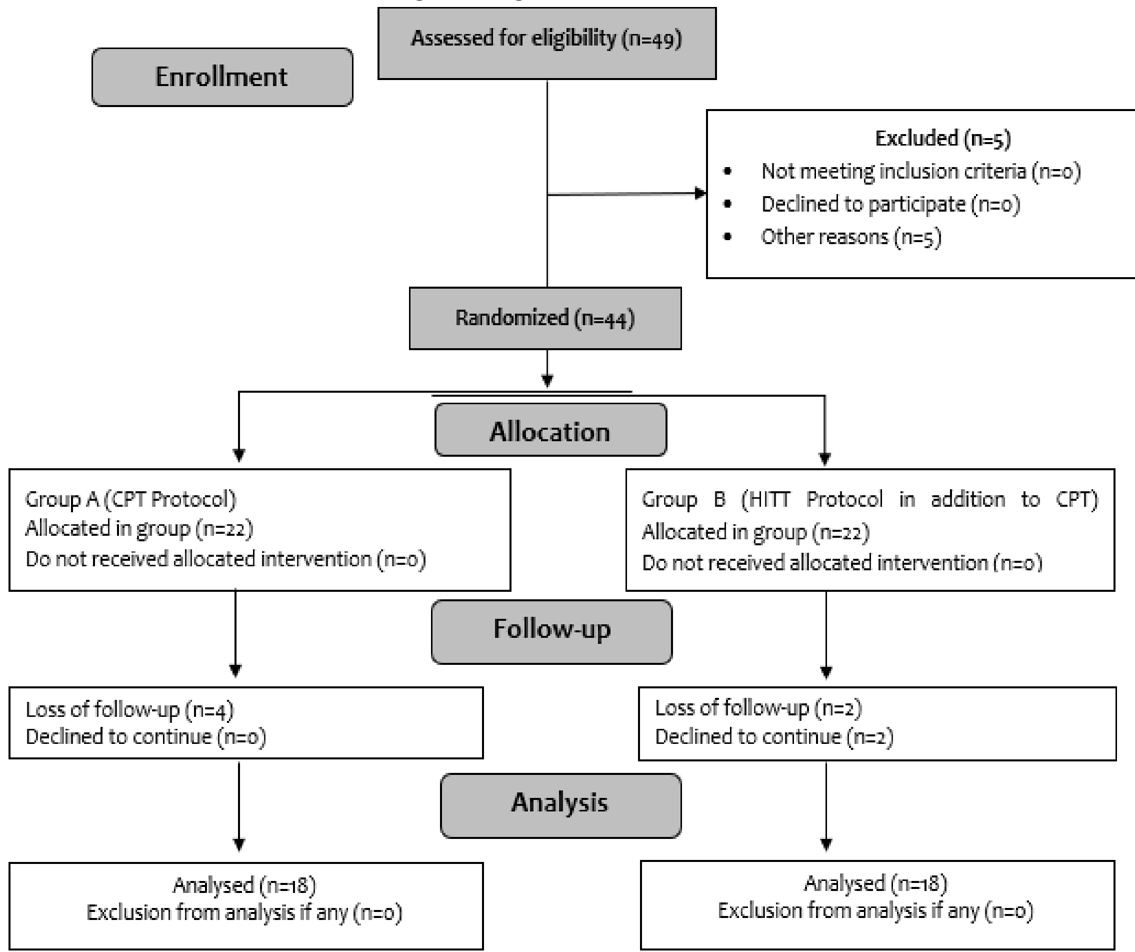

Figure 1: CONSORT flow diagram

Outcome Measure: The Six-Minute Walk Test (6MWT) is a validated and reliable assessment for stroke patients, measuring the distance they can walk in six minutes, which reflects their aerobic capacity and endurance[15]. Similarly, the Functional Ambulation Categories (FAC) scale evaluates the level of human support required for walking, using a 6-point scale from 0 to 5, and is effective in assessing mobility in stroke patients, requiring minimal space and equipment[16]. The Timed Up and Go Test (TUGT) assesses functional mobility by timing how long it takes a person to rise from a seated position, walk 3 meters, turn around, return, and sit down, serving as an indicator of fall risk and balance improvement[17]. The Berg Balance Scale (BBS) is another reliable tool that evaluates both static and dynamic balance through 14 tasks scored on a 4-point scale, although it does not assess gait[18]. Lastly, the Stroke Specific Quality of Life (SS-QOL) measure includes 12 domains assessing various aspects of life quality post-stroke, rated on a 5-point Likert scale, with higher scores indicating better quality of life[19]. All variables were measured at baseline, 6th week and 12th weeks.

Data analysis: Data was analyzed using SPSS version 21. Mixed ANOVA was applied for the interaction effects between treatment and level of assessment; 6MWT, FAC, TUGT, BBS, and SS-QOL. For main effects, the repeated measured ANOVA was applied with pairwise comparison, while for between-group comparison way, ANOVA was used with their effect size partial eta square (ηp2).

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Table 1: Detailed description of Interventions of Group A (CPT) and Group B (CPT+HITT)

Weeks	Group A (CPT Protocol)	Group B (HITT Protocol in addition to CPT)
1st	5 days/week, Low intensity, 30-45 minutes/session Baseline assessment, passive ROM, sitting balance training (reaching in different postures)	5 days/week, 50-60% HR max, 4 minutes Seated balance exercises (e.g., sitting and reaching)
2nd	5 days/week, Low to moderate intensity, 30-45 minutes/session Active-assisted ROM, transfer training, sitting balance exercises with increased difficulty	5 days/week, 50-60% HR max, 4 minutes Weight shifting exercises (e.g., side-to-side)
3rd	Same as week 2	5 days/week, 50-60% HR max, 4 minutes Standing balance exercises with support
4th	4 days/week, Moderate intensity, 45-60 minutes/session Resistance exercises, standing balance (e.g., weight shifting, one-leg standing), gait training	5 days/week, 50-60% HR max, 5 minutes Standing balance exercises without support
5th	Same as week 4	5 days/week, 60-70% HR max, 5 minutes Dynamic balance exercises (e.g., reaching, stepping)
6th	4 days/week, Moderate intensity, 45-60 minutes/session 4th-week assessment, walking training with decreased assistance	5 days/week, Low resistance, 5 minutes Walk for 6 minutes continuously
7th	Same as week 6	5 days/week, Low resistance, 4 minutes Dual-task balance activities (e.g., balancing while counting)
8th	4 days/week, Moderate to high intensity, 45-60 minutes/session Dynamic balance exercises (e.g., stepping in different directions, walking on uneven surfaces)	5 days/week, 60-70% HR max, 5 minutes Balance games (e.g., catching/throwing a ball) or obstacle courses
9th	3 days/week, Moderate to high intensity, 45-60 minutes/session Advanced balance exercises (e.g., tandem walking, walking on narrow paths)	5 days/week, Moderate resistance, 5 minutes Single-leg balance exercises
10th	Same as week 9	5 days/week, Moderate resistance, 4 minutes Tandem stance and walking
11th	3 days/week, High intensity, 45-60 minutes/session More complex mobility tasks (e.g., getting up from the floor, navigating obstacles)	5 days/week, Moderate resistance, 6 minutes Progressive weight-bearing exercises
12th	Same as week 11	5 days/week, Moderate resistance, 6 minutes Agility exercises (e.g., zigzags, step-overs)

RESULTS

The age of the participants was 55.23±6.034 years. A total population of 44 was included in this study, of which 32 were males (69.6%) and 12 (26.1%) were females.

Mixed ANOVA showed that there was significant interaction effect observed in 6MWT {F(1.36, 123) =116, p=<0.001}, BBS {F(2, 21)=57.54, p<0.001}, FAC{ F(2, 54)=4.39, p<0.001}, HRR{ F(1.82, 314)=24.47, p<0.001}, SSQOL{ F(90.2, 156)=86.51, p<0.001 } and TUG{ F(1.82, 241,)=8.40, p<0.001}.

For within group changes RMANOVA was applied. The RMANOVA was used with pairwise comparison to determine the within-group Changes. In group A 6-MWT was significantly improved (p=0.01) from baseline to 12th week, But in pairwise comparison, no significant (p≥0.05) improvement was observed in 0-6 weeks and 6-12 weeks. When observing FAC, there was no overall significant improvement, but only in the initial 6 weeks results significantly (p=0.01) improved. The BSS also showed novel significant (p<0.001) improvement, while in pair-wise comparison, BBS improved significantly (p<0.001) only in the initial 6 weeks. The scores of HRR and SSQOL were significantly improved (p<0.001) overall as well as at each level of assessment till the 12th week. The TUG test was not Improved significantly (p≥0.05) . In group B, which received the HITT protocol in addition to CPT, Significant improvement (p<0.001) in all variables was observed from baseline to end of the 12th week as well as at each assessment level with a large effect size, except for FAC where from 6-12 week no significant (p=0.42) improvement observed. (Table 1)

The HIIT group showed significant improvements over the CPT group in most measures, especially after 12 weeks. Significant differences were seen in 6MWT, BBS, FAC, HRR, SSQOL, and TUG at the 12-week mark, indicating the effectiveness of the intervention on functional and quality-of-life outcomes.

Table 2: Within group changes in 6MWT, BBS, FAC, HRR, SSQOL, TUG

	Group A (n=18)					Group B (n=18)			
	Levels	Mean±SD	$F_{(df)}$	P- Value		Mean±SD	$F_{(df)}$	P- Value	ηp²
6MWT	0-6 weeks	151.44±13.28	134.44 (1.12)	0.15	0.349	163.38±20.70	9.11 (1.14)	0.00***	0.88
	6-12 weeks	154.16±13.54		0.20		171.44±21.38		0.00***	
	0-12weeks	158.00±13.07		0.01*		192.33±26.61		0.00***	
FAC	0-6 weeks	3.22±0.42	12.05 (2)	0.01*	0.05	3.16±0.51	5.39 (2)	0.005**	0.57
	6-12 weeks	3.61±0.50		0.16		3.61±0.50		0.48	
	0-12weeks	3.33±0.48		0.99		3.83±0.38		0.00***	
BBS	0-6 weeks	32.27±2.96	122.29 (1.90)	0.00***	0.74	31.77±3.17	48.82 (1.47)	0.00***	0.87
	6-12 weeks	36.55±1.85		0.94		36.72±2.84		0.00***	
	0-12weeks	37.00±1.64		0.00***		42.88±2.72		0.00***	
HRR	0-6 weeks	74.88±10.23	95.12 (1)	0.00***	0.04	77.77±9.00	54.67 (1)	0.00***	0.74
	6-12 weeks	74.88±8.78		0.00***		73.94±7.64		0.00***	
	0-12weeks	75.61±8.70		0.00***		84.44±9.24		0.00***	
SSQOL	0-6 weeks	124.61±.14.22	94.12 (1.15)	0.00***	0.81	112.50±12.92	51.94 (1.34)	0.00***	0.85
	6-12 weeks	127.11±14.17		0.00***		131.44±16.55		0.00***	
	0-12weeks	132.50±14.21		0.00***		148.05±21.05		0.00***	
TUG	0-6 weeks	12.00±.90	32.26 (1.92)	0.64	0.14	12.27±0.82	2.54 (1.27)	0.00***	0.73
	6-12 weeks	11.77±0.73		0.40		11.11±0.83		0.01*	
	0-12weeks	11.50±0.70		0.32		10.44±1.14		0.00***	

*Level of significance- p<0.001***, p<0.01**, p<0.05*; SD-standard deviation; 6MWT-6-minute walk test; FAC- functional ambulatory category; BBS- Berg Balance Scale; HRR- heart rate reserve; SSQOL-stroke specific quality of life; TUG-timed up and test; df-degree of freedom; ηp^2-partialeta-squared*

The One-way ANOVA showed significant improvement (p<0.05) in Group B received CPT and HIIT compared to Group A where only CPT was given in all variables after the 12th week. (Table 2)

As 6-MWT is not comparable at the baseline, the mean difference was compared which was 34.33 after 12 weeks of intervention which shows marked improvement in mobility. The difference of 29.95 was observed in baseline and 12-week scores of 6MWT which are closer to a minimal clinically important difference in stroke subjects (34.4) in the HIIT group as compared to minimal change (6.56) in the control group.

Table 3: Between-group comparisons for 6MWT, BBS, FAC, HRR, SSQOL, TUG

Variables	Levels	Group A Mean+SD	Group B Mean+SD	MD	F(1)	p-value	ηp²
6MWT	0 week	151.44±13.28	163.38±20.70	11.94	4.24	0.04*	0.11
	6 weeks	154.16±13.54	171.44±21.38	17.28	8.38	0.007**	0.19
	12 weeks	158.00±13.07	192.33±26.61	34.33	23.47	0.00***	0.40
BBS	0 week	32.27±2.96	31.77±3.17	0.5	0.23	0.62	0.00
	6 weeks	36.55±1.85	36.72±2.84	0.17	0.04	0.83	0.00
	12 weeks	37.00±1.64	42.88±2.72	5.88	61.77	0.00***	0.64
FAC	0 week	3.22±0.42	3.16±0.51	0.06	0.12	0.72	0.00
	6 weeks	3.65±0.60	3.61±0.50	0.04	0.00	1.00	0.00
	12 weeks	3.33±0.48	3.83±0.38	0.5	11.76	0.002**	0.25
HRR	0 week	74.88±10.23	77.77±9.00	2.89	0.80	0.37	0.23
	6 weeks	74.88±8.78	73.94±7.64	0.94	0.00	0.93	0.00
	12 weeks	75.61±8.70	84.44±9.24	8.83	8.70	0.006**	0.20
SSQOL	0 week	124.61±.14.22	112.50±12.92	12.11	0.92	0.34	0.92
	6 weeks	127.11±14.17	131.44±16.55	4.33	0.71	0.40	0.02
	12 weeks	132.50±14.21	148.05±21.05	15.55	6.74	0.01*	0.16
TUG	0 week	12.00±.90	12.27±0.82	0.27	0.92	0.34	0.02
	6 weeks	11.77±0.73	11.11±0.83	0.66	6.51	0.01*	0.16
	12 weeks	11.50±0.70	10.44±1.14	1.06	11.01	0.002**	0.21

*Level of significance- p<0.001***, p<0.01**, p<0.05*; SD-standard deviation; MD- mean difference; 6-MWT-6-minute walk test; FAC- functional ambulatory category; BBS- Berg Balance Scale; HRR- heart rate reserve; SSQOL-stroke specific quality of life; TUG-timed up and test;ηp^2- partial eta-square*

DISCUSSION

This study found that high-intensity interval training (HIIT) significantly improved functional mobility, balance, endurance, and overall quality of life in stroke survivors. Over 12 weeks, participants in the group B who got HIIT in addition to conventional therapy outperformed group A, in several outcome measures.

Miller et al. (2019) observed that HIIT significantly enhanced walking capacity in stroke survivors, as analyzed by the 6-Minute Walk Test (6MWT), similar to the current study [20]. Both studies found an increase in walking distance, with the current study showing an average improvement of 18.54 meters, which is similar with Stoller et al.'s

findings of a 20-meter increase. The similarity indicates that HIIT is helpful across a variety of sample sizes and stroke groups. Stoller et al. used a bigger sample size and a different HIIT methodology, focusing more on treadmill-based training, whereas the current study included both stationary cycling and walking physical activity. This difference in technique may have an impact on the precise processes that promote aerobic capacity and mobility.

In contrast, Boyne et al. observed no significant difference in balance results between HIIT and MICT for stroke recovery [21]. The difference may be due to differences in the duration and frequency of interventions. The current study used a 12-week program with 3-5 sessions per week, whereas Boyne et al. used a shorter 8-week intervention. Furthermore, Boyne et al. applied a lower intensity range for the HIIT procedure, which could have explained the absence of significant balance gains. In contrast, the current study found significant improvements in balance as viewed by the Berg Balance Scale (BBS), implying that higher-intensity training over a longer length of time may be essential for successful gains in postural stability [21].

This study's findings on functional mobility correlate with those of Dean et al. (2020), who observed that HIIT improved Timed Up and Go (TUG) scores more effectively than traditional rehabilitation methods [22]. Both studies reported significant decreases in TUG completion times, indicating increased functional mobility. However, Dean et al. focused on a more thorough neurological rehabilitation program that included cognitive activities in addition to HIIT, which may have influenced the extent of recovery [22]. In contrast, the current trial focused primarily on physical rehabilitation and produced significant functional benefits.

Boyne et al. concluded that stroke survivors who underwent HIIT observed similar improvements in Stroke-Specific Quality of Life (SS-QOL) scores [23]. Both studies found that improvements in mobility and endurance led to higher self-reported quality of life.

A significant similarity between the current study and the study by Mayo et al exists; is the steady enhancement of walking ability and functional mobility through the implementation of HIIT protocols, highlighting its potential as a successful technique for rehabilitation. However the differences in balance results between this study and others highlight how crucial intensity and duration are when creating HIIT programs. The necessity for standardized protocols in stroke rehabilitation is further demonstrated by the differences in target populations, intervention designs, and sample sizes [24].

Although the study tried to cover various aspects of fitness, still there is a need for a detailed exploration of fitness outcomes along with mobility outcomes in stroke. The need for objective outcomes and the development of prognosis and recovery predicted by those outcomes can be included in future studies. The effects of HIIT can be studied for longer duration along with retention effects.

CONCLUSIONS

The study concludes that the combination of HHIT with conventional therapy has significantly improved mobility, balance, and fitness outcomes as compared to conventional therapy alone in post-stroke subjects.

DECLARATIONS & STATEMENTS

Author's Contribution

KK, YKB, AE, NS, and RM: substantial contributions to the conception and design of the study.
KK, AE and NS: acquisition of data for the study.
KK, YKB and AE: analysis of the data for the study.
KK, NS and RM: interpretation of data for the study.
KK: drafted the work.
KK, YKB, AE, NS, and RM: revised it critically for important intellectual content.
KK, YKB, AE, NS, and RM: 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 with ethical approval (RIRAHS-ISB/REC/MS-PT/01745) and permission (RIPHAH/FR&AHS/Letter 014310) at Capital Hospital Islamabad, Grace Medical Centre, and IAT Aesthetic and Therapy after approval from the administrators.

Consent Statement

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

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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None to declare.

Conflicts of Interest

The authors declare no conflict of interest.

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None to declare.

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Research Article

Effect of Preoperative Respiratory Rehabilitation on Post operative Outcomes in Coronary Artery Bypass Graft Patients: A randomized clinical trail

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ABSTRACT

Background: Coronary artery bypass graft, a surgical way to bypass blocked portions of coronary arteries, comes with many postoperative complications including a decline in pulmonary function. Some preoperative exercises help reduce such pulmonary complications and improve postoperative pulmonary function.

Objectives: to determine the effects of preoperative respiratory rehabilitation on post-operative pulmonary functioning in CABG patients.

Methods: a randomized clinical trial with two groups was conducted in the Armed Forces Institute of Cardiology & NIHD Rawalpindi from June 2022- July 2023. The n=86 participants included ages between 40-65 years, those undergoing elective CABG surgery for any cardiac disease, patients who covered at least 400 steps on a 6-minute walk test, patients with ejection fraction 45% or more, and those who reserved at 4th postoperative day of CABG. Group A received Pre and Postoperative Respiratory Rehabilitation. Both groups received postoperative care for 4 days. All the patients were assessed for FEV1, FVC, and their ratio (FEV1/FVC) at baseline, on the 7th day, and on the 4th postoperative day of CABG surgery

Results: the experimental group significantly improved FVC compared to the control group, with moderate improvements observed (p=0.03*) by Day 7 and substantial improvements (p<0.001) by Post Day 4. When compared, at day 7 before surgery no significant difference (p=0.07) observed but The experimental group showed more significant improvement (p=0.006**) post operative day 4. Overall, no significant difference (p<0.05) between the experimental group and the control group consistently in all assessment level of FEV_1/FVC ratio.

Conclusion: The experimental intervention demonstrated positive effects on FVC and FEV1, reflecting improved lung function, while no significant impact was observed on the FEV1/FVC ratio, suggesting that the intervention did not affect the airflow dynamics in relation to lung volume.

Keywords: Forced expiratory volume; Forced vital capacity; FEV1/FVC ratio; preoperative respiratory rehabilitation, coronary artery bypass graft surgery

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INTRODUCTION

Coronary artery disease (CAD) although most common in developing countries, is still one of major causes of deaths in developed countries[1]. Coronary artery bypass graft surgery (CABG) is performed to restore the blood supply of heart by bypassing the blocked vessels, after the diagnosis of disease through the angiography[2].

Preoperative respiratory rehabilitation has gained significant attention for the improved postoperative outcomes in coronary artery bypass graft (CABG) patients[3]. Studies have demonstrated that preoperative interventions, including inspiratory muscle training (IMT), deep breathing exercises, and incentive spirometry, can reduce the incidence of postoperative pulmonary complications (PPCs) and enhance recovery[4, 5].

Additionally, the use of preoperative respiratory rehabilitation programs that include expiratory positive airway pressure (EPAP), breathing exercises, and ambulation has been linked to improved pulmonary function, increased mobility, and better physical endurance in CABG patients[4-7]. Randomized control trials have supported the effectiveness of preoperative IMT in reducing atelectasis, enhancing oxygen saturation, and shortening ICU and hospital stays[8, 9]. However, the duration and intensity of these preoperative programs influence their efficacy, with prolonged training yielding better outcomes[10].

Despite the established benefits of preoperative respiratory rehabilitation in coronary artery bypass grafting (CABG) patients, there is limited evidence from Pakistan. In healthcare resources, patient education, and access to structured rehabilitation programs may differ significantly within the country as well as from developed nations. Most available studies are conducted in high-income countries with advanced healthcare systems, where patients are more likely to receive standardized care and preoperative counseling. Addressing this research gap is crucial for reducing morbidity, mortality, and healthcare costs. Evaluating the effect of preoperative respiratory rehabilitation in a local context, this study can provide evidence to inform clinical guidelines and policies tailored to the needs and limitations of the Pakistani healthcare system.

METHODS

Study Design and Setting: A single-blinded randomized clinical trial was conducted in the Armed Forces Institute of Cardiology & NIHD Rawalpindi (Approval # 9/2/R&D/2022/230). The study was completed within 1 year from June 2022- to July 2023 and approval was taken from the research and ethical committee (REC) of the Faculty of Rehabilitation and Allied Health Sciences (Ref # Riphah/RCRS/REC/ 01378) Riphah International University. Informed consent was obtained from potential trial participants or authorized surrogates by getting a signature form from them.

Participants: The participants included ages between 40-65 years, those undergoing elective CABG surgery for any cardiac disease, patients who covered at least 400 steps on a 6-minute walk test, patients with ejection fraction 45% or more, and those who reserved at 4th postoperative day of CABG. Any patients with acute ailments e.g. deteriorating cardiac condition, patients with a cardiac emergency (shock, acute MI), neurological disorders e.g. altered state of consciousness, paralysis, and those having redo surgeries were excluded from the study. Moreover, patients with any musculoskeletal disorder e.g. amputation of a limb, problems of balance and risks of falls, muscle weakness grade 3 or less, osteoporosis; leading to limitation in exercise were also excluded.

Sample Size: A nonprobability consecutive sampling technique was used to achieve the measured sample size. A total of n=86 sample size was calculated through G power, keeping the effect size small (0.1), α error margin at 0.05. To avoid β error probability, the power (1- β) was set at 0.80%. A total of n=120 patients were assessed for eligibility and n=86 participants fulfilled the inclusion criteria and were randomly allocated to group A (n=43) and group B (n=43). A total of n=73 participants were analyzed at the end of the study due to the loss of follow-up of n=5 patients from the experimental Group (n=38) and n=8 from the control group (n=35). (Figure 1)

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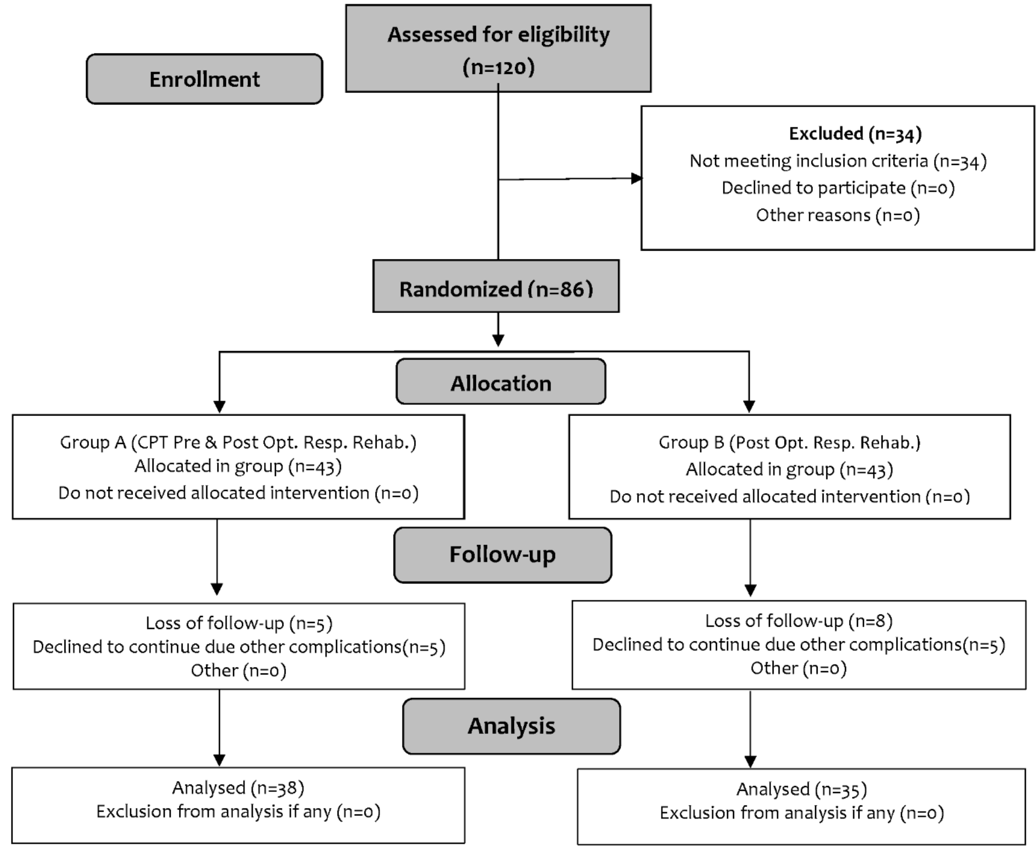


Figure 1: CONSORT diagram

Randomization and blinding: The participants were enrolled by nonprobability convenience sampling technique. There was no sequence generation by any means, participants were allocated randomly to interventions after screening according to selection criteria. The researcher blinded participants after assigning them to intervention by single blinding technique.

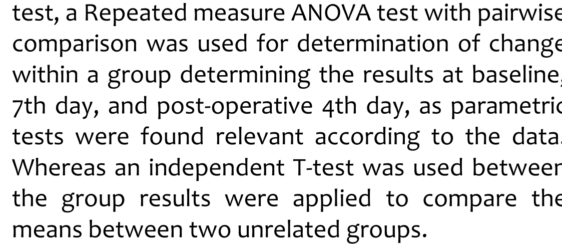
Intervention/Protocol: After the selection of patients who fulfilled the inclusion criteria and by obtaining consent from patients, Group A received Pre and Postoperative Respiratory Rehabilitation i.e. The Preoperative respiratory rehabilitation included the out of bed mobilization, forced expiratory techniques, active cycle of breathing techniques (ACBT) and incentive spirometry for 7 days. When both groups received postoperative incentive spirometry and chest percussion for 4 days. The patients were guided properly to perform each exercise or activity and to use the spirometer. All the interventions were performed under the monitoring of the researcher. For detailed intervention please see Table 1.

Table 1: Intervention Protocol in Both Groups

Group	Intervention	Details	Frequency/Duration
Group A: Pre and Post operative Respiratory Rehabilitation	Out of Bed Activity	Ankle pumps and lower extremity ROM in bed, 4-5 repetitions each. Sitting in bed/chair for 1 minute while monitoring vitals. 6-minute walk with rest on fatigue.	1 set, 3 times/day, for 7 days.
	Active Cycle of Breathing Techniques (ACBT)	Phase 1: 3-4 cycles of normal breathing (inspiration through nose, expiration through mouth). Phase 2: Slow inspiration through nose, 2-3 sec hold, and normal expiration. Phase 3: 2-3 huffs to expel secretions.	3 sets/day, for 7 days.
	Forced Expiratory Technique	Normal inhalation, prolonged exhalation into a bottle half filled with water to form bubbles. 2 sets of 4 repetitions.	4 times/day, for 7 days.
	Incentive Spirometry	Flow-based spirometer, 5 sets of 5 repetitions.	3 times/day, for 7 days.
Group B: Post operative Respiratory Rehabilitation	Incentive Spirometry	Flow-based spirometer, 5 sets of 5 repetitions.	3 times/day, for 4 days.
	Chest Percussion	Percussion of each lung lobe, performed if secretions were retained.	As needed, based on patient condition.

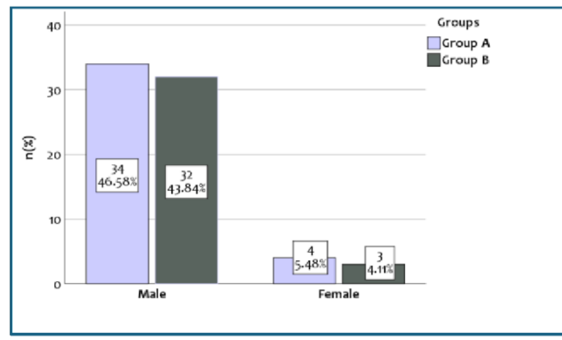
Assessment: After receiving the interventions of relative experimental and control groups, all the patients were assessed through pulmonary function testing by digital portable spirometer, and their FEV1, FVC, and ratio were assessed at baseline, on the 7th day, and on the 4th postoperative day of CABG surgery

Statistical Methods: For the analysis of data SPSS version 25 was used. The patient's demographics data including BMI, smoking history, age, and Ejection fraction were presented as mean, standard deviation, frequency, and percentages. As the data fulfilled the assumption of the parametric test, a Repeated measure ANOVA test with pairwise comparison was used for determination of change within a group determining the results at baseline, 7th day, and post-operative 4th day, as parametric tests were found relevant according to the data. Whereas an independent T-test was used between the group results were applied to compare the means between two unrelated groups.

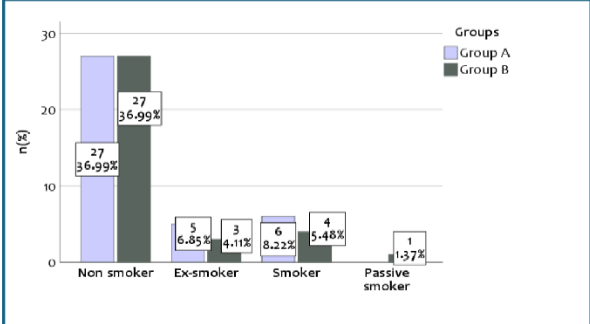


RESULTS

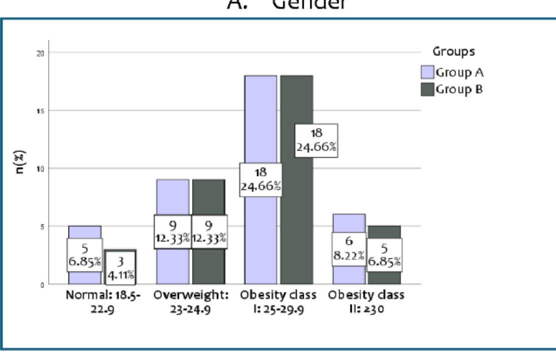
The Mean age of the patients was 55.68±7.29 years, BMI 26.33±3.51 kg/m², and ejection fraction was 51.71±7.4 percent, respectively.



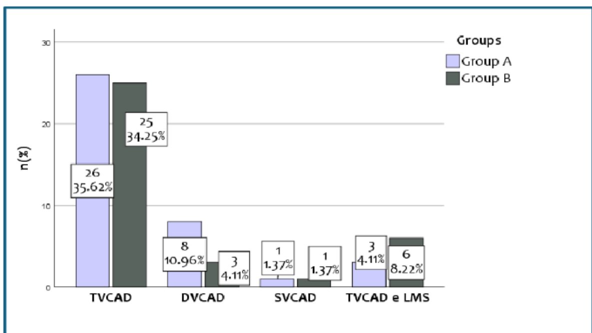
A. Gender



B. Smokers



C. BMI Category



D. Type of disease

Figure 2: Distribution of Demographic Variables

this study included n=66 males and n=07 females. (Figure 2A) A majority (n=64) of the participants were nonsmoker; whereas n=8 were ex-smokers who quitted smoking 1 year ago, while n=12 participants in the study were smoker, and n=1 was passive smoker. (Figure 2B) The Body mass index (BMI) was calculated in accordance with the Asia-Pacific classification, which showed that n=36 participants were categorized into Obese class I, n=18 into Overweight category, n=11 was into Obese class II category and only n=8 were categorized inti normal weight category. (Figure 2C) While triple vessel coronary artery disease (TVCAD) being more prevalent (n=58), 14 patients presented with double vessel CAD (DVCAD), 10 Patients had TVCAD through left main stem disease and 3 patients had single vessel coronary artery disease (SVCAD). (Figure 2D)

The results of the RMANOVA showed Forced Vital Capacity (FVC %), in the experimental group, a significant increase from baseline to Day 7 (p=0.02) and an even more significant improvement by Post Day 4 (p<0.001), indicating a large effect size and substantial impact of the intervention. In contrast, the control group exhibited no significant change from baseline to Day 7 (p=1), but a notable improvement by Post Day 4 (p<0.001), suggesting effect of Intervention. For Forced Expiratory Volume (FEV_1 %), the experimental group showed significant improvements from baseline to Day 7 (p=0.009) and a significant increase by Post Day 4 (p<0.001), augmenting the substantial benefit of the intervention over time. Similarly, the control group demonstrated a smaller but significant improvement from baseline to Day 7 (p=0.03) and a continued increase by Post Day 4 (p<0.01), indicating some recovery. For the FEV_1/FVC ratio, the experimental group experienced moderate improvements, with significant changes observed from baseline to Day 7 (p=0.02) and Post Day 4 (p=0.004). In contrast, the control group exhibited no significant changes across time points (p>0.5),

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suggesting that this parameter was less responsive to incentive spirometry. (Table 2)

Table 2: Within group changes (Group A & B)

Group		Mean	SD	MD/F(df)	p-value	ηp²
FVC (%)						
Group A (n=38)	Baseline	89.03	24.232	-7.82	0.02*	-
	Day 7	96.85	22.848	60.23	.000***	-
	Post Day 4	36.62	5.997	209.98(1.81,67.22)	.000***	.850
Group B (n=34)	Baseline	83.67	23.664	-1.11	1	-
	Day 7	84.78	23.408	54.92	.000***	-
	Post Day 4	29.86	6.850	184.60(1.48,44.64)	.000***	.848
FEV_1 (%)						
Group A (n=38)	Baseline	93.44	26.306	-4.51	0.009**	-
	Day 7	97.95	26.064	58.42	.000***	-
	Post Day 4	39.52	10.912	147.430	.000***	.799
Group B (n=34)	Baseline	82.91	21.853	-4.36	0.03*	-
	Day 7	87.27	23.664	55.14	.000***	-
	Post Day 4	32.13	11.518	147.797	.000***	.813
FEV_1/FVC Ratio						
Group A (n=38)	Baseline	84.4474	15.30712	-.90	1	-
	Day 7	85.3555	14.47026	-7.22	0.02*	-
	Post Day 4	92.5789	8.45858	5.923	.004**	.138
Group B (n=34)	Baseline	87.7589	19.90660	0.2	1	-
	Day 7	87.5597	18.49021	-7.64	0.33	-
	Post Day 4	95.2000	15.99412	2.443	.125	.067

*Level of significance- p<0.001***, p<0.01**, p<0.05*; SD-standard deviation; df-degree of freedom; ηp²-partialeta-squared; FVC-forced vital capacity; FEV_1-forced expiratory volume; MD-mean difference; Group A- pre and post operative respiratory rehabilitation; Group B-post operative respiratory rehabilitation*

The independent t-test results demonstrate that the experimental group significantly improved FVC compared to the control group, with moderate improvements observed (p=0.03*) by Day 7 and substantial improvements (p<0.001) by Post Day 4. When compared, at day 7 before surgery no significant difference (p=0.07) was observed but The experimental group showed more significant improvement (p=0.006**) post operative day 4. Overall, no significant difference (p<0.05) between the experimental group and the control group consistently in all assessment levels of FEV_1/FVC ratio. (Table 3)

Table 3: Comparison between group A & B

		Group A (n=38)		Group B (n=34)		MD	p-value	Cohen's d
		Mean	SD	Mean	SD			
FCV (%)	Baseline	89.03	24.23	83.67	23.66	5.72	.309	-
	Day 7	96.85	22.84	84.78	23.40	12.07	.030*	0.52
	Post Day 4	36.62	5.99	29.86	6.85	6.71	.000***	1.05
FEV (%)	Baseline	93.44	26.30	82.91	21.85	10.52	.068	-
	Day 7	97.95	26.06	87.27	23.66	10.67	.072	-
	Post Day 4	39.52	10.91	32.13	11.518	7.39	.006**	0.65
FEV_1/FVC Ratio	Baseline	84.44	15.30	87.75	19.90	-.6761	.877	-
	Day 7	85.35	14.47	87.55	18.49	-2.20	.571	-
	Post Day 4	92.57	8.45	95.20	15.99	-2.62	.379	-

*Level of significance- p<0.001***, p<0.01**, p<0.05*; SD-standard deviation; df-degree of freedom; ηp2-partialeta-squared; FVC-forced vital capacity; FEV1-forced expiratory volume; MD-mean difference; Group A- pre and post operative respiratory rehabilitation; Group B-post operative respiratory rehabilitation*

DISCUSSION

The findings of the study underscore the efficacy of preoperative respiratory rehabilitation, particularly through active interventions like out-of-bed mobilization and respiratory exercises, in enhancing Forced Vital Capacity (FVC) and Forced Expiratory Volume (FEV %) compared to traditional methods such as incentive spirometry. Evidence from various studies indicates that these dynamic rehabilitation techniques significantly improve pulmonary function, reduce the incidence of postoperative complications like pneumonia, and facilitate quicker recovery post-CABG surgery[11, 12].

The experimental group in the study exhibited marked improvements in FVC and FEV, aligning with literature that highlights the benefits of early mobilization and comprehensive preoperative care[13, 14]. Conversely, the control group, while showing some improvement, did not achieve the same level of benefits, emphasizing the necessity for more robust preoperative strategies to optimize

patient outcomes following cardiac surgery[12, 15]. The observed differences in postoperative outcomes can be attributed to the comprehensive multifaceted approach, including ankle pumps, lower extremity range of motion exercises, and Active Cycle of Breathing Techniques (ACBT), which enhanced respiratory function more effectively than incentive spirometry alone[16, 17].

Previous studies have shown that while incentive spirometry can reduce postoperative pulmonary complications, its efficacy is often limited compared to more integrated rehabilitation strategies[18, 19]. For instance, a systematic review indicated that preoperative breathing exercises significantly improve respiratory performance and reduce complications, suggesting that the combination of techniques used in the experimental group may provide synergistic benefits[17]. The significant improvements in FVC observed in the experimental group highlight the importance of a holistic approach to preoperative care in enhancing postoperative recovery[19, 20].

In contrast, the control group, while showing some improvement in FEV, did not achieve the same level of significance, indicating that the structured preoperative approach may be more effective in mitigating pulmonary complications[17, 18]. Previous literature supports that preoperative respiratory exercises can lead to better postoperative outcomes, including reduced atelectasis and improved oxygenation, thus highlighting the importance of tailored preoperative interventions[21].

The observed differences in the FEV_1/FVC ratio improvements between the experimental and control groups in the study on preoperative respiratory rehabilitation for CABG patients can be contextualized within the existing literature. While the experimental group showed significant enhancements in respiratory function (FEV_1/FVC ratio), particularly from baseline to Day 7 and Post Day 4, respectively, the control group did not exhibit notable changes[16, 18]. This aligns with findings from other studies that emphasize the efficacy of preoperative interventions, such as incentive spirometry and breathing exercises, in reducing postoperative pulmonary complications and improving oxygenation[21-23]. However, some literature suggests that the benefits of such interventions can be inconsistent, with certain studies reporting no significant differences in outcomes like atelectasis and hypoxemia[24].

The variability in results may stem from differences in study design, patient populations, and the specific rehabilitation protocols employed, highlighting the need for standardized approaches to maximize postoperative respiratory outcomes.

CONCLUSION

The experimental intervention demonstrated positive effects on FVC and FEV1, reflecting improved lung function. While the FEV_1/FVC ratio exhibited moderate improvements in the experimental group, it remained less responsive in the control group, underscoring the need for tailored, multifaceted approaches to optimize respiratory recovery post-surgery. Overall, this study demonstrates that a structured and integrative preoperative rehabilitation program can significantly enhance recovery and pulmonary outcomes in CABG patients, advocating for its routine incorporation into pre-surgical care protocols.

DECLARATIONS & STATEMENTS

Author's Contribution

AI and MAAM, and IT: substantial contributions to the conception and design of the study.
AI and AK: acquisition of data for the study.
AI, KM and SSAI, : analysis of the data for the study. AA and AI, QU, MM and KM : interpretation of data for the study.
AA: drafted the work.
AI, SS, QU, MM, KM, MAAM, and IT: revised it critically for important intellectual content.
AI, SS, QU, MM, KM, MAAM, and IT: 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 the Armed Forces Institute of Cardiology & NIHD Rawalpindi (Ref No. 9/2/R&D/2022/230) and approval was taken from the research and ethical committee (REC) of the Faculty of Rehabilitation and Allied Health Sciences (Ref. No. Riphah/RCRS/REC/ 01378) Riphah International University.

Consent Statement

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

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

None to declare.

Conflicts of Interest

The authors declare no conflict of interest.

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None to declare.

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Research Article

Psychological distress, burnout, sense of coherence and social support among caregivers of cerebral palsy children

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ABSTRACT

Background: Caregivers of children with cerebral palsy face significant psychological distress and burnout due to caregiving demands. Protective factors like a strong sense of coherence and social support may mitigate these effects.

Objective: to assess the relationship between psychological distress, burnout, sense of coherence, and social support among caregivers of cerebral palsy children.

Methodology: A cross-sectional study was conducted on n=100 caregivers of CP in the National Institute of Rehabilitation Medicine (NIRM) from June to December 20222. The data was collected through a purposive sampling technique from the caregivers of the CP children in the outpatient and inpatient departments of NIRM. Urdu-translated versions of the Depression, Anxiety & Stress Scale (DASS), Parental Burnout Assessment (PBA), Multidimensional Perceived Social Support, and Orientation of Life Scale (sense of coherence) were administered to collect the data.

Results: The higher parental burnout was strongly correlated with higher overall psychological distress(r=0.64), and moderate negative correlation (r=-0.45) with perceived social support. A higher intercorrelation of depression, anxiety, and stress (r=0.77 to 0.93) was observed. There were also strong negative correlations of sense of coherence across depression r=-0.62, anxiety (r=-0.55), and stress (r=-0.51). The MPSS had a moderate negative correlation (r=-0.41) with distress. The MSPSS also showed a Moderate positive correlation (r=0.57) with a sense of coherence.

Conclusion: It was concluded that caregivers of Cerebral palsy children are psychologically distressed and have burnout that effect their mental health. With an increasing sense of coherence and social support, their mental health can be supported.

Keywords: Cerebral palsy; caregiver; depression; burnout; social support; sense of coherence.

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INTRODUCTION

Caregivers of children with cerebral palsy (CP) experience burnout, and varying levels of social support, which profoundly impact their mental health [1]. Studies report high levels of stress, with nearly half experiencing elevated parental stress, particularly in the domain of parental distress[2, 3]. Factors such as the severity of the child's condition, frequent hospitalizations, and lack of respite contribute to this distress [1, 4]. Additionally, caregivers often prioritize their child's needs over their own, leading to feelings of unpreparedness and emotional challenges[3, 4]. Social support plays an importing role in mitigating stress; however, many caregivers still report unmet needs for professional and familial support [5].

Recent literature highlights significant psychological distress and burnout among caregivers of children with cerebral palsy (CP) in Pakistan, revealing a pressing need for targeted interventions[6-10]. Caregivers experience heightened stress levels, which negatively impact both their well-being and the developmental outcomes of their children[6, 7]. The prevalence of CP in Pakistan, estimated at 2 to 3 per 1000 children, exacerbates caregiver burden, with studies indicating a strong correlation between child behavior and caregiver stress[7]. Systematic reviews emphasize the importance of social support and the psychological needs of caregivers, suggesting that participation in support groups can alleviate stress and improve quality of life[8, 9]. However, there remains a research gap in longitudinal studies specifically addressing the unique challenges faced by Pakistani caregivers, particularly regarding their sense of coherence and the effectiveness of support mechanisms[10].

In Pakistan, while there is extensive research on the psychological impacts of caregiving for cerebral palsy. However limited data exists on how psychological factors like sense of coherence (SOC) and social support interact with burnout and distress in this population. This study will help to understand the interplay between psychological distress, burnout, SOC, and social support. It will guide to develop of targeted mental health interventions to improve the quality of life for caregivers of children with CP.

MATERIALS AND METHODS

Study design & setting: The cross-sectional research Study was conducted in the psychology department of NIRM (Rehabilitation unit) of Islamabad, Pakistan in 2022 from June to December for 6 months approximately (No. F.1-127/06-NIRM).

Selection criteria: Inclusion criteria were 25-55 years old caregivers of cerebral palsy children between 3-13 years without any medical or psychological illness were included in the study. The educational status of the caregivers was matric and above. Uneducated participants were not included in the study.

Sample size: The sample was n=99 caregivers of cerebral palsy children calculated by setting the effect size (f2) small (0.13), probability of alpha (α) error was set at 0.05, power (1-β) was set at 90%, with three predictors. The data was collected from n=100 participants through a purposive sampling technique.

Outcome measures & tools: Psychological distress in terms of depression, anxiety, and stress were measured through Depression, Anxiety Stress Scale (DASS) Urdu version[11], parental burnout was measured with Parental Burnout Assessment (PBA)[12], Social support was measured with Multidimensional Perceived Social Support (MPSS)[13], and Orientation of Life Scale (OLS)[14] used for sense of coherence among caregivers of cerebral palsy children.

Data collection procedure: After obtaining the consent from the participants the questionnaires were administered on the caregivers. Every participant filled the questionnaire individually as the instructions were mentioned on the questionnaires.

Data Analysis procedure: After taking the data from the participants analysis was done on SPSS. Reliability of all the scales were measured on the present sample. To determine the relationships and differences was analyzed through Pearson's correlation, and independent t-test and mediation analysis was done through Multiple linear regression. The SPSS version 23 was used for data analysis.

RESULT

Many of the caregivers were female (74%) accounting for mothers (68%) and belonging to the 25-35 years (47%) age category. Most caregivers (68%) had a secondary school certificate. (figure 1)

The Mean of the parent burnout assessment (PBA) score is 72.19±27.08, with high reliability (α = 0.91). The actual range (23 to 134) is narrower than the potential range (7 to 161), indicating scores cluster within a limited segment of the scale. Moreover, Skewness (0.43) and kurtosis (-0.64) indicate a slightly positively skewed and platykurtic. The depression, anxiety, and stress scale (DASS) were high reliability overall (α =0.94) and throughout subscales (Depression=0.85, Anxiety=0.84, Stress=0.85). The mean scores for depression (16.13±4.84), anxiety (15.06±4.53), and stress (17.18±4.67) are moderately high, implying caregivers experienced significant distress. The

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subscale distributions were slightly positively skewed skewness and kurtosis values near 0, close to normal. The Sense of Coherence (SOC) on the orientation life scale (OLS) also showed high reliability (α=0.89) with a mean score (of 49.61±16.35) indicating moderate coherence among caregivers. The distribution is nearly symmetrical and normal (skewness=0.05, kurtosis=0.08). The reliability of the Multidimensional Scale of Perceived Social Support (MSPSS) in current data showed very high reliability (α=0.96). The mean score (43.03±18.98) suggests moderate levels of perceived social support. It distribution is also nearly normal and slightly platykurtic (kurtosis=-0.92). (table 1)

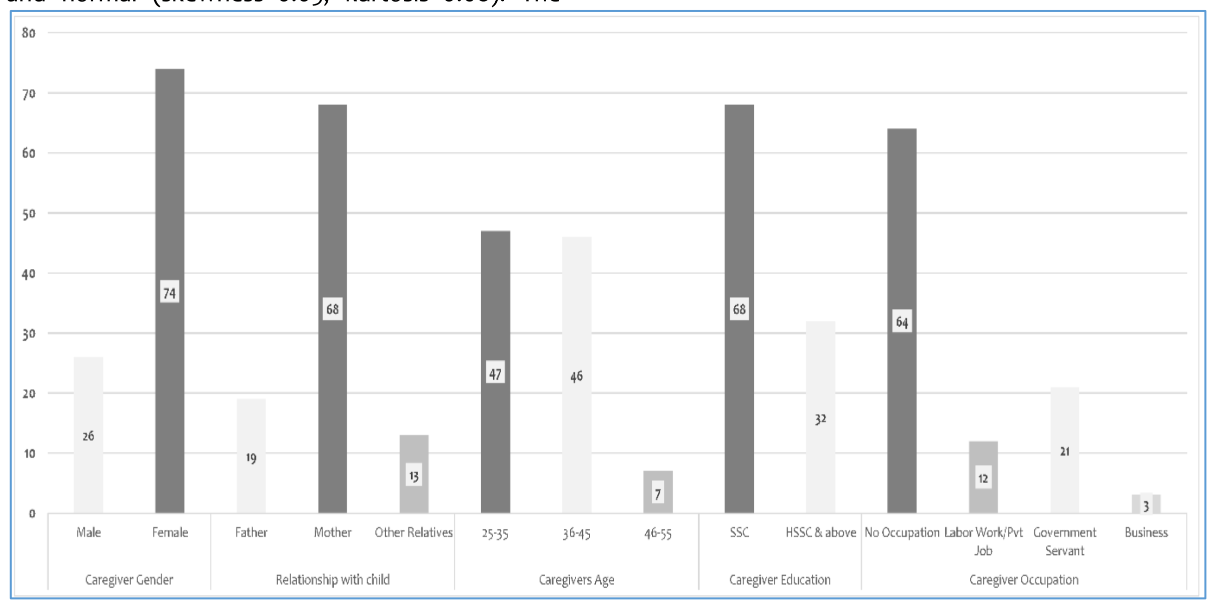

Figure 1: Frequency of demographics of Caregivers of Cerebral Palsy (n=100)

Table 1: Descriptive Statistics and Alpha-Reliability Coefficient of Variables among Caregivers of Cerebral Palsy Children (n=100)

Variables	k	α	M	SD	Range		Skewness	Kurtosis
					Actual	Potential		
PBA	23	0.91	72.19	27.08	23-134	7-161	.43	-.64
DASS	21	0.94	48.44	13.09	22-82	4-84	.21	-.45
Depression	07	0.85	16.13	4.84	7-28	4-28	.22	-.36
Anxiety	07	.84	15.06	4.53	7-28	4-28	.28	-.50
Stress	07	.85	17.18	4.67	7-28	4-28	.24	.48
SOC	13	.89	49.61	16.35	13-91	7-91	.05	.08
MSPSS	12	.96	43.03	18.98	12-84	7-84	.04	-.92

PBA- parent burnout assessment; DASS- depression, anxiety, and stress scale; SOC- Sense of Coherence; MSPSS- Multidimensional Scale of Perceived Social Support; SD-standard deviation; M- Mean

The above table 1 shows the frequency and percentage of each demographic variable of the study.

The higher parental burnout was strongly correlated with higher overall psychological distress(r=0.64), and depression(r=0.66), while had a strong negative correlation (r=-0.71) with a sense of coherence (soc) on also and moderate negative correlation (r=-0.45) perceived social support. The higher intercorrelation of depression, anxiety, and stress (r=0.77 to 0.93) was observed, indicating these constructs are closely related components and overall distress. They also had strong negative correlations of sense of coherence across depression r=-0.62, anxiety (r=-0.55), and stress (r=-0.51). The MPSS had a moderate negative correlation (r=-0.41) with distress. The MSPSS also showed a Moderate positive correlation (r=0.57) with a sense of coherence. (Table 2)

The female caregivers exhibit significantly higher than males in overall distress (p=0.01), including depression (p=0.01), anxiety (p=0.03), and stress (p=0.02). This highlights the emotional burden they experience more acutely than their male counterparts. On the other hand, no statistically significant (p=0.08) gender difference was observed, though males show a slightly stronger SOC. While male caregivers perceive significantly higher (p=0.02) social support compared to females. (table 3)

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Table 2: Correlation between burnout, psychological distress, sense of coherence & social support among caregivers of Cerebral palsy children.

	PBA	DASS (Total)	Depression	Anxiety	Stress	OLS (SOC)	MSPSS
PBA	-	0.64**	0.66**	0.58**	0.54**	-0.71**	-0.45**
DASS (Total)		-	0.92**	0.91**	0.93**	--.63**	-0.41**
Depression			-	0.77**	0.79**	-0.62**	-0.43**
Anxiety				-	0.78**	-0.55**	-0.39**
Stress					-	-0.51**	-0.32**
OLS (SOC)						-	0.57**
MSPSS							-

*Level of significance- p<0.001***, p<0.01**, p<0.05*; PBA- parent burnout assessment; DASS- depression, anxiety, and stress scale; SOC- sense of coherence; MSPSS- multidimensional scale of perceived social support ; OLC- orientation life scale*

Table 3: Gender-based comparison of psychological distress (depression, Anxiety & Stress), Sense of Coherence, and Social support

Group	Male Caregivers (n=26)		Female caregivers (n=74)				
	Mean	SD	Mean	SD	t(df)	p-value	Cohen's d
PBA	65.62	22.90	74.50	28.19	1.44(98)	.15	.08
DASS	43.00	10.20	50.35	13.51	2.53(98)	.01*	.06
Depression	14.15	4.22	16.83	4.88	2.48(98)	.01*	.06
Anxiety	13.46	4.03	15.62	4.59	2.13(98)	.03*	.50
Stress	15.38	3.66	17.81	4.84	2.33(98)	.02*	.57
SOC	54.46	16.43	47.91	16.08	1.77(98)	.08	.40
SS	50.73	17.21	40.32	18.93	2.47(98)	.02*	.58

*Level of significance- p<0.001***, p<0.01**, p<0.05*;PBA- parent burnout assessment ; DASS- depression, anxiety, and stress scale ; SOC- sense of coherence; MSPSS- multidimensional scale of perceived social support ;SS-social support*

The result showed that the difference between less educated and highly educated caregivers were not statistically significant ($p \geq 0.05$) regarding burnout, psychological distress (depression, Anxiety & Stress), and social support. But Sense of Coherence was significantly ($p=0.03$) higher in highly educated caregivers than less educated. (table 4) the indirect pathway indicates that burnout does not significantly affects {β=0.12, SE=0.04, p≥0.05, 95% CI=(0.05, 0.20) psychological distress through SOC. burnout has a significant direct effect {β=0.19, SE=0.05, p<0.05, 95% CI=(0.09, 0.29)} on psychological distress, even when SOC is included in the model. The total combined effect (direct + indirect) shows that burnout has a strong and significant {β=0.31, SE=0.037, p<0.05, 95%CI=(0.23, 0.38)} overall effect on psychological distress. (table 5)

Table 4: Comparison based on Education in caregivers

Group	Less Educated (n=68)		Highly Educated (n=32)		t(df)	p-value	Cohen's d
	Mean	SD	Mean	SD			
PBA	73.43	27.00	69.53	27.51	.67(98)	.51	-
DASS	49.71	12.95	45.75	13.19	1.42(98)	.16	-
Depression	16.53	4.73	.28	5.06	1.20(98)	.23	-
Anxiety	15.35	4.25	14.44	5.09	.94(98)	.35	-
Stress	17.72	7.73	16.03	4.38	1.70(98)	.09	-
SOC	47.16	16.49	54.81	14.98	2.22(98)	.03*	0.49
SS	40.75	19.02	47.88	18.23	1.77(98)	.08	-

*Level of significance- p<0.001***, p<0.01**, p<0.05*; PBA- parent burnout assessment; DASS- depression, anxiety, and stress scale ; SOC- sense of coherence; MSPSS- multidimensional scale of perceived social support; SS-social support; SD- standard deviation*

Table 5: Mediating role of sense of coherence between Burnout & Psychological Distress among caregivers of cerebral palsy children (N=100).

Effect	β	SE	p-value	95% CI	
				Lower	Upper
Indirect Effect (a*b) Burnout→Sense of Coherence→Psychological Distress	0.12	0.04	-	0.05	0.20
Direct Effect (`c) Burnout→ Psychological Distress	0.19	0.05	0.00***	0.09	0.29
Total Effect (c) Burnout →Psychological Distress	0.31	0.037	0.00***	0.23	0.38

*Level of significance- p<0.001***, p<0.01**, p<0.05*; β -beta; SE-standard error; CI - confidence level*

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Figure 2: mediation model indicating direct, indirect paths and their significance

The model suggests that a Sense of Coherence partially mediates the relationship between burnout and psychological distress. From the above model, it can infer a partial mediation effect of social support through burnout and psychological distress, but it is not significant. (Figure 2)

The direct effect of burnout on psychological distress is a statistically significant positive relationship (β=0.28, p<0.001). However, the indirect effect suggests that social support does not mediate the significant (β=0.34, p≥0.05) relationship between burnout and psychological distress. The total effect confirmed that burnout has a strong and significant (β = 0.31, p < 0.001) impact on psychological distress among caregivers of children with cerebral palsy. (table 6)

Table 6: Mediating role of social support between burnout & psychological distress among caregivers of cerebral palsy children (N=100).

Effect	B	SE	P value	95% CI	
				Lower	upper
Indirect Effect (a*b) Burnout→Social support→Psychological Distress	0.34	0.02	≥0.05	-.003	0.09
Direct Effect (`c) Burnout→ Psychological Distress	0.28	0.041	0.00	0.19	0.35
Total Effect (c) Burnout →Psychological Distress	0.31	0.037	0.00	0.23	0.38

B-beta; SE-standard error; CI - confidence level

DISCUSSION

The present research was conducted on caregivers of cerebral palsy children, to determine the relationship among Psychological distress, Burnout, Sense of coherence, and social support. The current study showed a strong positive correlation between parental burnout and overall psychological distress, with higher correlations for depression and moderate correlations for anxiety and stress. These results are coherent with literature indicating that caregiving for children with disabilities often leads to emotional exhaustion and psychological strain. The prolonged caregiving responsibilities can aggravate feelings of desperation and psychological challenges in high-stress situations[15, 16]. A strong negative correlation showed that Caregivers with a higher sense of coherence (SOC) are better able to perceive caregiving challenges as comprehensible, controllable, and meaningful, decreasing burnout risks[17]. Moreover, the moderate negative correlation between burnout and perceived social support suggests that a strong social network considerably buffers the effects of caregiving stress, and that social connections provide both emotional relief and practical assistance[18].

The study also revealed a high intercorrelation among depression, anxiety, and stress, reflecting as components of overall psychological distress. This result is supported by the tripartite model of anxiety and depression, which emphasizes the shared characteristics of these states. The strong negative correlation of SOC with depression, anxiety, and stress supports its role in reducing mental health issues by adopting coping strategies[19]. Furthermore, the moderate negative correlation of perceived social support (MSPSS) with overall distress and a positive correlation with SOC, highlights social support's mitigating effect on stress and its enhancement of SOC. By integrating these findings with existing literature, the study emphasizes the need for evidence-based practices to improve the psychological well-being of caregivers of children with cerebral palsy[20].

The study highlights notable gender differences in psychological distress, burnout, sense of coherence (SOC), and perceived social support among caregivers of children with cerebral palsy. Female caregivers demonstrated significantly higher levels of overall distress, including depression, anxiety, and stress, compared to male caregivers. The women often display an unequal emotional burden due to social expectations and their primary caregiving roles as they navigate caregiving responsibilities beside conventional social roles[21-23]. This weakness highlights the need for stress management programs and caregiver support groups to reduce distress in female caregivers[24].

While no statistically significant gender difference in SOC was observed, males demonstrated a slightly stronger SOC. Previous research suggests that males are more likely to assume problem-focused coping strategies to enhance SOC[25, 26]. Male caregivers reported significantly higher perceived social support

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compared to females. The studies indicate that males are more likely to utilize family and community resources, for emotional and practical support. Female caregivers may hesitate to seek such support due to cultural norms, feelings of guilt, or internalized expectations[3, 21, 23]. These findings emphasize the need for gender-sensitive caregiver support programs.

The study also revealed no significant differences between less educated and highly educated caregivers regarding burnout, psychological distress (including depression, anxiety, and stress), and social support. In contrast, a study reported that greater burden was significantly associated with lower caregiver education[27]. However, the current study found a significant difference in the sense of coherence (SOC), which was higher among highly educated caregivers. The literature suggests that education likely increases SOC by cognitive skills, problem-solving abilities, and access to information of an individual[28]. Highly educated caregivers may have a better understanding of cerebral palsy, its prognosis, and its management, enabling them to approach caregiving with a sense of control and purpose[29].

The non-significant indirect effect of burnout on psychological distress through SOC suggests that SOC may not be a key mediator in the burnout-distress pathway in this study. While SOC can be protective, its role in buffering the relationship between burnout and psychological distress may not always be prominent, particularly in high-stress caregiving situations. It is possible that coping strategies, personal resilience, and other factors, may play a more significant mediating role than SOC[30]. On the other hand, the significant direct effect of burnout on psychological distress characterized by burnout due to the emotional and physical demands of caregiving, coupled with the stress of managing the complications of CP[31]. Furthermore, the significant total effect of burnout on psychological distress highlights the crucial role of burnout in worsening caregivers' mental health.

The study found that social support did not mediate the relationship between burnout and psychological distress, suggesting unexpected results, given that social support is commonly considered a protective factor against burnout and distress[32]. One possible explanation is that caregivers may not have received adequate or effective social support, which has been shown to be a crucial factor in mitigating the negative impact of burnout[33].

Limitation: the study is likely based on the Pakistani population residents of twin cities; the findings may not be generalizable to caregivers in other regions or countries. The experience of burnout and psychological distress may differ depending on cultural norms, available resources, and healthcare systems across the country.

CONCLUSION

The study indicates that higher levels of burnout contribute to increased psychological distress. However, social support did not mediate the relationship between burnout and psychological distress, suggesting that the perceived social support might not be sufficient or effective in alleviating burnout's impact. Moreover, burnout has a strong and significant impact on psychological distress, emphasizing the need to address caregiver burnout as a key factor in reducing psychological distress in caregivers of children with cerebral palsy. To establish causal relationships, future studies should adopt longitudinal designs to track caregivers over time. Future research should also examine the physical health of caregivers in addition to their mental health, as physical strain can contribute to burnout and psychological distress.

DECLARATIONS & STATEMENTS

Author’s Contribution

SW and RM: substantial contributions to the conception and design of the study.
SW and HMMHK: acquisition of data for the study.
SW and HMMHK: analysis of the data for the study.
SW and RM: interpretation of data for the study.
SW: drafted the work.
SW, RM and HMMHK: revised it critically for important intellectual content.
SW, RM and HMMHK: 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 research Study was conducted in the psychology department of National Institute of Rehabilitation Medicine (NIRM) Islamabad, Pakistan after approval from Executive committee (No. F.1-127/06-NIRM) in 2022.

Consent Statement

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

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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None to declare.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

None to declare.

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