THE REHABILITATION JOURNAL
P-ISSN: 2521-344X / E-ISSN: 2521-3458

T. Rehabili. J.
Volume 09, Issue 03
September 2025

RAND PUBLICATIONS
HERF HEALTH EDUCATION RESEARCH FOUNDATION

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EDITORIAL TEAM

Editorial

AI tools in rehabilitation research: a call for full disclosure

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ABSTRACT

Advances in artificial intelligence (AI) are rapidly transforming rehabilitation research, from predictive models of gait and recovery to AI driven robotics and tele-rehabilitation systems. Such work promises more personalized therapy, but it also raises a question about fully disclosing AI tool's use in research. Despite the hype, recent study shows that AI involvement in medical research is often underreported. In a systematic review of 65 clinical trials involving AI, only 10 explicitly mentioned that they used AI, and many AI specific details were missing[1]. These findings suggest that there is wide transparency gap.

Some authors simply may not realize that standard reporting guidelines and others may resist publishing code or details of AI usage. Resnik and Hosseini (2025) reported that some publishers different and sometimes contradictory policies on AI disclosure[2]. So, without clear directives, many investigators share minimum information. However, whatever the reason is, if methodology isn't fully reported, it can't be independently verified or reproduced. Failing to declare AI methods is not a mere editorial oversight, it poses real risks to science and patients. From a scientific standpoint, transparency is essential for reproducibility.

Finally, not disclosing AI use can backfire academically. Many journals and professional societies now recognize that using AI (even for writing or image generation) can raise questions of authorship and ethics. The ICMJE updated its guidelines to address AI explicitly, noting that manuscripts must disclose information on how work conducted with the assistance of artificial intelligence (AI) technology [3]. So, the publishers are moving toward mandatory disclosure: if you used AI in any substantive way, you must tell readers. Rehabilitation research must get ahead of this curve rather than be caught unprepared.

However, merely having guidelines is not enough, they must be adopted. As noted several Rehabilitation journals have not issued AI-specific author instructions. Specialty fields may assume general reporting standards suffice, but AI's complexity demands explicit mention. We believe The Rehabilitation Journal and peer publications will adopt and consider revising their policies and submission checklists to explicitly ask about the use of any AI tools in this study, If so, describe in detail. Without these directives, underreporting is likely to continue. By embracing clear guidelines and ethical norms today, we can use AI's potential to improve rehabilitation without compromising the integrity or equity of our science.

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Citation

Kanwal R, Tayyub U, Awan WA. AI tools in rehabilitation research: a call for full disclosure. T Rehabili. J. 2025:09(03); 01-02 doi:10.52567/trehabj.v9i03.115

Article History

Submitted: 26-08-2025
Accepted: 30-08-2025
Published: 20-09-2025

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DECLARATIONS & STATEMENTS

Ethical Statement

Not Applicable

AI Use Statement

The authors utilized SciSpace and Semantic Scholar for literature support, and Grammarly to enhance language clarity during manuscript preparation. All final content was critically reviewed, verified, and approved by the authors

Consent Statement

Not Applicable

Data Availability Statement

Not Applicable

Acknowledgments

None to declare.

Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Effects of 8- week plyometric training on physical fitness and technical skills of domestic cricket players: a randomized clinical trial

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ABSTRACT

Background: Cricket requires a special blend of mental sharpness, technical skill, and physical fitness. Plyometric exercises, known for enhancing explosive power and speed, have gained popularity in cricket training.

Objective: to investigate the impact of plyometric exercises on the overall performance of domestic cricket players, considering their demanding physical requirements

Methods: A randomized controlled trial was conducted at Bestion Cricket Club (Gujrat Sports Complex). The study included n=22 cricket players, a plyometric group (n=11), and a conventional group (n=11) that underwent a training program focusing on upper and lower body exercises. Training sessions occurred three times a week for 60 minutes, with appropriate rest periods. Data was collected at baseline, 2nd week, 4th week, 6th week, and 8th week.

Results: The average age is 19.74±1.65 years, BMI is 26.0±13.95 and average sleep duration was 8.48±1.309 hours. Plyometric training led to significant improvements in agility (p=0.04), strength (1RM, p=0.03), flexibility (Sit & Reach, p<0.001), balance (SEBT-L, p=0.04; SEBT-AM, p=0.04), and throw length (p<0.001) among university-level cricketers, with notable gains from the 4th to 8th weeks. Bowling speed increased within the plyometric group (p<0.001), though not significantly between groups (p=0.15). Conventional training showed limited improvements. Overall, plyometric training proved more effective than conventional methods in enhancing cricket-specific fitness.

Conclusion: It has been demonstrated that plyometric training enhances the physical fitness components and also has some effect on the technical skills of domestic cricket players as well.

Keywords: agility; balance; coordination; endurance; plyometric; physical activity.

Clinical trials # NCT06155071

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Rehman A, Siddique Z, Khalid A, Manzoor A, Din AU. Effects of 8- week plyometric training on physical fitness and technical skills of domestic cricket players: randomized clinical trial. T Rehabili. J. 2025:09(03); 03-13 doi: 10.52567/trehabj.v9i03.105

Article History

Submitted: 08-05-2025
Accepted: 29-06-2025
Published: 14-07-2025

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INTRODUCTION

Cricket requires a special blend of mental sharpness, technical skill, and physical fitness. Cricket is played in different formats like one-day, T-twenty, and test series at domestic, national, and international levels. The ability to perform a wide range of skills, such as batting, bowling, fielding, throwing, running, and agility, on the pitch, is essential for success in sport. Players in the country who play cricket and compete at different levels with the goal of representing their country internationally need a rigorous training program that develops both their technical and physical skills[1, 2].

It has been suggested that increasing muscle strength can improve the efficacy of cricket-related activities. Fielders use upper body strength for accurate throws, bowlers use upper body and leg strength to improve deliveries, batters use arm and core strength for powerful strokes and balance, and wicketkeepers use strong wrists and forearms to catch and stump. For the purpose of running, striding, sprinting, making quick turns, and jumping, leg strength is essential[3, 4]. A person's physical fitness is characterized by a combination of attributes that they possess or acquire in relation to their capacity for physical activity[5, 6].

Plyometric training, sometimes known as "jump training," uses movements like bounding, hopping, and jumping to force the muscles to contract quickly and forcefully[7, 8]. In cricket, plyometric training is gaining popularity since it can improve a variety of physical attributes, such as speed, power, agility, flexibility, and reaction time, as well as aid in the development of technical skills. Increasing demand to move performance forward as quickly as is practical. Plyometric training is an essential component of any fitness program that can help you accomplish all of the previously mentioned outcomes [7,8,9].

Power development is extremely important during the performance phase of rehabilitation because sports and athletics place extreme stresses on the extremities. Of all the workout options, plyometrics help build power, a base from which the athlete may hone the skills necessary for their particular activity[10,11,12].

This research has done to investigate the impact of an 8-week plyometric training program on domestic cricket players, aimed to assess its effects on their physical fitness parameters and technical cricket skills. Understanding the potential benefits of plyometric training in the context of domestic cricket can provide valuable insights for coaches, trainers, and players seeking to optimize their performance in this highly competitive and skill-driven sport. The current study explored the various aspects of plyometric training and its potential to elevate the capabilities of cricket players, ultimately contributing to the advancement of the sport at the domestic level.

METHODOLOGY

Study Design: This was a single-center, parallel-group randomized controlled trial that investigated the effects of an 8-week plyometric training program compared with a conventional training program on physical fitness and technical skills of domestic cricket players.

Setting: The trial was conducted at Bestion Cricket Club (Gujrat Sports Complex) from 15th August 2022 to 20th October 2023. Ethical approval was granted by the Research Ethics Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Ref.No.Riphah/RCRS/REC/01668). The study followed the CONSORT guidelines to ensure transparency and reproducibility.

Participants: A total of 40 domestic cricket players were initially assessed for eligibility. Eighteen were excluded for not meeting the inclusion criteria, resulting in 22 eligible participants. Players' age ranged from 18 to 23 years, with a mean of 19.74 years and a mean BMI of 26.00 kg/m^2. Participants with any injury, recent surgery, or contraindications to training were excluded.

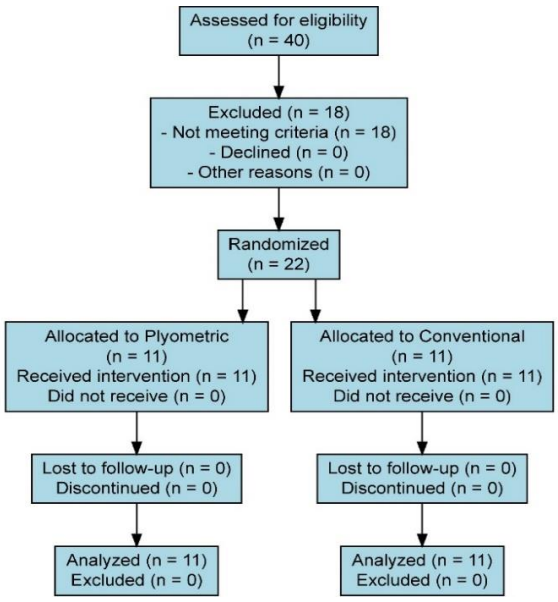

Figure 1: Consort Diagram

Randomization & Blinding: Participants were randomized into two groups (Plyometric training group, n=11; Conventional training group, n=11) using a simple randomization technique (flip coin method). Allocation was concealed until group assignment. Outcome assessors were blinded to the participants' group allocation. Due to the

https://doi.org/10.52567/trehabj.v9i03.105

nature of the intervention, blinding of participants and trainers was not possible.

Sample Size: The required sample size was estimated a priori using G*Power (Version 3.1), with an effect size of 0.50, α=0.05, power=0.80. Based on this calculation, a minimum of n=22 participants were required to detect significant effects. No dropouts occurred, and all participants completed the trial. (figure 1)

Outcome Measures: Primary outcomes were physical fitness tests, including the Yo-Yo Test, One-Mile Run Test, Sit-and-Reach Test, Run-A-Three Test, 1-Repetition Maximum Test, Abdominal Strength Test, Star Excursion Balance Tests (anterior, lateral, posteromedial directions), and Ruler Drop Test. Secondary outcomes included cricket-specific technical skills: Bowling Speed Test, Bowling Accuracy, Throwing Accuracy, and Throwing Distance. Data were collected at baseline and at 2nd, 4th, 6th, and 8th week follow-up points.

Table 1: Plyometric Protocol for Current study

Weeks	Foot contacts	Exercise	Sets x Reps	Intensity
1	90	Plyo Pushup	3x5	Low
		Chest Pass		
		Overhead Throw		
		Squat Jump		
		Plyo Step-Up		
		Cone Jumps		
2	100	Plyo Pushup	2x10	Low
		Chest Pass		
		Overhead Throw	3x5	
		Squat Jump		
		Plyo Step-Up		
		Cone Jumps		
3	120	Plyo Pushup	2x10	Intermediate
		Chest Pass		
		Med Ball Drop		
		Kneeling squat Jump		
		Lateral Jump Over Hurdle		
		Cone Jumps	3x5	
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 Step-Up	4x5	
		Lateral Jump Over Hurdle		
6	180	Plyo Pushup	5x6	High
		Med Ball Drop		
		Overhead Throw		
		Squat Jump		
		Plyo Step-Up		
		Lateral Jump Over Hurdle		
7	200	Under Hand Throws	5x6	High
		Dynamic Rotational Chest Pass		
		Overhead Throw with Step		
		Kneeling Squat Jump		
		Lateral Jump Over Hurdle	5x8	
		Cone Jumps		
8	220	Underhand Throw	5x8	High
		Dynamic Rotational Chest Pass		
		Overhead Throw with Step	5x6	
		Kneeling Squat Jump	5x8	

Intervention: Plyometric Training Group performed an 8-week plyometric program consisting of six exercises per week (e.g, plyometric pushups, chest passes, overhead throws, squat jumps, cone jumps), three days per week, 60 minutes per session. Intensity progressed systematically from low to high intensity over the 8 weeks. (table 1) The Conventional Training Group engaged in a structured, traditional physical training program that included exercises such as running, sit-ups, squats, lunges, push-ups, jumping jacks, and Russian twists. These exercises were performed once daily, five days per week, with the intensity progressively increasing over the 8-week period. For instance, exercises like running and jumping jacks were executed at 15 repetitions per

https://doi.org/10.52567/trehabj.v9i03.105

set, with three to five sets depending on the activity, and the intensity was gradually raised each week from low to high. Each training session began with a standard warm-up and concluded with a cool-down routine to promote recovery and prevent injuries. All sessions were closely supervised by experienced trainers to ensure proper technique and consistent adherence to the protocol.

Statistical Analysis: Data was analyzed using SPSS version 21, while statistical significance was set at $p<0.05$. Descriptive statistics were computed as mean ± standard deviation. The repeated-measures ANOVA was performed to examine the time effects over time and group comparisons on outcome measures at each time point, and independent t-tests were used. Effect sizes were reported as partial eta-squared for within-group changes and Cohens'd for between-group and pairwise differences.

RESULTS

The dataset, comprising n=22 observations, provides insights into age, BMI, and sleep duration. The average age is 19.74±1.65 years (range: 18-23). BMI's mean is 26.0±13.95 (range: 21.02-33.80). Players report average sleep duration of 8.48±1.309 hours (range: 6-11).

Table 2: Within-Group Changes of Physical Fitness Test Scores

		Plyometric Training			Conventional		
Test	**Time**	**Mean±SD**	**MD/F(df)**	**p-value**	**Mean±SD**	**MD/F(df)**	**p-value**
YoYo Test	Baseline	463.33±138.78	-8.33	1.00[a]	481.82±158.10	-5.46	1.00[a]
	2nd week	471.66±153.38	-15.00	0.21[b]	487.27±164.99	-12.73	0.67[b]
	4th week	486.66±154.76	-20.00	0.02[c]*	500.00±169.94	-10.91	1.00[c]
	6th week	506.66±162.56	-16.67	0.11[d]	510.91±161.83	-9.09	1.00[d]
	8th week	523.33±180.27	15.40 (1.40, 15.80)	0.00[e]***	520.00±167.33	8.43 (2.40, 24.33)	0.00[e] **
One Mile Run Test	Baseline	5.46±0.41	0.06	1.00[a]	5.40±0.60	0.01	1.00[a]
	2nd week	5.40±0.39	-0.07	1.00[b]	5.39±0.60	0.07	1.00[b]
	4th week	5.47±0.51	0.14	0.15[c]	5.32±0.66	-0.00	1.00[c]
	6th week	5.33±0.52	0.06	1.00[d]	5.32±0.65	0.06	1.00[d]
	8th week	5.26±0.52	0.98 (1.39, 15.33)	0.37[e]	5.26±0.61	0.99 (1.87, 18.66)	0.38[e]
Ruler Drop Test	Baseline	6.38±1.69	0.50	0.119[a]	6.04±1.48	0.25	0.523[a]
	2nd week	5.88±1.80	0.73	0.003[b] **	5.79±1.53	0.35	0.214[b]
	4th week	5.14±1.97	0.46	0.040[c] *	5.45±1.65	0.46	0.028[c] *
	6th week	4.68±1.73	0.75	0.000[d] ***	4.99±1.63	0.48	0.194[d]
	8th week	3.93±1.70	65.18 (2.77, 30.50)	0.000[e] ***	4.51±1.84	23.14 (2.04, 20.38)	0.000[e] ***
Sit and Reach Test	Baseline	11.20±2.29	0.06	1.00[a]	10.63±0.94	0.01	1.00[a]
	2nd week	11.86±2.39	-0.07	1.00[b]	10.91±0.95	0.07	1.00[b]
	4th week	12.79±2.52	0.14	0.15[c]	11.37±1.31	-0.00	1.00[c]
	6th week	13.93±2.57	0.06	1.00[d]	11.87±1.58	0.06	1.00[d]
	8th week	14.54±2.80	17.80 (1.39, 15.23)	0.00[e] ***	12.24±2.39	3.27 (1.22, 12.24)	0.09[e]
Run A Three Test	Baseline	12.90±0.93	0.27	1.00[a]	12.77±0.64	0.24	0.64[a]
	2nd week	12.64±1.96	0.97	0.12[b]	12.53±0.78	0.07	1.00[b]
	4th week	11.66±1.86	0.79	0.03[c] *	12.46±1.12	0.48	0.22[c]
	6th week	10.88±2.30	0.35	0.73[d]	11.98±1.52	0.17	1.00[d]
	8th week	10.53±2.51	14.97 (1.99, 21.86)	0.00[e] ***	11.80±1.35	5.13 (1.45, 14.54)	0.03[e]*
1 Rep Max Test	Baseline	21.25±5.69	-2.08	0.54[a]	19.55±5.22	-0.91	1.00[a]
	2nd week	23.33±6.15	-4.17	0.05[b]	20.45±7.23	-0.46	1.00[b]
	4th week	27.50±8.39	-5.00	0.01[c] **	20.91±7.35	-2.73	0.25[c]
	6th week	32.50±8.39	-5.42	0.03[d] *	23.64±7.45	-1.36	0.82[d]
	8th week	37.92±10.10	30.87 (1.78, 19.59)	0.00[e] ***	25.00±8.37	6.56 (2.43, 24.32)	0.00[e]**
Abdominal Strength	Baseline	6.33±0.65	0.00	1.00[a]	6.45±0.52	0.00	1.00[a]
	2nd week	6.33±0.65	-0.25	0.82[b]	6.45±0.69	-0.18	1.00[b]
	4th week	6.58±0.67	-0.17	1.00[c]	6.64±0.50	-0.09	1.00[c]
	6th week	6.75±0.45	-0.08	1.00[d]	6.73±0.47	-0.09	1.00[d]
	8th week	6.83±0.39	6.09 (3.01, 33.10)	0.00[e] **	6.82±0.40	3.20 (3.09, 30.91)	0.04[e]*

[a]baseline vs 2nd week, [b]2nd week vs 4th week, [c]4th week vs 6th week, [d]6th week vs 8th week & [e]baseline vs 8th week.
*Significance level- *p<0.05, **p<0.01, ***p<0.001*
MD-Mean Difference; df-degrees of freedom; SD- Standard Deviation.

The result of RMANOVA for within group changes plyometric show significant changes on physical fitness components except one mile run test (p=0.36). Similarly, within group changes for conventional group are significant for all the other test except one mile run test(p=0.38), sit and reach test (p=0.09), SEBT-ML (p=0.17), SEBT-PM (p=0.39) and bowling speed test (p=0.56). Regarding YoYo Test for endurance, the plyometric group demonstrated a significant improvement by the 4th week (p=0.02), with a highly significant gain by the 8th week ($p<0.001$, $\eta^2p=0.49$), whereas the conventional group only showed significance at the 8th week (p=0.002, $\eta^2p=0.25$). In the Ruler Drop Test, which measures reaction time, the plyometric group showed significant improvements from the

https://doi.org/10.52567/trehabj.v9i03.105

2nd week onward (p=0.003 at week 2, p=0.040 at week 4, p<0.001 at week 6, p<0.001 at week 8), while the conventional group demonstrated delayed significance only at the 4th (p=0.028) and 8th weeks (p=0.000). In the Sit and Reach Test for flexibility, the plyometric group showed a significant improvement by the 8th week (p<0.001), while the conventional group exhibited a non-significant change (p=0.09). The Run-A-Three Test, assessing agility, also favoured the plyometric group with significant improvements from the 4th week (p=0.03) and a highly significant result at the 8th week (p=0.000). The conventional group showed a delayed and weaker effect, reaching significance only by the 8th week (p=0.03). In the 1 Repetition Max Test (strength), the plyometric group demonstrated consistent strength improvements starting from the 2nd week (p=0.05), with continued significance at the 4th (p=0.01), 6th (p=0.03), and 8th weeks (p<0.001). In comparison, the conventional group showed significant improvement only at the 8th week (p<0.001), with no notable gains earlier. Abdominal strength, measured via a static endurance task, showed significant improvement in both groups by the 8th week (p=0.002 for plyometric; p=0.036 for conventional), though the magnitude of change was greater in the plyometric group. (table 2)

The Star Excursion Balance Test (SEBT) across multiple directions (medial-lateral, lateral, posteromedial, posterior, anterior, anterolateral, anteromedial) further illustrated the effectiveness of plyometric training. For instance, significant improvements in the medial-lateral direction were noted at the 6th week (p<0.001) and 8th week (p=0.000), with similar trends observed across other directions (e.g., SEBT-L: p<0.001 by 8th week, SEBT-PM: p<0.001 by 8th week, SEBT-Post: p<0.001 by 8th week). Conventional training, on the other hand, resulted in more modest and delayed changes, with fewer directions reaching statistical significance. (table 3)

Table 3: Within Group Changes In SEBT And Ruler Drop Test Results

		Plyometric			Conventional		
Test	**Time**	**Mean±SD**	**MD/f(df)**	**P-value**	**Mean±SD**	**MD/f(df)**	**P-value**
SEBT (ML)	Baseline	22.83±5.83	-1.17	0.06	24.55±4.23	-0.18	1.00
	2nd week	24.00±6.67	-0.83	0.34	24.73±4.98	-0.36	1.00
	4th week	24.83±7.16	-1.00	0.11	25.09±5.80	-0.46	0.53
	6th week	25.83±6.69	-1.08	0.00**	25.55±5.68	-0.46	0.96
	8th week	26.92±6.65	24.99 (1.94, 21.32)	0.00***	26.00±6.29	2.06 (1.23, 12.31)	0.18
SEBT (L)	Baseline	28.25±6.37	-1.25	0.06	30.73±7.34	-0.09	1.00
	2nd week	29.50±6.04	-1.83	0.00***	30.82±7.29	-0.27	1.00
	4th week	31.33±6.34	-1.92	0.01**	31.09±7.25	-0.73	0.24
	6th week	33.25±6.18	-1.67	0.01**	31.82±7.39	-0.18	1.00
	8th week	34.92±5.65	55.41 (1.59, 69.83)	0.00***	32.00±7.36	4.59 (1.42, 14.21)	0.04*
SEBT (PM)	Baseline	28.92±5.78	-0.83	0.44	32.09±2.70	0.09	1.00
	2nd week	29.75±6.34	-1.67	0.04*	32.00±2.90	-0.46	1.00
	4th week	31.42±7.00	-0.92	0.09	32.45±3.11	-0.09	1.00
	6th week	32.33±7.04	-1.58	0.01**	32.55±3.47	-0.27	1.00
	8th week	33.92±6.89	22.40 (1.58, 17.32)	0.00***	32.82±3.79	0.85 (1.20, 11.97)	0.40
SEBT (Post)	Baseline	32.33±5.97	-1.16	0.02*	33.36±4.57	-0.18	1.00
	2nd week	33.50±6.36	-2.00	0.03*	33.55±4.97	-0.36	0.37
	4th week	35.50±7.19	-1.58	0.01*	33.91±5.19	-0.73	0.11
	6th week	37.08±7.24	-1.25	0.08	34.64±5.01	-0.82	0.20
	8th week	38.33±7.32	33.97 (1.58, 17.45)	0.00***	35.45±5.41	9.60 (1.73, 17.34)	0.00**
SEBT-A	Baseline	6.33±0.65	0.00	1.00	6.45±0.52	0.00	1.00
	2nd week	6.33±0.65	-0.25	0.81	6.45±0.69	-0.18	1.00
	4th week	6.58±0.67	-0.17	1.00	6.64±0.50	-0.09	1.00
	6th week	6.75±0.45	-0.08	1.00	6.73±0.47	-0.09	1.00
	8th week	6.83±0.39	6.09 (3.01, 33.10)	0.002**	6.82±0.40	3.20 (3.09, 30.91)	0.036*
SEBT_AL	Baseline	32.67±3.52	-1.00	0.039*	32.64±2.84	-0.27	1.00
	2nd week	33.67±3.73	-1.67	0.010*	32.91±2.95	-0.73	0.87
	4th week	35.33±3.96	-1.42	0.001**	33.64±3.50	-0.82	0.82
	6th week	36.75±4.29	-2.00	0.000***	34.45±4.52	-0.64	1.00
	8th week	38.75±4.52	39.92 (1.27, 13.95)	0.000***	35.09±5.20	3.99 (1.12, 11.24)	0.067
SEBT_AM	Baseline	31.42±7.91	-1.08	0.24	30.27±8.22	-0.46	1.00
	2nd week	32.50±8.47	-1.42	0.033*	30.73±8.70	-0.36	1.00
	4th week	33.92±8.38	-1.42	0.045*	31.09±8.67	-0.55	1.00
	6th week	35.33±8.57	-1.00	0.039*	31.64±8.61	-0.55	1.00
	8th week	36.33±8.95	26.45 (1.69, 18.63)	0.000***	32.18±9.16	3.68 (1.56, 15.63)	0.058

[a]baseline vs 2nd week, [b]2nd week vs 4th week, [c]4th week vs 6th week, [d]6th week vs 8th week & [e]baseline vs 8th week.
*Significance level- *p<0.05, **p<0.01, ***p<0.001*
MD-Mean Difference; df-degrees of freedom; SEBT-Star Excursion Balance Test; ML-Medial-Lateral; L-Lateral; PM-Posteromedial; Post-Posterior; A-Anterior; AL-Anterolateral; AM-Anteromedial; SD- Standard Deviation.

https://doi.org/10.52567/trehabj.v9i03.105

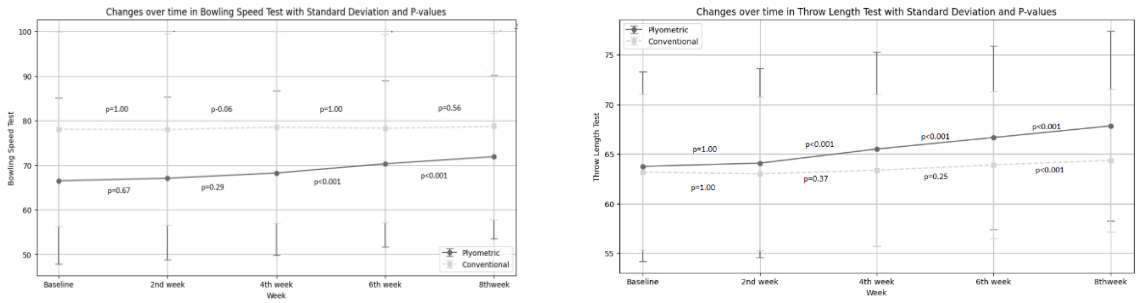

Figure 2: Changes Over Time In Bowling Speed Test And Throw Length Test

Regarding the bowling speed, at baseline, participants in the plyometric group showed 66.50±18.65 km/h, while the conventional group recorded 78.09±21.81 km/h, showing no significant difference (p=0.67). From baseline to the 2nd week, the plyometric group insignificantly improved to 67.08±18.31 km/h (p=0.29), whereas the conventional group remained stable at 78.00±21.53 km/h (p=0.06), with no statistically significant changes. Between the 2nd and 4th week, a notable improvement was observed in the plyometric group, reaching 68.25±18.50 km/h, with a small-to-moderate effect size (p<0.001, d=0.14). The conventional group recorded a minor increase to 78.54±21.54 km/h (p=1.00), which remained statistically insignificant. From the 4th to 6th week, the plyometric group further improved to 70.33±18.68 km/h (p<0.001, d=0.11), while the conventional group slightly decreased to 78.27±21.13 km/h (p=0.95). In the period between the 6th and 8th week, the plyometric group reached 71.91±18.35 km/h, showing continued gains with a small effect (p<0.001, d0.08), whereas the conventional group increased only marginally to 78.72±21.00 km/h (p0.56). Over the full 8-week period, the plyometric group showed a statistically significant and substantial improvement, with a large within-group effect size {F(1.58,17.41)39.77, p<0.001, partial η^2=0.70}, while the conventional group showed no significant change {F(1.14,11.42)0.41, p=0.56, partial η^2=0.03}. (figure 2)

While at baseline, the mean throw length was similar between groups: 63.75±9.56 m in the plyometric group and 63.18±7.83 m in the conventional group (p=1.00). Between baseline and the 2nd week, the plyometric group improved to 64.08±9.53 m, reflecting a small effect (p<0.001, d=0.03), while the conventional group slightly declined to 63.00±7.74 m (p=0.37). From the 2nd to 4th week, the plyometric group improved further to 65.50±9.78 m with a small effect size (p<0.001, d=0.15), whereas the conventional group increased only slightly to 63.36±7.65 m (p=0.25). Between the 4th and 6th week, throw length in the plyometric group increased to 66.66±9.26 m (p<0.001, d=0.12), while the conventional group rose modestly to 63.90±7.42 m (p=0.53). From the 6th to 8th week, the plyometric group demonstrated continued progress, reaching 67.83±9.57 m (p<0.001, d=0.13), while the conventional group reached 64.36±7.18 m (p<0.001, d=0.06). Over the entire duration, the plyometric group exhibited a large and statistically significant improvement {F(2.84,31.34)88.06, p<0.001, partial η^2=0.89}, while the conventional group also showed a significant, though smaller, effect {F(2.07,20.72)10.76, p<0.001, partial η^2=0.52}.(figure 2)

The between-group comparisons of physical fitness tests over the 8-week intervention period revealed varied outcomes. In the Yo-Yo test, although both groups showed progressive improvements, none of the differences reached statistical significance (p-values ranging from 0.06 to 0.93), with very small effect sizes (d=-0.12 to 0.02), indicating comparable gains in aerobic endurance. Similarly, the One-Mile Run test did not yield any significant between-group differences across all time points (p=0.77 to 0.96), and the effect sizes remained small to trivial (d=-0.13 to 0.26), suggesting equivalent improvements in cardiovascular endurance in both groups. In contrast, significant differences favoring the intervention group were observed in other physical fitness domains. The Run-A-Three test, which assesses agility and sprinting performance, showed a statistically significant between-group difference at the 8th week (p=0.04) with a moderate effect size (d=-0.62), indicating superior improvements in agility in the intervention group. The Ruler Drop test, a measure of reaction time, also demonstrated between-group differences at week 6 (p=0.03, d=-0.18) and week 8 (p=0.05, d=-0.33), reflecting small but meaningful improvements in the intervention group's reaction speed. The 1 Repetition Maximum (1RM) test showed the most prominent difference, with the intervention group exhibiting significantly greater strength gains by the 8th week (p=0.03), supported by a large effect size (d=1.38), indicating substantial improvement in muscular strength. Similarly, the Sit and Reach test revealed significant improvements in flexibility for the intervention group at both week 6 (p=0.01, d=0.94) and week 8 (p<0.001, d=0.89), denoting large effect sizes and confirming the intervention's strong impact on flexibility enhancement. (Table 4)

Plyometric training did not significantly (p≥0.05) improve bowling speed when compared to conventional training over the 8-week period. For instance, at baseline, the plyometric group had a mean bowling speed of 66.50±18.65 km/h, compared to 78.09±21.81 km/h in the conventional group (p=0.570). This non-significant trend continued at the 2nd week (67.08±18.31 vs. 78.00±21.53, p=0.508), 4th week (68.25±18.50 vs. 78.54±21.54, p=0.427), 6th week (70.33±18.68 vs. 78.27±21.13, p=0.215), and 8th week (71.91±18.35 vs. 78.72±21.00, p=0.151), reflecting no meaningful between-group difference in bowling speed. In contrast, results for throw length demonstrated a progressive and statistically significant improvement in the plyometric group over time. At baseline, the plyometric group showed 63.75±9.56 cm compared to 63.18±7.83 cm in the conventional group (p=0.004, d=0.07), indicating no meaningful difference. However, by the 2nd week, the plyometric group had improved to 64.08±9.53 cm versus 63.00±7.74 cm (p=0.002, d=0.12), reflecting a small effect size. This trend continued and strengthened over time, with group differences of 65.50±9.78 vs. 63.36±7.65 cm at the 4th week (p<0.001, d=0.24), 66.66±9.26 vs. 63.90±7.42 cm at the 6th week (p<0.001, d=0.33), and 67.83±9.57 vs. 64.36±7.18 cm at the 8th week (p<0.001, d=0.41), showing a moderate and consistent plyometric training effect on throw length performance. (Figure 3)

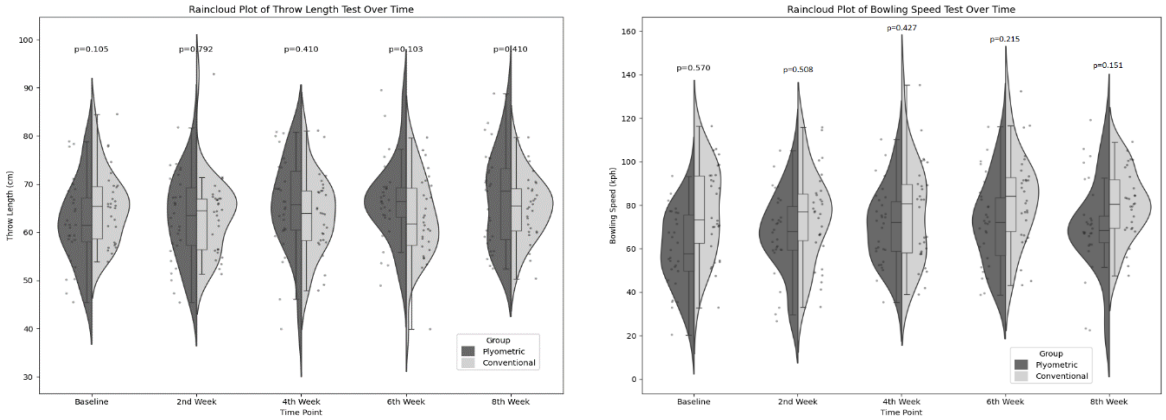

Figure 3: Differences Between Groups in Bowling Speed Test and Throw Length Test

Table 4: Comparison between groups on Physical Fitness Tests

Test	Time	Mean±SD	Mean±SD	MD	P-value	Cohen's d
Yoyo Test	Baseline	463.33±138.78	481.82±158.10	-18.49	0.06	-0.12
	2nd week	471.66±153.38	487.27±164.99	-15.61	0.74	-0.10
	4th week	486.66±154.76	500.00±169.94	-13.34	0.93	-0.08
	6th week	506.66±162.56	510.91±161.83	-4.25	0.86	-0.03
	8th week	523.33±180.27	520.00±167.33	3.33	0.51	0.02
One Mile Run test	Baseline	5.47±0.41	5.40±0.60	-18.48	0.77	-0.13
	2nd week	5.41±0.39	5.39±0.60	-15.61	0.82	-0.04
	4th week	5.47±0.51	5.32±0.66	-13.33	0.85	0.26
	6th week	5.33±0.52	5.32±0.65	-4.24	0.95	0.02
	8th week	5.27±0.52	5.26±0.61	3.33	0.96	0.01
Run A Three Test	Baseline	12.98±0.93	12.77±0.64	0.07	0.76	0.26
	2nd week	12.64±1.96	12.53±0.78	0.01	0.55	0.07
	4th week	11.66±1.86	12.46±1.12	0.15	0.24	-0.50
	6th week	10.88±2.30	11.98±1.52	0.01	0.11	-0.56
	8th week	10.53±2.51	11.80±1.35	0.01	0.04*	-0.62
Ruler Drop Test	Baseline	6.38±1.69	6.04±1.48	0.57	0.45	0.21
	2nd week	5.88±1.80	5.79±1.53	0.95	0.23	0.05
	4th week	5.14±1.97	5.45±1.65	1.43	0.11	-0.17
	6th week	4.68±1.73	4.99±1.63	2.06	0.03*	-0.18
	8th week	3.93±1.70	4.51±1.84	2.30	0.05	-0.33
1 Rep Max Test	Baseline	21.25±5.69	19.55±5.22	0.13	0.70	0.32
	2nd week	23.33±6.15	20.45±7.23	0.10	0.87	0.44
	4th week	27.50±8.39	20.91±7.35	-0.79	0.23	0.83
	6th week	32.50±8.39	23.64±7.45	-1.10	0.20	1.10
	8th week	37.92±10.10	25.00±8.37	-1.27	0.03*	1.38
Sit and Reach Test	Baseline	11.20±2.29	10.63±0.94	1.70	0.46	0.32
	2nd week	11.86±2.39	10.91±0.95	2.88	0.31	0.52
	4th week	12.80±2.52	11.37±1.31	6.59	0.06	0.71
	6th week	13.93±2.57	11.87±1.58	8.86	0.01*	0.94
	8th week	14.54±2.80	12.24±2.39	12.92	0.00***	0.89

*Significance level- *p<0.05, **p<0.01, ***p<0.001*
MD-Mean Difference; SD- Standard Deviation.

https://doi.org/10.52567/trehabj.v9i03.105

Regarding dynamic postural control, measured via the Star Excursion Balance Test (SEBT), significant between-group differences emerged at the 8th week in several directions: anterior (p=0.03, d=0.03), posteromedial (p=0.04, d=0.20), lateral (p=0.04,d=0.45), anteromedial (p=0.04,d=0.47), posterolateral (p=0.04, d=-0.01), and medial-lateral (p=0.04, d=0.14). While the effect sizes in some directions were small, the consistent pattern of significance supports the notion that the intervention led to meaningful improvements in dynamic balance. (table 5)

Table 5: Comparison between Groups for Dynamic Balance

Test	Time	Mean±SD	Mean±SD	MD	P-value	Cohen's d
SEBT (L)	Baseline	28.25±6.37	30.73±7.34	-2.48	0.71	-0.36
	2nd week	29.50±6.04	30.82±7.29	-1.32	0.80	-0.19
	4th week	31.33±6.34	31.09±7.25	0.24	0.39	0.04
	6th week	33.25±6.18	31.82±7.39	1.43	0.12	0.21
	8th week	34.92±5.65	32.00±7.36	2.92	0.04*	0.45
SEBT (PM)	Baseline	28.92±5.78	32.09±2.70	-3.17	0.73	-0.70
	2nd week	29.75±6.34	32.00±2.90	-2.25	0.62	-0.48
	4th week	31.42±7.00	32.45±3.11	-1.03	0.43	-0.19
	6th week	32.33±7.04	32.55±3.47	-0.21	0.31	-0.04
	8th week	33.92±6.89	32.82±3.79	1.10	0.04*	0.20
SEBT (Post)	Baseline	32.33±5.97	33.36±4.57	-1.03	0.43	-0.19
	2nd week	33.50±6.36	33.55±4.97	-0.05	0.77	-0.01
	4th week	35.50±7.19	33.91±5.19	1.59	0.92	0.26
	6th week	37.08±7.24	34.64±5.01	2.45	0.91	0.39
	8th week	38.33±7.32	35.45±5.41	2.88	0.73	0.45
SEBT (A)	Baseline	6.33±0.65	6.45±0.52	-0.12	0.64	-0.20
	2nd week	6.33±0.65	6.45±0.69	-0.12	0.98	-0.19
	4th week	6.58±0.67	6.64±0.50	-0.05	0.55	-0.09
	6th week	6.75±0.45	6.73±0.47	0.02	0.36	0.04
	8th week	6.83±0.39	6.82±0.40	0.02	0.03*	0.03
SEBT (M)	Baseline	32.67±3.52	32.64±2.84	0.03	0.05	0.01
	2nd week	33.67±3.73	32.91±2.95	0.76	0.08	0.23
	4th week	35.33±3.96	33.64±3.50	1.70	0.21	0.46
	6th week	36.75±4.29	34.45±4.52	2.30	0.48	0.53
	8th week	38.75±4.52	35.09±5.20	3.66	0.97	0.77
SEBT (AM)	Baseline	31.42±7.91	30.27±8.22	1.14	0.39	0.14
	2nd week	32.50±8.47	30.73±8.70	1.77	0.64	0.21
	4th week	33.92±8.38	31.09±8.67	2.83	0.93	0.33
	6th week	35.33±8.57	31.64±8.61	3.70	0.61	0.43
	8th week	36.33±8.95	32.18±9.16	4.15	0.04*	0.47
SEBT (PL)	Baseline	32.17±4.75	35.09±0.94	-2.92	0.98	-0.85
	2nd week	32.83±4.86	35.55±1.04	-2.71	0.59	-0.75
	4th week	34.33±5.03	36.36±1.50	-2.03	0.29	-0.53
	6th week	35.92±4.62	37.00±2.00	-1.08	0.22	-0.27
	8th week	37.50±4.72	37.55±2.91	-0.05	0.04*	-0.01
SEBT (ML)	Baseline	22.83±5.83	24.55±4.23	-1.71	0.61	-0.33
	2nd week	24.00±6.67	24.73±4.98	-0.73	0.91	-0.13
	4th week	24.83±7.16	25.09±5.80	-0.26	0.69	-0.04
	6th week	25.83±6.69	25.55±5.68	0.29	0.66	0.05
	8th week	26.92±6.65	26.00±6.29	0.92	0.04*	0.14

*Significance level- *p<0.05, **p<0.01, ***p<0.001*
MD-Mean Difference; df-degrees of freedom; SEBT-Star Excursion Balance Test; ML-Medial-Lateral; L-Lateral; PM-Posteromedial; Post-Posterior; A-Anterior; AL-Anterolateral; AM-Anteromedial; SD- Standard Deviation.

DISCUSSION

This study found that an 8-week plyometric training program showed early and robust gains in strength, power, agility, and neuromuscular coordination.

Plyometric training elicited significant improvements in muscular power and agility. The plyometric group's 1RM strength rose steadily from week 2 onward, whereas the conventional group only improved by week 8. Correspondingly, the plyometric group achieved significantly faster times on the Run-A-Three agility test by week 4 (p=0.03) and highly significant gains by week 8 (p<0.001), while the conventional group's agility did not reach significance until week 8. These results align with meta-analyses showing that plyometrics enhances leg muscle power, sprint speed, and agility [13].

The one-mile run for aerobic endurance did not improve significantly in either group; this is unsurprising, as plyometric training primarily augments anaerobic power rather than long-duration endurance. Previous meta-analyses have found only modest or non-significant effects of plyometrics on cardiorespiratory fitness[4]. In

https://doi.org/10.52567/trehabj.v9i03.105

contrast, distance covered in the Yo-Yo test improved early in the plyometric group.

Plyometric training substantially improved reaction time on The Ruler Drop Test, showed significant improvement in the plyometric group from week 2 ($p=0.003$) onward, reflecting faster neuromotor reflexes. The conventional group's reaction time only significantly improved at week 4 ($p=0.028$) and week 8. Likewise, dynamic balance measured by the SEBT improved across multiple directions in the plyometric group (e.g, medial-lateral reach was significantly better by week 6, $p=0.00$; lateral and posteromedial directions by week 8, $p<0.001$). These balance and reaction gains suggest enhanced neuromuscular control and proprioception, consistent with evidence that plyometrics can improve landing mechanics and neuromotor coordination[13].

Further, only the plyometric group showed a significant flexibility measured by the Sit-and-Reach. Improvement by week 8 ($p=0.000$). The dynamic stretching inherent in plyometric exercises likely contributed to these gains. This is in line with research indicating that plyometric programs can modestly improve flexibility alongside strength[14].

While observing the endurance and technical skills, neither group showed significant gains in traditional endurance tests (1-mile run) or in fine technical skills (bowling and throwing accuracy). This likely reflects the specific training stimulus: plyometric programs are high-intensity, short-duration, and target explosive power, not aerobic endurance or skill precision[15, 16]. Indeed, our multi-stage fitness (Yo-Yo) and push-up (muscular endurance) tests did not differ between groups[4]. Likewise, complex ball skills require extensive practice; systematic reviews suggest plyometrics can improve technical measures like throwing velocity, but primarily after longer training durations (>7 weeks) and with skill-specific drills[17, 18] In our study the plyometric group did display significant increases in ball performance: bowling speed improved significantly by week 4 ($p<0.001$) and peaked at week 8 ($p<0.001$), and throw distance increased from week 2 onward ($p<0.001$). These improvements in sport-specific power tasks demonstrate that enhanced leg and trunk power translated to better ball propulsion, even though target accuracy did not change[19].

These results are broadly supported by the literature. Plyometric training is well-established to boost muscle power and speed through the stretch–shortening cycle[13]. For example, plyometric programs in soccer and other team sports consistently improve sprint and jump outcomes[13]. Similarly, plyometric training combined with functional drills has yielded significant improvements in speed, agility, leg power, and cardiovascular capacity in other athlete groups[20]. A recent meta-analysis confirmed that plyometrics produces positive, often large effects on throwing and kicking velocity and dribbling performance in athletes[17]. Our findings parallel these effects in cricket players: the plyometric group outperformed controls on nearly all measures of explosive performance, and subgroup analysis suggests that the longer (8-week) program enabled significant gains in throwing and agility[17]. Moreover, the practical recommendations of Hussain et al. emphasize that incorporating plyometric exercises into athletes' training is an effective way to optimize strength, power, and overall performance[4], which aligns with our conclusion that plyometrics should be integrated into routine cricket training.

Plyometric exercises leverage the neurophysiological stretch-shortening cycle. During rapid eccentric loading (e.g, landing from a jump), elastic energy is stored in muscle and tendon, which is then released in a powerful concentric contraction[21]. This mechanism enhances muscular force and explosiveness, explaining the gains in 1RM strength, jump reach, and sprint speed observed. Plyometrics also repeatedly challenge balance and require rapid stabilization, which likely underlies the improvements in SEBT measures and reaction times[22]. Additionally, plyometric training has been shown to improve neuromuscular coordination and landing technique, potentially reducing injury risk[23]. In cricket, stronger leg and core muscles are crucial for batting, bowling, and fielding tasks[4], so the strength and power gains from plyometrics are highly relevant to performance.

Although plyometrics produced large improvements in explosive fitness, cricket skills like bowling accuracy or catching involve many factors (technique, concentration, game situation) and may need targeted drill practice beyond generalized power training.

CONCLUSION

8 weeks of plyometric training significantly improved cricket players' explosive strength, power, agility, flexibility, and neuromuscular control relative to conventional training, confirming the efficacy of plyometrics for enhancing athletic performance. These physical gains translated to better bowling speed and throwing distance, suggesting practical benefits for cricket performance. Coaches should consider incorporating plyometric exercises into routine training to optimally develop players' power and speed. However, to improve endurance and fine technical skills, supplementary moderate-intensity

training and sport-specific practice are recommended.

DECLARATIONS & STATEMENTS

Author's Contribution

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

Ethical Statement

This randomized controlled trial was conducted at Bestion Cricket Club (Gujrat Sports Complex) from 15th August 2022 to 20th October 2023. Ethical approval was taken from Research Ethical Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Riphah/RCRS/REC/01668).

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. All final content was reviewed and approved by the authors.

Consent Statement

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

Data Availability Statement

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

Acknowledgments

None to declare.

Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Physical activity and dietary factors associated with glucose concentration among young adults: a cross sectional study

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ABSTRACT

Background: The rising incidence of impaired glucose metabolism among young adults poses a significant public health concern. Sedentary lifestyles and poor dietary habits have been identified as key modifiable risk factors for the development of early-onset metabolic disturbances, including elevated blood glucose levels. Understanding the relationship between these lifestyle factors and glucose concentration is essential for early prevention of type 2 diabetes in this population.

Objective: To determine the association between glucose concentration, physical activity, and dietary factors among young adults.

Method: A cross-sectional analytical study with a sample size of n=139 participants was conducted at Railway General Hospital, Rawalpindi. The duration of this study was about 12 months. Both males and females between 18 and 30 years were included. To assess physical activity, the using the IPAQ questionnaire, as well as fasting and random glucose levels, a Glucometer was used. Further, the dietary profile was taken from USDA FoodData Central. SPSS version 21 was used for statistical analysis.

Results: The mean age of the participants were 23.76±0.37 years. The n=44 (31.7%) was male and n=95(68.3%) were female out of n=139. The ANOVA model significantly predicted the physical activity has the significant impact on blood sugar level ($p<0.38$). The low physical activity significantly ($p=0.005$) increases the blood sugar level while higher total METs are linked to lower blood sugar levels. But the impact of the dietary factors on blood sugar level, did not predict the significant variance in Glucose level ($p=0.662$).

Conclusion: the physical activity in young adults have important impact on glucose concentration, while dietary factors shows no significant effect due to limitations in how dietary data was collected.

Keywords: blood glucose; diet; physical activity; young adult.

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Citation

Durrani IU, Arshad M, Fatima L. Physical activity and dietary factors associated with glucose concentration among young adults: a cross sectional study. T Rehabili. J. 2025:09(03); 13-18 doi: 10.52567/trehabj.v9i03.106

Article History

Submitted: 08-05-2025
Accepted: 21-07-2025
Published: 13-08-2025

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INTRODUCTION

The rising prevalence of non-communicable diseases such as diabetes mellitus is becoming a critical public health challenge, particularly among young adults[1]. This demographic, often perceived as metabolically resilient, is increasingly exhibiting early signs of metabolic dysfunction, including elevated blood glucose levels[2]. Lifestyle patterns, especially physical inactivity and poor dietary habits, have been recognized as key contributors to metabolic disturbances. With the increasing adoption of sedentary behaviors and consumption of calorie-dense, nutrient-poor foods (commonly referred to as "junk food"), young adults are at heightened risk for impaired glucose regulation and subsequent metabolic disorders[3, 4].

The transition from adolescence to adulthood is marked by increased academic pressure, social engagement, and digital screen time, which collectively contribute to reduced the levels of physical activity[5]. Simultaneously, the widespread availability and marketing of fast food and sugary beverages have led to a shift away from balanced, home-cooked meals toward high-fat, high-sugar convenience foods. These lifestyle changes are particularly concerning because they occur during a critical period for establishing long-term health behaviors[6].

Regular physical activity has been shown to improve insulin sensitivity and reduce fasting glucose levels by enhancing muscle glucose uptake and modulating metabolic pathways. Conversely, limited or low physical activity is associated with increased insulin resistance and adiposity[7, 8]. On the dietary front, the consumption of processed and fast foods, often high in refined carbohydrates, unhealthy fats, and added sugars, has been strongly correlated with elevated blood glucose and insulin levels[9]. The students who frequently consumed junk food exhibited higher fasting glucose and poorer overall metabolic profiles compared to those with healthier dietary patterns. Additionally, inadequate fiber intake and micronutrient deficiencies commonly seen in junk food diets further exacerbate metabolic dysfunction [10, 11].

However, despite the association between lifestyle factors and glucose metabolism being well documented in adults and clinical populations, there is a limited understanding of how early lifestyle behaviors, including physical activity and dietary factors, affect glucose concentration in young adults who are not yet clinically diagnosed with metabolic disorders. This study is designed to investigate the effects of physical activity levels and dietary patterns on glucose concentration among young adults.

METHODOLOGY

Study Design: This was a cross-sectional analytical study conducted at the Railway General Hospital, Rawalpindi. This study was approved by the Research and Ethical Committee (Riphah/RCRAHS-ISB/REC/MS-PT/01739). Written informed consent was obtained from participants in the study.

Participants: The 18 to 30-year-old young adult participants were included in the study. The participants diagnosed with diabetes, neurological disease, systemic conditions, and having cognitive impairment, and/or unable to communicate, were excluded from this study. A non-probability convenience sampling technique was used for sample collection.

Sample Size: The total sample size of n=139 was calculated by G-power, which was 138 participants. On the basis of the effect size of 0.15, alpha error probability was 0.05, the power was 0.95, and the number of predictors was 5.

Variables/Outcome Measure: To predict the risk of Diabetes in the adult population on the basis of their dietary intake and physical activity, the following variables include: Age, gender, weight, height, BMI, family history, BP, fasting glucose level, as well as comorbidities, which were included after a thorough review of literature. For the assessment of fasting and random glucose levels, the glucometer was used. For the assessment of physical activity among adults, the International Physical Activity Questionnaire Short Form (IPAQ-SF) was used[12]. Data collection was carried out over a period of seven consecutive days to assess the participants' habitual dietary intake through self-reported food diaries and subsequent nutrient analysis using validated online tools. They were asked to record all foods and beverages consumed each day. The 7-day intake was analyzed for nutritional content using nutrient profiles from USDA FoodData Central. Each food entry was carefully input into the calculator according to the portion sizes, and nutrient values were extracted per item per day. Daily totals were calculated and averaged over the seven days to estimate each participant's habitual nutrient intake[13].

Statistical methods: The data were presented in the table and graphs as mean±Sd and n (%). The multiple linear regression test was applied to predict the association between physical activity, dietary factors with glucose concentration. The SPSS version 26 was used for data analysis.

RESULTS

The study sample comprised n=139 participants with an age range between 18 and 25 years (23.76±0.37). The mean Body Mass Index (BMI) was

https://doi.org/10.52567/trehabj.v9i03.106

23.85±5.51, with a minimum of 13.00 and a maximum of 50.60. Waist circumference ranged from 28.39 to 42.00 inches, with an average value of 34.92±7.28 inches. The mean frequency of gender of the participants in this study is n=44 (31.7%) for male and n=95(68.3%) for female out of n=139 (100%).

The ANOVA model significantly predicted the physical activity has the significant impact on blood sugar level {F (2.441) =5, p<0.38}. All variables cause 8.4% (Adj.R2= 0.084%) variance in blood sugar level on the basis of physical activity. All dietary variables did not predict the significant variance (R^2=7%) in Glucose level {F (12,126) =0.788, p=0.662}.

The multiple linear regression analysis explored the association between physical activity levels, dietary factors, and BSR (presumably Blood Sugar Regulation or a related biomarker). The results revealed that physical activity variables showed a stronger and statistically significant association with BSR compared to dietary variables. Specifically, individuals with low levels of physical activity had a significantly higher BSR compared to those with vigorous activity (B=0.002, p=0.005). This suggests that reduced physical activity is positively associated with poorer blood sugar regulation. Additionally, total daily MET-minutes were inversely associated with BSR (B=–0.001, p=0.004), indicating that increased overall physical activity is linked to better BSR. Although moderate activity showed a positive trend (B=0.001), it did not reach statistical significance (p=0.098). Other variables, such as waist circumference and BMI, showed no significant association with BSR, suggesting that body composition alone did not independently influence BSR once activity levels were accounted for. Regarding dietary factors, none of the variables, including calorie intake, macronutrients (fats, carbohydrates, protein), micronutrients (vitamin D, calcium), and dietary components like sugar and fibers, were significantly associated with BSR. While protein intake and vitamin D approached significance (p=0.117), their effects were not strong enough to draw firm conclusions in this model. (Table 1)

Table 1: Association Between Physical Activity and Dietary Factors with BSR

	Unstandardized Coefficients		95.0% Confidence Interval for B	
	B	Sig.	Lower Bound	Upper Bound
Physical Activity				
(Constant)	88.915	.000	83.427	94.403
Moderate †	.001	.098	.000	.003
Low †	.002	.005**	.001	.003
Waist Circumference	.034	.325	-.034	.101
BMI	.104	.336	-.109	.318
Total METs	-.001	.004**	-.002	-.000
Dietary Factor				
(Constant)	83.071	.000	64.050	102.093
Calories	.408	.416	-.581	1.397
Total Fats	-1.035	.282	-2.930	.860
Saturated Fats	2.516	.416	-3.590	8.623
Trans Fat	-.012	.756	-.091	.067
Cholesterol	.004	.608	-.011	.019
Sodium	.032	.692	-.127	.191
Total Carbs	.202	.800	-1.368	1.772
Dietary Fiber	.010	.945	-.292	.313
Sugar	-.536	.177	-1.318	.245
Protein	4.049	.117	-1.031	9.129
Vit D	.031	.117	-.008	.071
Calcium	-.177	.867	-2.276	1.922

*†Reference category for "Moderate" and "Low" is presumed to be **vigorous activity**.*
**p<0.05, **p<0.01 & ***p<0.001*

DISCUSSION

To determine the association between glucose concentration and physical activity and dietary factors among young adults, our analysis showed that lower physical activity levels were independently associated with higher glucose concentrations, whereas the broad panel of dietary variables was not a salient predictor of fasting/random glucose in this sample of young adults. Together, physical activity measures explained 8 % of the variance in glucose, with the "low activity" category and total daily MET minutes emerging as the strongest coefficients. In contrast, the fully adjusted diet model accounted for only 7 % of the variance, and no single nutrient met the conventional $\alpha \leq 0.05$ threshold.

Our finding that sedentary or low-active participants exhibited significantly higher glucose values aligns with a growing body of prospective and experimental evidence. Tracking children into early adulthood, Agbaje et al. showed that every additional hour per day spent in MVPA reduced

https://doi.org/10.52567/trehabj.v9i03.106

fasting glucose by 0.05 mmol/L and HOMA-IR by 3% after 13 years of follow-up [14]. Mainous III et al. reported that adults with ≤3 days/week of moderate exercise were 1.9 times more likely to have pre-diabetic glucose levels than their active peers[15], and Sanca et al. found similar patterns using the IPAQ in sub-Saharan young adults[16]. An eight-week aerobic-exercise program lowered fasting glucose by 6 % and improved insulin sensitivity in Qatari college women, whereas a four-week dose was insufficient[17]. Physical activity up-regulates skeletal-muscle GLUT-4 translocation, enhances mitochondrial oxidative capacity, and improves hepatic insulin extraction, all of which converge to reduce circulating glucose [7].

Contrary to several epidemiological reports that link high intakes of refined carbohydrates, processed meat, and added sugars to dysglycaemia[10, 18], the current study did not identify calories, macronutrient partitioning, or specific micronutrients as independent correlates. Notably, weak associations have also been documented elsewhere. A cohort found no link between glycaemic load and fasting glucose after multivariable adjustment [19], and an Iranian study reported that overall diet-quality indices were unrelated to fasting glucose in adult women[20]. These studies reinforce the possibility that diet glucose relationships are more readily detected in older or metabolically compromised samples than in ostensibly healthy young adults.

The lack of a significant relationship might be due to the small sample size or the use of a single 7-day food recall, which was averaged for analysis. It's also possible that participants underreported certain foods, especially unhealthy or "junk" foods, or misjudged portion sizes. This could have weakened the observed link between diet and blood glucose levels. In addition, young adults typically have better insulin function compared to older adults, so short-term unhealthy eating may not yet show up as high fasting blood sugar. Finally, because this study used a cross-sectional design and measured glucose at only one time point, it couldn't capture the long-term effects of regular eating habits on blood sugar levels.

CONCLUSION

The findings of the study highlight the important role of physical activity in managing blood sugar levels during early adulthood, which is consistent with global research from both observational and experimental studies. The weak link between diet and glucose in our study may be due to limitations in how dietary data was collected, rather than a true lack of effect. Future studies that follow participants over time and use more accurate, objective measures of diet and lifestyle are needed to better understand how physical activity and nutrition together influence early metabolic health.

DECLARATIONS & STATEMENTS

Author's Contribution

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

Ethical Statement

This study was approved by the Research and Ethical Committee (Riphah/RCRAHS-ISB/REC/MS-PT/01739). Written informed consent was obtained from participants in the study.

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. All final content was reviewed and approved by the all authors.

Consent Statement

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

Data Availability Statement

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

Acknowledgments

None to declare.

Funding Sources

None to declare.

Conflicts of Interest

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https://doi.org/10.52567/trehabj.v9i03.106

Research Article

Instrument assisted soft tissue mobilization versus dynamic oscillatory stretch technique in females wearing high heels: a randomized clinical trial

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Abstract

Background: Prolonged and frequent use of high-heeled footwear has been associated with musculoskeletal maladaptation and impairments. These include calf tightness, reduced ankle dorsiflexion range of motion (ROM), and altered gait mechanics. Over time, these changes may compromise the functional mobility of the lower extremity.

Objective: to compare the instrument-assisted soft tissue mobilization and dynamic oscillatory stretch technique on ankle ROM and Lower Extremity Functions among high-heeled users.

Method: This single-blinded, randomized Controlled Trial was carried out at Begam Akhtar Memorial Trust Safari Hospital from August 2023 to January 2024. A total of n=54 females aged between 20-40 years with <17 degrees dorsiflexion, wearing high heels of at least 2 inches, for 5 hours/day, for more than 3 days/week, and > one year included in the study. The sample was divided into group A, which received Graston mobilization (IASTM), and group B received the dynamic oscillatory stretch technique (DOST) for gastrocnemius and soleus muscles. For lower limb functions, ankle ROM goniometer and Pain were assessed through lower extremity functional status, goniometer, and numeric pain rating scale.at baseline and after the 12th session.

Results: The Results showed significant improvement ($p<0.001$) in the IASTM group as compared to the DOST group with respect to ankle ROM, pain reduction, and LEFS showed equal ($p=0.303$) improvements for both groups.

Conclusions: IASTM is more effective than DOST in improving ankle ROMs and decreasing pain in female high heel users. However, both techniques showed similar improvements in lower extremity functional status.

Keywords: calf muscle; dynamic oscillatory stretch technique; instrument-assisted soft tissue mobilization; lower extremity functional status; range of motion; numeric pain rating scale.

Clinical trial registry: NCT06086600

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Citation

Nisa MU, Tariq R, Razzaq A, Nisa FU, Sabir M. Instrument assisted soft tissue mobilization versus dynamic oscillatory stretch technique in females wearing high heels: a randomized clinical trial. T Rehabili. J. 2025:09(03); 19-26 doi: 10.52567/trehabj.v9i02.103

Article History

Submitted: 03-05-2025
Accepted: 21-08-2025
Published: 30-08-2025

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https://doi.org/10.52567/trehabj.v9i02.103

INTRODUCTION

Over the past few decades, high-heeled (HH) shoes have become an essential part of contemporary fashion and business attire for women worldwide, causing biomechanical problems in lower limbs[1,2,3]. with high prevalence reported in institutional and clinical settings ranging from 39% to 78, among those 46% exhibited poor functional activities[4,5]. Musculoskeletal injuries are caused by overuse and poor foot posture causing both mechanical and functionally changes[6].

A high heeled shoe is normally 10cm tall, but a flat-soled shoe is 0-4cm tall and consist of stiff heel cap and thin toe holder that anteriorly protrudes with exaggerated plantar curve that encourages continuous plantarflexion in the ankle joint, [5] which can cause calf muscle tendon unit (MTU) shortening[6]. The gastrocnemius muscle can be shortened by 5% by elevating the heel by 13 cm,[7] resulting in simultaneous rigidity of these muscles. Stiffness in these muscles results in development of trigger points in muscles. Myofascial trigger points are hyperirritable zones in muscles that are identified by reduced vasculature[3,6]. Thus, wearing high heels on a daily basis would cause shortening of the gastrocnemius muscular fascicles, reduced triceps surae muscle extensibility, increased Achilles tendon stiffness and reduced ankle joint ROM. High heel wearers demonstrated reduced dorsiflexion and eversion and increased ankle ROM in Plantarflexion and inversion when compared to flat shoe (FS) wearers. The high heel wearers also reported pain in dorsiflexion, when walking in flat shoes[7]. Function of lower extremity also get effected due to alteration in mechanical characteristics of the Achilles' Tendon, which in turn cause gastrocnemius strain, Achilles tendinitis, and plantar fasciitis [5].

Physical therapists are employing a broader range of therapies to prevent dysfunction and deformities brought on by muscular contractures, maintain and improve flexibility, and lessen joint stiffness. This includes using wet heat pads, applying ultrasound therapy, engaging in Muscle energy techniques (MET), continuous passive motion (CPM), stretching or mix these techniques[8]. Stretching and Kinesiotaping of calf muscle are frequently advised to improve ankle joint dorsiflexion or lessen symptoms of these conditions[9,10]. In response to the increased knowledge of these concerns, interventions i.e. IASTM and DOST have developed as viable techniques to address the negative effects of excessive heel usage on calf muscles.

Overuse of muscles can cause excessive tension leading to soft tissue injuries. After injury, fibrosis and scar tissue formation can occur in the injured tissue which reduces the tissue elasticity and forms adhesions that can results in pain and diminished function of soft tissues. When using IASTM with appropriate pressure and shear force on specific area, inflammation along with capillary and micro vascular haemorrhage can be the result. This inflammation removes the scar tissue and release adhesions thus initiating the healing response. It also increases the nutrient and blood supply to the effected injured area and migration of fibroblasts. At last, new collagen is formed and realigned that regenerate the injured tissues[11]. Dynamic oscillatory stretch technique proves better than static stretch in increasing hamstring flexibility and stretch threshold effects in increasing joint range of motion[12].

Literature shows the effects of interventions only on ankle movements i.e., dorsiflexion and inversion in regular high heel wearer[5,7]. The current study observed effect in both the ankle and sub-talar joints including all range of motion dorsiflexion, inversion, eversion and Plantar flexion of ankle joint and functional status of lower limbs. Both techniques (IASTM and DOST) seem to be effective in improving ROM, reduce fascia tightness, muscle tightness and release of trigger points in sports populations however its effects on shortened calf muscle–tendon unit (MTU), thicker and stiffer Achilles tendon and muscle fatigue in female wearing high heels has not been done before. This study seeks to bridge the gap by performing an organized study of the effects of IASTM and DOST on calf muscles in females who wear high heels on a daily basis so this study might add effective treatment in literature. The current study is planned to compare the effects of IASTM and DOST in Pain, ankle ROM and on functional status in females wearing high heel.

METHODOLOGY

Study design & setting: It was a Randomized Control Trial (RCT # NCT06086600) with and. After taking the ethical approval from Research ethical committee (Ref: Riphah/RCRAHS-ISB/REC/MS-PT/01610) the data was collected from Begham Akhter Rukhsana Memorial Trust, Safari Hospital. Study duration was 6 months from August 2023 to January 2024.

Participants: The participants age was 20-40 years having <17^{O} dorsiflexion, wearing ≥2 inches high heel for 5 hrs/ day, more than 3 days/week and for more than 1 year. The participants with DVT, malignancy, infection, Eczema, MSK injury or surgery of lower limb,

https://doi.org/10.52567/trehabj.v9i02.103

Sciatica or other Neuropathy/Neurological disorder, acute cardio-respiratory disorder or any medical co-morbidities [13] were excluded from the study. All participants provided written informed consent following the Declaration of Helsinki guidelines.

Sample size: Sample size was n=54 calculated through G-power with priori effect size of 0.25, alpha 0.95 and power 80% and number of measurements was set at 2.the sample was collected through convenience non-probability sampling.

Randomization & Blinding: The randomization was done through random number generator and the allocation concealment was done through sealed envelope method. Author FN did the allocation in groups and MN did the intervention. The research was Single blinded study; outcome assessor was unaware of the patient's allocation in groups to reduce bias.

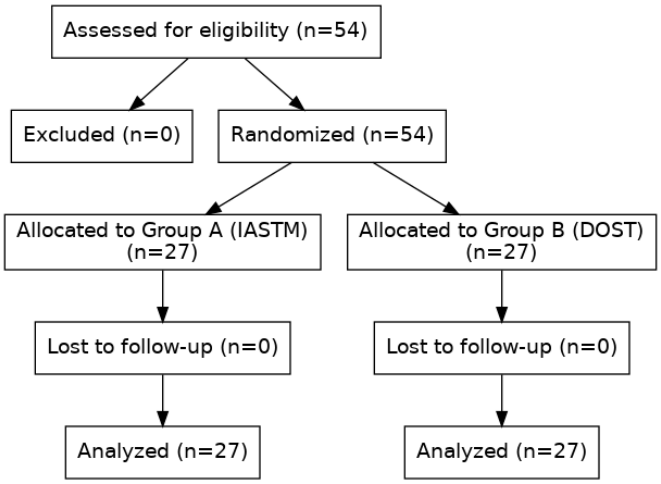
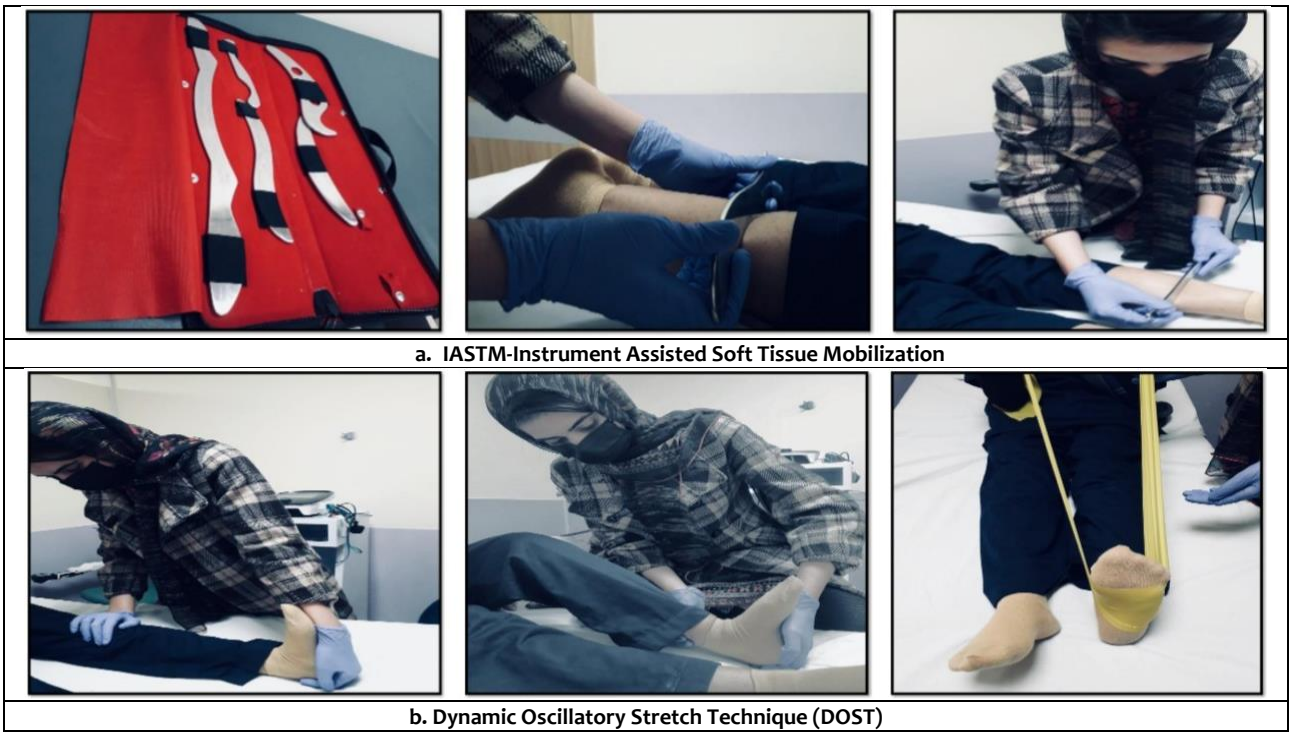


Figure 1: CONSORT diagram

Intervention: Each participant took part in 12 treatment sessions spread over four weeks, with three sessions scheduled per week. Evaluations were carried out at the beginning of the study and again after the final (12th) session. Alongside their assigned interventions, participants in both groups also received standard conventional treatment throughout the study period. The participants in both groups received a passive warmup using a hot pack applied to the calf muscles for 10–15 minutes before intervention. Participants in *Group A received IASTM* using the Graston Technique with a stainless steel, S-shaped Tai-Chi knife (GT-2 tool). The treatment targeted the gastrocnemius and soleus muscles in prone position with feet overhanging the plinth. The therapist stood at the side of the plinth and applied moisturiser before intervention. after that gentle stroke using the tool in a proximal to distal direction to identify trigger points or taut bands. after localisation, strokes were applied in multiple directions at a 30° to 60° angle with minimal pressure for 40 to 120 seconds. *Group B participants received DOST* targeting both the gastrocnemius and soleus muscles. The total stretching time was 60 seconds per set (2 second stretches×10 repetitions×3 sets). The gastrocnemius was stretched in Supine lying with full knee extension. The therapist passively dorsiflexed the ankle to the first point of stretch and applied slow oscillations for 2 seconds each at the end range and repeated 10 time per set in 3 set total, increasing the range progressively with every set. While soleus muscle was stretched in supine as well but with 15° knee flexion having the foot flat on the table. The therapist than dorsiflexed the ankle after stabilising the lower leg to the initial stretch point than applied oscillatory passive stretches at end range for 2 seconds[13]. All participants received 10 repetitions, 2 sets stretching exercises for the gastrocnemius and soleus muscles using a seated calf stretch with a resistance**.** To conclude every session, a cold pack was then applied to the calf muscles for 5 minutes. (Figure 2)

https://doi.org/10.52567/trehabj.v9i02.103



a. IASTM-Instrument Assisted Soft Tissue Mobilization

b. Dynamic Oscillatory Stretch Technique (DOST)

Figure 2: Stretching Techniques to Manage Calf Muscles

Outcome measures: numeric pain rating scale (NPRS), an 11-point subjective measure for pain intensity ranging from least pain (0) to unbearable pain (10) was used [14]. To measure the ROMs including ankle dorsiflexion, plantarflexion, inversion, eversion, the goniometer was used universally. The ROMs measurements were taken thrice to ensure reliability[15]. Lower extremity functional scale (LEFS) was used to assess functional abilities with lower extremity impairments, containing 20 questions, with five options that range from (0) unable to perform to (4) able to perform without difficulty. The LEFS covers a wide range of activities, including basic mobility tasks such as walking and standing, as well as more complex activities like running, jumping, and climbing stairs. It assesses the patient's ability to perform these activities both with and without assistive devices. The score ranges from 0-80, a higher score indicate better function[16].

Statistical analysis: The outcome measures were taken at baseline and on last treatment session (12th session). Data analysed through Statistical Procedure of Social Sciences (SPSS)). Normality was calculated of all variables which concluded that and all variables were non-parametric. For between group analyses Maan Whitney U-Test was applied. Wilcoxon Signed Rank Test was applied for within group analysis.

RESULTS

The total of n=54 samples was analysed, mean age of all participants were 29.33± 5.76 years. And the mean heel height was 3.04 ±0.870 inches. Further among the participants, n=36(66.7%) individuals reported wearing high heels three times per week, while n=18(33.3%) individuals reported wearing them five times per week.

Independent sample T test was applied for between group A and B analysis. There was significant difference in both groups according to mean and standard deviation in all variables including ankle dorsiflexion, ankle plantar flexion, ankle inversion, ankle right eversion, NPRS and LEFS ($p<0.05$) except left ankle eversion. Detailed description given in table 2.

Paired sample T test was applied for within group analysis of groups with respect to outcome measures. Both groups showed significant improvement ($p<0.001$) in all variable i.e. in ankle ROMs, NPRS and LEFS as shown in table 3.

https://doi.org/10.52567/trehabj.v9i02.103

Table 1: Between group comparison independent sample t test

Outcome Variables	Time	Group A (IASTM) n=27 Mean±SD	Group B (DOST) n=27 Mean±SD	Mean Difference	p-value	Cohen's d
Right Ankle DF	Baseline	12.56 ± 2.15	12.59 ± 2.00	0.037	0.95	–
	Final	20.37 ± 3.38	16.33 ± 2.43	4.037	0.00***	1.37
Left Ankle DF	Baseline	12.41 ± 2.13	12.22 ± 2.13	0.185	0.75	–
	Final	20.22 ± 3.71	16.33 ± 2.43	3.88	0.00***	1.24
Right Ankle PF	Baseline	26.56 ± 4.44	26.00 ± 4.46	0.55	0.65	–
	Final	35.52 ± 4.52	30.85 ± 5.21	4.66	0.002**	0.96
Left Ankle PF	Baseline	26.44 ± 4.29	25.30 ± 4.53	1.148	0.34	–
	Final	35.26 ± 4.49	30.85 ± 5.21	4.407	0.002**	0.91
Right Ankle Inversion	Baseline	13.74 ± 1.89	13.89 ± 1.73	0.148	0.77	–
	Final	21.48 ± 2.35	17.15 ± 1.81	4.33	0.00***	2.06
Left Ankle Inversion	Baseline	13.78 ± 1.71	13.96 ± 1.95	0.185	0.71	–
	Final	20.89 ± 2.91	17.15 ± 1.81	3.74	0.00***	1.56
Right Ankle Eversion	Baseline	8.59 ± 1.44	8.89 ± 1.15	0.296	0.41	–
	Final	12.00 ± 0.73	11.15 ± 0.98	0.852	0.001**	0.98
Left Ankle Eversion	Baseline	7.19 ± 2.23	7.48 ± 1.84	0.296	0.59	–
	Final	10.48 ± 1.01	10.89 ± 1.05	0.407	0.15	0.397
Right Leg NPRS	Baseline	2.48 ± 1.39	2.33 ± 1.17	0.148	0.67	–
	Final	0.67 ± 0.48	1.15 ± 0.362	0.481	0.00***	1.12
Left Leg NPRS	Baseline	2.48 ± 1.25	2.30 ± 1.26	0.185	0.59	–
	Final	0.78 ± 0.64	1.15 ± 0.362	0.370	0.012*	0.71
LEFS	Baseline	51.74 ± 5.12	52.00 ± 7.06	1.07	0.89	–
	Final	68.81 ± 6.23	68.63 ± 4.58	1.66	0.265	0.033

Note: DF- Dorsi flexion; PF- Plantar flexion; NPRS- Numerical Pain Rating Scale; LEFS-Lower Extremity Functional Scale; DOST-Dynamic Oscillatory Stretch Technique; IASTM-Instrument Assisted Soft Tissue Mobilization.
Level of significance - p<0.05, p<0.01**, p<0.001****

Table 2: Within group comparison using paired sample t test

Outcome Variables	Groups	Baseline (n=27) Mean±SD	Final session (n=27) Mean±SD	p-value
Right Ankle DF	Group A (IASTM)	12.56 ± 2.1	20.37 ± 3.38	.000***
	Group B (DOST)	12.59 ± 2.00	16. 33 ± 2.43	.000***
Left Ankle DF	Group A (IASTM)	12.41 ± 2.13	20.22 ± 3.71	.000***
	Group B (DOST)	12.22 ± 2.13	16.33 ± 2.43	.000***
Right Ankle PF	Group A (IASTM)	26.56 ± 4.44	35.52 ± 4.52	.000***
	Group B (DOST)	26.00 ± 4.46	30.85 ± 5.21	.000***
Left Ankle PF	Group A (IASTM)	26.44 ± 4.29	35.26 ± 4.49	.000***
	Group B (DOST)	25.30 ± 4.53	30.85 ± 5.21	.000***
Right Ankle Inversion	Group A (IASTM)	13.74 ± 1.89	21.48 ± 2.35	.000***
	Group B (DOST)	13.89 ± 1.73	17.15 ± 1.81	.000***
Left Ankle Inversion	Group A (IASTM)	13.78 ± 1.71	20.89 ± 2.91	.000***
	Group B (DOST)	13.96 ± 1.95	17.15 ± 1.81	.000***
Right Ankle Eversion	Group A (IASTM)	8.59 ± 1,44	12.00 ± 0.73	.000***
	Group B (DOST)	8.89 ± 1.15	11.15 ± 0.98	.000***
Left Ankle Eversion	Group A (IASTM)	7.19 ± 2.23	10.48 ± 1.01	.000***
	Group B (DOST)	7.48 ± 1.84	10.89 ± 1.05	.000***
Right leg NPRS	Group A (IASTM)	2.48 ± 1.39	0.67 ± 0.48	.000***
	Group B (DOST)	2.33 ± 1.17	1.15 ± 0.362	.000***
Left leg NPRS	Group A (IASTM)	2.48 ± 1.25	0.78 ± 0.64	.000***
	Group B (DOST)	2.30 ± 1.26	1.15 ± 0.362	.000***
LEFS	Group A (IASTM)	51.74 ± 5.12	68.81 ± 6.23	.000***
	Group B (DOST)	52.00 ± 7.06	68.63 ± 4.58	.000***

DF-Dorsiflexion; PF-Plantarflexion; NPRS-Numeric Pain Rating Scale; LEFS-Lower Extremity Functional Scale; IASTM-Instrument-Assisted Soft Tissue Mobilization; DOST-Dynamic Oscillatory Stretching Technique
Level of significance - p<0.05, p<0.01**, p<0.001****

https://doi.org/10.52567/trehabj.v9i02.103

DISCUSSION

The purpose of the study was to compare the effects of Instrument assisted soft tissue mobilization and Dynamic oscillatory stretch technique on females wearing high heels. The findings show that IASTM and DOST are effective strategies for improving ankle ROMS and lower limb functional status. When compared to DOST, the inter-group study indicated that IASTM is far more effective at improving range of motion, and pain levels however it has no advantage with respect to left foot eversion and lower limb functional status.

Ikeda N, et.al conducted research on effects of instrument assisted soft tissue mobilization applied on gastrocnemii, soleus, and tibialis posterior muscles; overlying deep fascia; and Achilles tendon in healthy individuals and concluded that IASTM showed significant improvement in Dorsiflexion-ROM and reduction in ankle stiffness[17]. Another study conducted by Carrie A Rowlett et al compared of Instrument assisted soft tissue mobilization and traditional stretching on the gastrocnemius-soleus complex in healthy participants and concluded that both IASTM and stretching demonstrably increased ankle dorsiflexion RO [18]. Another study comparing IASTM with stretching in pronated dominant foot individuals shows significant results in IASTM with respect to ankle range of motion, foot posture, foot function and dynamic balance. In the present study, IASTM significantly improve ankle range of motion and foot pain in women wearing high heels as compared to dynamic oscillatory stretch[19]. The superior effects of IASTM in improving ankle ROM and reducing foot pain may be attributed to its ability to target deeper myofascial restrictions and stimulate mechanoreceptors, enhancing tissue extensibility and neuromuscular responses. Unlike dynamic oscillatory stretching, IASTM provides controlled microtrauma, promoting localized inflammation and tissue remodelling, which may result in more sustained improvements, especially in chronically stressed structures like those affected by prolonged high heel use

Bhurchandi compared the IASTM with ultrasound on ankle pain and function and found that IASTM outperform in alleviating heel pain and discomfort[20]. Another study conducted by shows the effectiveness of IASTM as compared to static stretching in decreasing pain caused by delayed onset of muscle soreness (DOMS) in young healthy females[21]. Jooyoung Kim et al. conducted a study that concluded, IASTM considerably reduces pain levels which supports the notion of current research that IASTM significantly reduce pain in both right and left leg. Increased blood flow to effected area might be the reason of pain reduction. IASTM induces localized microtrauma and inflammation, which restarts the healing process by promoting fibroblast activation and collagen synthesis. This facilitates removal of scar tissue, improves vascularity, and enhances oxygen and nutrient delivery to the area. These effects help clear pain-mediating substances and reduce mechanical irritation, leading to significant pain relief over time[11].

Jahnvi T. Shah, compared Active release technique and Instrument assisted soft tissue mobilization on the gastro soleus muscles in high heels concluded that IASTM is a more effective trigger point release intervention since it increases ankle dorsiflexion range of motion[13] which support current research findings.

Heejun Kim, showed that the application of instrument assisted soft tissue technique on medial and lateral gastrocnemius and tibilalis anterior in patient with limited ankle dorsiflexion syndrome showed improvement in ankle mobility and muscle activation however there were no changes on foot pressures[22]. A pilot study of a doctoral project showing that no significant difference in effects of the IASTM combined with dynamic stretching and dynamic stretching alone on lower extremity dynamic strength after 48 hours in healthy volunteers with > 90% limb symmetry index[23]. Reason probably is it consists on single session and healthy volunteer's with >90% symmetry. IASTM might have more effects if the individual have < 90% asymmetry. The dynamic oscillatory muscle stretch technique has no available data up to my knowledge in ankle mobility. Kanza et al concluded that DOST is more effective in improving hamstring flexibility in asymptomatic healthy individuals[24].

Current study aimed at the comparison of impact of IASTM and DOST on pain, lower extremity functional status as well as all ankle ROMS. The inter-group analysis concluded that IASTM is more effective in improving ROM, lower extremity functional status and NPRS, hence it can be used in clinical practice. The study has the limitation that BMI was not considered in outcomes, that may act as the confounder with the high heel. Future studies should focus on objective measurement of stroke intensity of instrument assisted soft tissue mobilization and measure the effects on muscle strength.

CONCLUSION

Instrument assistive soft tissue manipulation (IASTM) is more effective than Dynamic Oscillatory stretch technique (DOST) in improving ankle range of

https://doi.org/10.52567/trehabj.v9i02.103

motion and decreasing pain in female high heels user. However, both techniques showed similar improvements in lower extremity functional status.

DECLARATIONS & STATEMENTS

Author's Contribution

MN: substantial contributions to the conception and design of the study, acquisition of data for the study, and drafting the work.
RT: substantial contributions to the conception and design of the study, methodology development, formal analysis, supervision, and project administration.
FN: acquisition of data for the study and critical revision of the work for important intellectual content.
MS: substantial contributions to the conception and design of the study and drafting the work.
AR: drafting, editing, critical revision for important intellectual content, and final review.
MN, RT, FN, MS, and AR: 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 approved Riphah Human Research Ethics Committee of Riphah international university (approval number: Riphah/RCRAHS-ISB/REC/MS-PT/01610), where it was performed and subjects gave informed consent to the work.

AI Use Statement

The author used the AI tools like Grammarly, to improve language clarity during manuscript preparation. All final content was reviewed and approved by the authors.

Consent Statement

Informed written and verbal consent was taken from the patients for using the clinical data and pictures, hiding their identity, anonymously to be used in publication.

conflict of interest

None to declare.

Data Availability Statement

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

Acknowledgments

None to declare.

Funding Sources

The authors received no financial support for this article to declare

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https://doi.org/10.52567/trehabj.v9i02.103

Research Article

Performance evaluation of urdu speech audiometry in hearing impaired people

Muhammad Zubair[1]*, Satheesh Babu Natarajan[2]

ABSTRACT

Background: Urdu has historically lacked validated speech audiometry materials, limiting clinicians to improvised and unreliable tests. Recently developed Urdu spondee and monosyllabic word lists have been validated in normal-hearing listeners. This study evaluated their clinical utility in hearing-impaired adults.

Methods: Forty Urdu-speaking adults aged 18–60 years including conductive loss (n=10), mild sensorineural hearing loss (SNHL; n=10), moderate SNHL (n=10), and moderately severe SNHL (n=10) and with bilateral hearing loss were recruited in the study. Pure-tone audiometry was used as an established threshold. Speech Reception Thresholds (SRT) were measured using the Urdu spondee list. While Word Recognition Scores (WRS) were assessed using validated monosyllabic lists at four intensity levels (10 dB above SRT to 5 dB below uncomfortable loudness level).

Results: pure-tone averages as SRTs raised systematically with severity and closely matched, the mild SNHL 34.5±3.7 dB (PTA 35.6±4.8), moderate SNHL 49.5±3.7 dB (PTA 52.5±3.8), moderately severe SNHL 62.1±2.5 dB (PTA 63.6±4.2), and conductive HL 42.0±5.4 dB (PTA 45.0±5.0). Word recognition improved with intensity across all groups. Conductive HL achieved the highest scores up to 100%, mild SNHL up to 89%, moderate SNHL up to 78%, and moderately severe SNHL up to 69%. Performance-intensity curves showed up a plateau at higher levels with no rollover.

Conclusions: The Urdu spondee and monosyllabic lists yielded results consistent with audiological norms. SRTs agreed closely with audiometric thresholds, and WRS patterns reflected hearing loss type and severity. These findings validate the new Urdu materials as reliable clinical tools for Urdu-speaking patients with hearing impairment.

Keywords: speech audiometry; speech reception threshold; urdu; word recognition scores

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Citation
Zubair M, Natarajan SB. Performance evaluation of urdu speech audiometry in hearing impaired people. T Rehabili. J. 2025:09(03); 27-32 doi: 10.52567/trehabj.v9i03.113.

Article History
Submitted: 19-08-2025
Accepted: 10-09-2025
Published: 19-09-2025

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INTRODUCTION

Speech audiometry is a fundamental component of the audiological test battery, complementing pure-tone audiometry by assessing an individual's ability to perceive and understand spoken language[1]. Unlike tone thresholds, speech tests use words or sentences as stimuli to yield measures such as the speech reception threshold (SRT) often using spondee words and word recognition score (WRS) using monosyllabic lists[2].These measures provide critical information about real-world hearing function and guide clinical management. Speech audiometry helps determine the severity and nature of hearing loss, assists in differentiating sensorineural versus conductive impairment, and informs hearing aid fitting and rehabilitation strategies. Speech scores indicate how well patients can understand speech at conversational levels and thus are essential for evaluating the functional impact of hearing loss[3].

However, speech audiometry is inherently language-specific, and its effectiveness relies on using word materials appropriate for the patient's native language and dialect. Standardized speech test lists have traditionally been developed in English and few other widely spoken languages. Non-English speakers face unique challenges. English word lists may contain sounds or vocabulary unfamiliar to them, and direct translations often lack phonetic balance or cultural relevance. As Najem and Marie (2021) point out, many existing speech lists have phonemic or structural shortcomings, prompting the creation of new language-specific materials[4].

Pakistan's national language is Urdu, has historically deficient validated audiometric materials, restricts clinicians to non-standard tests with unreliable outcomes. The recent research has addressed this gap by developing standardized Urdu speech audiometry tools. Zubair et al. (2025) created two monosyllabic word lists for word recognition score (WRS) testing in adults, demonstrating strong psychometric validity[5]. while Rauf et al. (2025) developed 30 bi-syllabic spondee words for speech reception threshold (SRT) and 34 monosyllabic words for WRS in children, all meeting intelligibility and homogeneity criteria[6]. Similarly, Ijaz et al. (2023) produced an 18-word Urdu spondee list for adolescents with equal stress, audibility, and familiarity[7]. Collectively, these efforts provided the first content-validated Urdu word lists for SRT and WRS in normal-hearing listeners, filling a long-standing clinical void. Though their true clinical applicability requires validation in hearing-impaired populations, since sensorineural loss can reduce speech recognition even at high intensity whereas conductive loss may preserve clarity once volume is restored[8].

Thus, psychometric functions derived from normal listeners may not be held for hearing-impaired patients. Speech audiometry is, in fact, especially important in distinguishing types of hearing loss and gauging rehabilitation needs, so it is critical to validate speech materials in the target clinical populations[8]. If an Urdu word list yields reliable SRT and WRS measures in individuals with conductive or sensorineural loss, clinicians can confidently use it for diagnosis and management. To our knowledge, no prior study has reported normative speech scores or slope functions for these new Urdu lists in hearing-impaired listeners. Therefore, the present study evaluates the performance of the developed Urdu monosyllabic and spondee word lists in adults with sensorineural and conductive hearing loss. Establishing the validity and clinical relevance of these tools will enable audiologists to provide more accurate, language-appropriate assessments for Urdu-speaking patients.

METHODOLOGY

Study Design and Setting: This was a cross-sectional study conducted in the Audiology Department of KRL Hospital, Islamabad, between December 2024 to May 2025. The study aimed to evaluate newly developed Urdu spondee and monosyllabic word lists in adults with hearing impairment by comparing speech reception thresholds (SRT) and word recognition scores (WRS) with pure-tone averages (PTA).

Participants: Forty adults aged 18=60 years (mean 29.1 ± 7.2) with documented bilateral hearing impairment were consecutively recruited and equally distributed into four groups of 10 participants each. Group 1 included individuals with conductive hearing loss, characterized by an air=bone gap of at least 10 dB with normal bone-conduction thresholds. Group 2 comprised those with mild sensorineural hearing loss (SNHL), defined by a pure-tone average (PTA) of 26=40 dB HL, while Group 3 included participants with moderate SNHL (PTA 41=55 dB HL). Group 4 consisted of individuals with moderately severe SNHL, defined by a PTA of 56=70 dB HL[9].

Eligibility: Eligible participants were adults aged 18=60 years with bilateral conductive or sensorineural hearing loss confirmed by audiological assessment. Only those with stable thresholds, defined as no change greater than 5 dB in the previous six months, and who were native Urdu speakers were included. Individuals with mixed or retrocochlear hearing loss, a history of otologic surgery, or any cognitive or neurological impairment that could interfere with test reliability were excluded. All participants provided written informed consent, and the study protocol was approved by

https://doi.org/10.52567/trehabj.v9i03.113

the Institutional Review Board of KRL Hospital, Islamabad (Approval No. KRL-HI-PUB-ERC/24/10).

Audiological Assessment: Each participant underwent pure-tone audiometry (250=8000 Hz, air and bone conduction) using the Hughson=Westlake method in a double-walled sound-treated booth. Conductive hearing loss was confirmed by normal bone-conduction thresholds in the presence of an air=bone gap >10 dB. Tympanometry was performed to assess middle-ear function. Speech reception thresholds (SRT) were measured with a validated Urdu spondee word list using an adaptive descending method[10]. SRT was cross-checked against the PTA (agreement required within 5=10 dB)[3]. Uncomfortable loudness levels (UCL) were determined by increasing stimulus intensity until the participant reported it as intolerable.

Speech Stimuli and Testing Procedure: Digitally recorded and validated Urdu monosyllabic and spondee word lists were used. All lists were phonetically balanced for everyday Urdu speech[5,11]. Stimuli were presented via supra-aural headphones using the audiometer's recorded input channel, calibrated with a 1 kHz reference tone. Monosyllabic word lists were presented at four suprathreshold levels for each participant: beginning at 10 dB above the individual's SRT and extending up to 5 dB below the UCL. These levels captured the dynamic range for speech perception. Word lists and order of presentation were randomized to minimize bias. Participants repeated each word aloud, and responses were scored as correct or incorrect by the examiner.

Outcomes: The primary outcomes of the study were the measurement of speech reception threshold (SRT) values and their agreement with pure-tone averages (PTA) across the different hearing loss groups, and the assessment of word recognition scores (WRS, expressed as percentages) at four suprathreshold intensity levels. These WRS data were further used to generate performance intensity functions for each group.

Statistical Analysis: Descriptive statistics (mean±SD) were calculated for demographic and audiological variables. Agreement between SRT and PTA was assessed using Bland-Altman analysis with mean difference and 95% limits of agreement. Between-group differences in SRT and PTA were evaluated with one-way analysis of variance (ANOVA). Pairwise comparisons were conducted using Tukey's honestly significant difference (HSD) test, with mean differences and 95% confidence intervals reported. For WRS, repeated-measures ANOVA was performed with intensity level as the within-subject factor and hearing loss group as the between-subject factor. Interaction effects were examined, and Greenhouse-Geisser correction was applied when sphericity was violated. Effect sizes (η^2) were reported for ANOVA. All statistical tests were two-tailed, and significance was set at $p<0.05$. Analyses were conducted using IBM SPSS Statistics (Version 24, IBM Corp., Armonk, NY) as well as Python for visualization.

RESULTS

The study included n=40 participants with a mean age of 29.1 ± 7.2 years. The distribution of hearing loss types was equal across groups: Mild SNHL (n=10), Conductive HL (n=10), Moderate SNHL (n=10), and Moderately Severe SNHL (n=10).

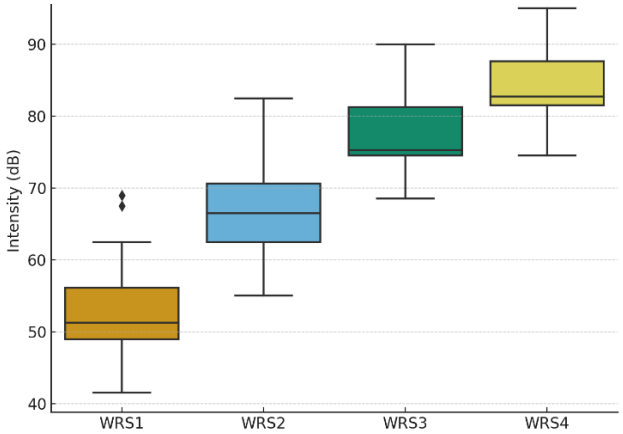

Figure 1: Boxplot of Intensities by WRS Lists

The intensity analysis confirmed that each WRS list was administered at the corresponding PTA level. WRS1 was presented around 45-55 dB, WRS2 around 60-70 dB, WRS3 around 75-85 dB, and WRS4 around 90-100 dB. Graphical representations demonstrated a progressive and consistent increase in intensity across WRS levels, supporting the validity of the study protocol. (Figure 1)

In the Conductive HL group, SRT was slightly lower than PTA (MD=-3.0, 95% CI -6.23 to 0.23). A similar small difference was observed in Mild SNHL (MD=-1.1, 95% CI -3.76 to 1.56). In Moderate SNHL,

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SRT was significantly lower than PTA (MD=-3.0, 95% CI -5.32 to -0.68). For Moderately Severe SNHL, SRT and PTA were closely aligned (MD=-1.5, 95% CI -3.64 to 0.64). (Table 1)

Table 1: Comparison of SRT and PTA at different severity level of HI

Severity	SRT Mean±SD	PTA Mean±SD	MD	Confidence Interval
Conductive HL	42.0±5.4	45.0±5.0	-3.0	-6.23, 0.23
Mild SNHL	34.5±3.7	35.6±4.8	-1.1	-3.76, 1.56
Moderate SNHL	49.5±3.7	52.5±3.8	-3.0	-5.32, -0.68
Moderately Severe SNHL	62.1±2.5	63.6±4.2	-1.5	-3.64, 0.64

SRT-Speech Reception Threshold; PTA-Pure Tone Average; HL-Hearing Loss; SNHL-Sensorineural Hearing Loss; MD-Mean Difference; CI-Confidence Interval.

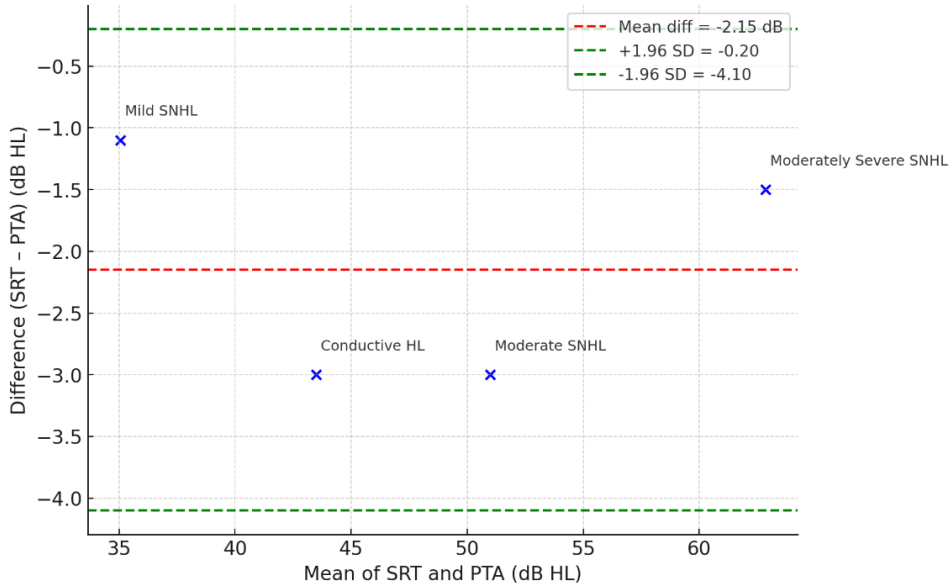

Figure 2: Bland Altman for agreement between SRT and PTA across different severities of hearing loss

The Bland Altman analysis demonstrated overall good agreement between SRT and PTA across different severities of hearing loss. The mean difference (SRT vs PTA) was approximately -2.15 dB HL, indicating that, on average, SRT values were slightly lower than PTA. The 95% limits of agreement (LoA) ranged from about -4.91 to +0.61 dB HL, suggesting that for most cases, the difference between the two measures falls within this narrow range, which is clinically acceptable. When examining the severity levels individually, conductive HL, mild SNHL, and moderately severe SNHL all clustered close to the zero-difference line, reflecting strong concordance between SRT and PTA. However, in moderate SNHL, the difference was more pronounced, with PTA values consistently higher than SRT. This points to a small but systematic bias, where PTA tends to overestimate hearing thresholds compared to SRT in moderate SNHL. (Figure 2)

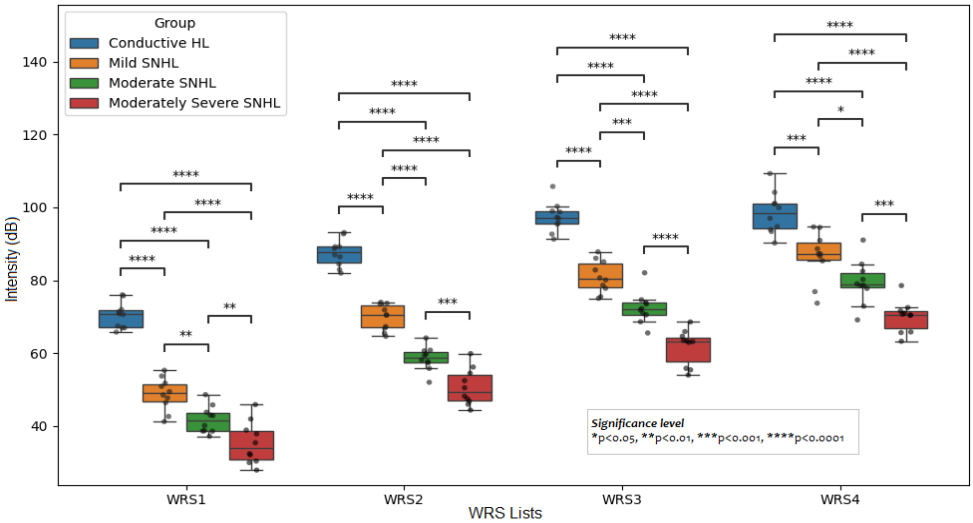

Figure 3: Boxplots of WRS List Across Groups and Intensities

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A two-way between subjects ANOVA was conducted to examine the effects of Group and Intensity on Word Recognition Scores (WRS). The boxplots of WRS across groups and intensities, overlaid with strip plots to show individual values. The main effect of Group was statistically significant {$F(3,144)=380.21$, $p<0.0001$}, as was the main effect of Intensity {$F(3,144)=421.10$, $p<0.0001$}. The Group × Intensity interaction was also significant {$F(9,144)=2.48$, $p=0.011$}, indicating that the effect of intensity on WRS varied across hearing-loss groups. Post-hoc pairwise comparisons with independent-samples t-tests revealed that, for the WRS1 condition, Conductive HL differed significantly from Mild SNHL ($t=11.83$, $p=6.34\times10^{-10}$, ****), Moderate SNHL ($t=17.51$, $p=9.43\times10^{-13}$, ****), and Moderately Severe SNHL ($t=16.27$, $p=3.29\times10^{-12}$, ****). (Figure 3)

DISCUSSION

The main findings of this study showed that speech audiometry with Urdu spondee and monosyllabic word lists performed as expected across all participant groups. The SRT measured with the Urdu spondees closely matched each group's pure-tone average (PTA) for the key speech frequencies. The SRTs differed from PTA by only a few decibels in every group. This concordance aligns with standard audiological norms. Clinical guidelines note that the PTA and SRT should agree within roughly 5-12 dB under normal conditions[12]. The very close agreement seen here (differences ≤3 dB) confirms that the Urdu spondee list provides valid threshold estimates for Urdu speakers. The mean SRT rose systematically with hearing loss severity, mirroring the increasing PTAs across groups. This parallel pattern between SRT and PTA verifies that the Urdu material behaves like established speech tests in other languages, where numerous studies report good correlation between the SRT and PTA[13]. Thus, our Urdu spondee list appears to be a reliable tool for estimating speech thresholds, much as spondee-based SRT tests do in English and other languages.

The intensity-growth patterns we found for Urdu largely parallel reports from other languages, albeit with some expected differences related to test materials and native-language familiarity. Carlo *et al.* found that Spanish bisyllabic (spondee) words reached >90% correct by 25 dB HL, whereas monosyllabic Spanish words required higher levels to hit that mark[14]. Likewise, Urdu spondee lists (bisyllables) exhibited steeper psychometric slopes and earlier saturation than Urdu monosyllables, analogous to the Spanish results.

Findings in Arabic are also congruent. Najem and Marie (2021) reported that Jordanian Arabic CNC word lists reached very high WRS (>96%) by about 40 dB SL, with no further improvement beyond that level[4]. We observed a comparable plateau in Urdu: beyond roughly 35-40 dB SL, Urdu WRS gains were minimal, indicating an asymptotic maximum. Thus, across Urdu and Arabic spondee/CNC tests, maximal intelligibility is achieved by a moderate supra-threshold level, consistent with English data that normal-hearing listeners also reach top scores by 25-40 dB SL[15].

When compared with normative English data and findings in other languages, the results follow expected patterns. In English-speaking populations, standard monosyllabic lists (e.g. CID W-22, NU-6) typically elicit near-ceiling (≈100%) scores in normal-hearing adults at comfortable listening levels[5]. In contrast, hearing loss generally produces lower word-recognition scores and shallower performance-level functions. Carhart and colleagues showed that listeners with sensorineural hearing loss achieved asymptotic recognition scores about 10% lower than normal-hearing individuals[8]. Similarly, large clinical datasets indicate that word-recognition (in quiet) remains high for mild-to-moderate hearing losses but declines as the loss becomes more severe. Our hearing-impaired Urdu listeners showed the same tendency: they scored lower than the normal-hearing group and the increase in intelligibility with presentation level was less steep

Our results also align with analogous studies in other languages. For instance, Barman et al. (2016) developed Hindi bisyllabic word lists focusing on low-frequency cues and validated them using simulated cochlear hearing loss[16]. They found the lists were sensitive enough to tap the speech understanding difficulty in the simulated hearing loss condition. Likewise, Al Matar (2021) created Arabic word-recognition lists and reported that they were equivalent and reliable across normal and hearing-impaired adults, indicating such native-language tests can diagnose hearing loss across dialects. Although direct data on Urdu hearing-impaired tests are scarce, these parallels suggest our findings are credible, well-designed indigenous word lists reliably reflect the impact of hearing impairment on speech recognition.

The new Urdu word lists performed as intended. Hearing-impaired Urdu speakers achieved expectedly lower word scores and more gradual performance-intensity slopes than normal-hearing listeners, consistent with results from English and other languages. These findings validate the Urdu lists as effective clinical tools: they are linguistically appropriate for Urdu speakers and sensitive to hearing loss, mirroring how standard English lists operate for English speakers. Clinicians can use these Urdu lists in speech audiometry to evaluate speech understanding in deaf or hard-of-hearing

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Urdu speakers, improving on prior practices that lacked native materials.

CONCLUSION

The Urdu spondee and monosyllable word list used here produced speech audiometry results that are completely consistent with established audiological principles. SRT values aligned with average audiometric thresholds, and word recognition performance followed the predicted trends for conductive versus sensorineural losses. These parallels to findings in other languages support the validity of the Urdu materials and fit for purpose as clinical tools. Clinicians can therefore use these Urdu word lists with confidence that they will assess hearing thresholds and speech understanding in Urdu speaking patients as reliably as standard English and other language word lists.

DECLARATIONS & STATEMENTS

Author's Contribution

MZ: substantial contributions to the conception and design of the study.
MZ and NSB: acquisition of data for the study.
NSB: interpretation of data for the study.
MZ: analysis of the data for the study.
MZ and NSB: drafted the work.
MZ and NSB: revised it critically for important intellectual content.
MZ and NSB: 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 protocol was approved by the Institutional Review Board of KRL Hospital, Islamabad (Approval No. KRL-HI-PUB-ERC/24/10).

AI Use Statement

The authors used Grammarly to improve language, clarity during manuscript preparation. All final content was reviewed and approved by the authors.

Consent Statement

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

Data Availability Statement

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

Acknowledgments

None to declare.

Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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Research Article

Elastic resistance band vs. conventional weight based exercises in chronic low back pain rehabilitation: a comparative analysis for functional recovery

Ammanullah Khan[1]*, Dua Fatima[2], Farhan Waqar[3]

ABSTRACT

Background: Globally, chronic non-specific low back pain (CNSLBP) is the most prevalent disability associated with musculoskeletal disorders, particularly in low-and middle-income countries, where access to equipment and supervised rehabilitation may be limited. Elastic resistance bands are an inexpensive, portable, and adaptable option to perform resistance training without conventional equipment; however, their comparative value in low back pain rehabilitation remains under researched.

Methods: This randomized controlled trial recruited 60 participants with CNSLBP, randomly assigned to two groups: Group A, which performed elastic band resistance exercises, and Group B, which engaged in conventional resistance exercises using gym equipment. Both groups followed the same supervised exercise protocol, three days a week, for six weeks. Participants were assessed on the Visual Analogue Scale, Oswestry Disability Index, and plank hold time at baseline and post-intervention. Fifty-three participants completed the study (88.3% retention).

Results: Both groups demonstrated significant and clinically meaningful improvements in pain intensity and functional disability with no significant between-group differences ($p>0.05$), indicating therapeutic equivalence. However, the elastic band group exhibited significantly better adherence to the program (92.2% vs 83.9%, $p=0.01$) and greater improvement in core endurance ($p=0.03$). Additionally, more participants in the elastic band group expressed intention to continue exercises beyond the study period (93% vs 77%, $p=0.04$).

Conclusions: Elastic band exercises were found to be equally effective in CNSLBP management compared to conventional weight-based resistance exercises, with the added benefits of superior adherence, core endurance improvements, and greater intention for long-term continuation. These findings suggest elastic resistance training as a viable alternative for clinicians, particularly valuable in resource-constrained environments.

Keywords: elastic resistance; core strength; low back pain; physiotherapy; rehabilitation

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Citation

Khan A, Fatima D, Author C, Waqar F. Elastic resistance band vs. Conventional weight-based exercises in chronic low back pain rehabilitation: a comparative analysis for functional recovery. T Rehabili. J. 2025:09(03); 33-41
doi: 10.52567/trehabj.v9i03.109

Article History

Submitted: 15-06-2025
Accepted: 20-09-2025
Published: 22-09-2025

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INTRODUCTION

Chronic non-specific low back pain (CNSLBP) is described as pain and discomfort in the area below the costal margin and above the inferior gluteal folds, either with or without pain into the leg, which has been present for at least 12 weeks with no known identifiable specific pathology [1,2]. One of the top causes of disability worldwide, it has a prevalence of about 23% in the adult population [3]. CNSLBP is associated with substantial economic costs, with healthcare costs around $200 billion annually in developed countries [4].

The management of CNSLBP has evolved significantly over the past decade, shifting from passive interventions and rest toward active rehabilitation approaches [5]. Clinical practice guidelines universally recommend exercise therapy as a core component of CNSLBP management [6,7]. Resistance training specifically has been shown to have a positive effect on improving pain, function, and quality of life in individuals with CNSLBP [8], with possible mechanisms being increased trunk muscle strength, improved neuromuscular control, and enhanced spinal stability [9].

Conventional resistance training usually includes the use of free weights, weight machines, or bodyweight exercises in gymnasiums. Although effective, resistance training has many disadvantages, primarily in low-and-middle-income countries (LMICs) in which access to equipment or facilities may be limited [10]. Furthermore, most patients experience barriers to compliance, such as transportation challenges, time issues, and cost constraints [11].

Elastic resistance bands are a possible substitute for conventional weight-based training. Inexpensive, portable tools and elastic resistance bands deliver progressive resistance via various degrees of elasticity and can exercise the same muscle groups as traditional equipment [12]. Initial evidence indicates that elastic resistance training can generate equivalent strength improvements to conventional resistance training in healthy populations [13,14]. Nonetheless, evidence regarding the relative effectiveness of these trainings for managing CNSLBP is limited.

Conventional weight-based resistance exercises often require gym-based equipment, may pose a risk of injury due to improper loading, and can be intimidating for patients with limited mobility or low exercise confidence. Elastic resistance bands offer a portable, cost-effective, and scalable alternative to traditional weight training. They allow for variable resistance through the range of motion, can be easily integrated into home-based programs, and have demonstrated positive effects in CLBP management. Therefore, this study aimed to compare the effectiveness of elastic resistance band training versus conventional weight-based resistance exercises on functional disability, pain intensity, and core endurance in patients with CNSLBP. Secondary objectives included evaluating adherence rates and participant satisfaction with each intervention approach.

METHODOLOGY

Study Design and Duration: This study was a prospective, randomized controlled, parallel-group design conducted from January 2024 to July 2024. Participants with CNSLBP were recruited from the physiotherapy departments of tertiary care hospitals in Karachi, Pakistan. This study was approved by the Institutional Review Board of Hamdard College of Medicine & Dentistry, Faculty of Health & Medical Sciences, Hamdard University (Ref. No. HCM&D/415/2025). The study was conducted in accordance with the Declaration of Helsinki, and all participants provided written informed consent prior to participation.

Participants: Participants eligible for inclusion were adults between 18-45 years of age with CNSLBP lasting at least 12 weeks and an ODI score of 20% or higher, indicating at least moderate disability. All participants needed to demonstrate the capacity to understand and follow instructions throughout the study period. Participants were excluded if they presented with radicular symptoms extending below the knee, had undergone recent spinal surgery within 12 months, were pregnant, or were concurrently enrolled in another structured exercise program. Additional exclusion criteria included uncontrolled cardiovascular or respiratory disease and severe psychiatric conditions that would impair study participation.

Randomization Procedure: Following confirmation of eligibility criteria, participants were randomly allocated to either the elastic resistance band exercise group (Group A) or the conventional resistance exercise group (Group B) using stratified block randomization. To ensure balanced allocation across clinically relevant subgroups, stratification was performed based on two factors: gender (male vs female) and baseline functional disability severity using ODI scores (moderate disability: ≤35% vs severe disability: >35%).

Allocation Concealment: The randomization sequence was generated using computer-based random number generation (Random.org) by an independent statistician not involved in participant recruitment or outcome assessment. Treatment allocations were placed in consecutively numbered, opaque, sealed envelopes and stored securely until participant enrolment. Upon enrollment, the

recruiting physiotherapist opened the next sequential envelope to reveal group assignment.

Blinding Procedures: Due to the nature of the interventions, participants and treating physiotherapists could not be blinded to group allocation. However, outcome assessors conducting all measurements at baseline and post-intervention remained blinded to group assignments throughout the study period. Additionally, the biostatistician performing all data analyses was provided with coded datasets (Group X and Group Y) and remained unaware of which code corresponded to which intervention until analysis completion.

Interventions: Both intervention groups attended supervised exercise sessions thrice weekly for six weeks (18 sessions in total). Each session took about 60 minutes and was of a structured format included 10-minute warm-up (light aerobic activity and dynamic stretching), 40-minute primary exercise protocol and finally 10-minute cool-down (static stretching and relaxation). Exercise regimens for both groups were planned to address the primary muscle groups involved in spinal stabilization and functional movement patterns associated with everyday activities. These included trunk extensors and flexors, hip extensors and abductors, and scapular stabilizers. Progression of exercise intensity was achieved gradually, depending on individual tolerance and performance, by the American College of Sports Medicine guidelines for resistance training progression [16].

Group A (Elastic Resistance Band Training): Participants of Group A followed a formalized exercise regimen consisting of elastic resistance bands with increasing levels of progressive resistance (yellow, red, green, blue, black) according to personal capacity. Group B: Traditional Resistance Training: Participants in Group B completed a comparable exercise program utilizing traditional resistance training equipment (weight machines, free weights, and bodyweight) in a gym environment. Weight progression was established when a participant could perform 15 repetitions of an exercise with proper technique (neutral spine alignment, controlled movement speed, full range of motion, no pain provocation) for two consecutive sessions, as assessed by certified physiotherapists. The detail protocol is described in Table 1.

Table 1: Intervention protocol

Week	Sets	Reps	Band Resistance	Rest (sec)	Exercises	Progression Criteria
Group A (Elastic Resistance Band Training)						
1-2	2	8-10	Yellow (Light)	60	Band-resisted trunk stabilization (anti-rotation press) Band-resisted squat Band-resisted row Band-resisted hip extension Band-resisted horizontal abduction Band-resisted trunk flexion Band-resisted hip abduction	Complete 10 reps with proper form for 2 consecutive sessions
3-4	2-3	10-12	Red (Medium)	60	Same exercises with increased resistance	Complete 12 reps with proper form for 2 consecutive sessions
5-6	3	12-15	Green (Heavy)	45	Same exercises with highest resistance	Complete 15 reps with proper form for 2 consecutive sessions
Group B (Traditional Resistance Training)						
1-2	2	8-10	Bodyweight/Light weights	60	Bird-dog exercise Bodyweight squat Seated cable row Hip extension machine Dumbbell horizontal abduction Supine curl-up on stability ball Hip abduction machine	Complete 10 reps with proper form for 2 consecutive sessions
3-4	2-3	10-12	Light to moderate weights	60	Progress to weighted versions	Complete 12 reps with proper form for 2 consecutive sessions
5-6	3	12-15	Moderate weights	45	Maximum tolerated resistance	Complete 15 reps with proper form for 2 consecutive sessions

Sample Size: the sample size based on an expected 10-point difference in the ODI, with 80% power and an alpha level of 5% [15]. The sample size yielded the need for n=22 per group, even with some anticipatory dropouts. Our study recruited n=60 equally divided n=30 participants per group, an adequate sample size beyond our minimum requirements to ensure we obtained sufficient statistical power to detect a meaningful difference between elastic resistance and conventional weight-based training. A total of n=78 participants were assessed for eligibility, of whom n=18 were excluded (n=10 did not meet the inclusion

https://doi.org/10.52567/trehabj.v9i03.109

criteria, n= 6 declined to participate, and n=2 for other reasons). The remaining n=60 participants were randomized equally into two groups. In the group A (Elastic Band Exercises, n=30), all participants received the allocated intervention, with n=3 participants lost to follow-up due to illness/health issues, family obligations, or scheduling conflicts. In the group B (Traditional Resistance Training, n = 30), all participants also received the allocated intervention, with n=4 participants lost to follow-up due to transportation difficulties, time constraints, or scheduling conflicts. At the end of the study, n=27 participants in the intervention group and n=26 in the comparison group were included in the final analysis. Thus, of the n=60 randomized participants, n=53 completed the study and were analyzed. (Figure 1)

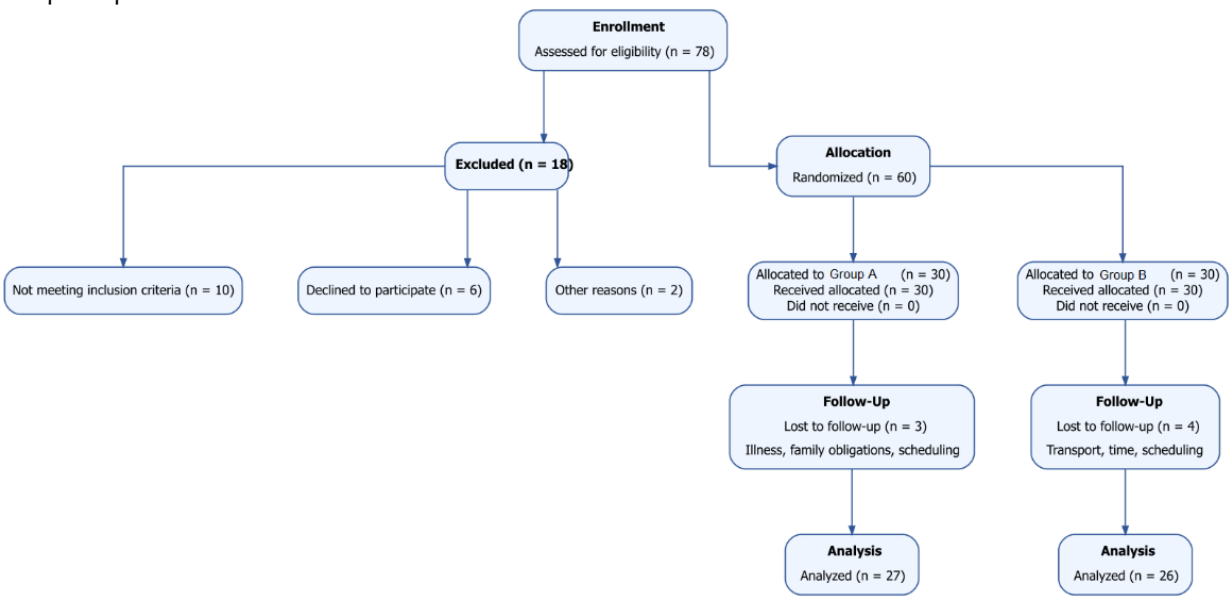


Figure 1: CONSORT diagram for participant's flow in the study

Outcome Measures: Assessments were carried out at baseline (week 0) and after the intervention (week 6) by trained, blinded assessors using validated tools. Disability was measured with the Oswestry Disability Index (ODI), a 10-item questionnaire scored 0–100%, where higher scores indicate greater disability [17]; it has shown excellent reliability and responsiveness in people with chronic low back pain[18]. Pain intensity was recorded using a 10-cm Visual Analogue Scale (VAS), from 0 ("no pain") to 10 ("worst possible pain"), with participants rating their average pain over the past week; the VAS is reliable and valid for chronic pain[19]. Core endurance was tested with the prone plank test, where the time a participant could hold proper form was measured until exhaustion; this test has demonstrated strong reliability for trunk muscle endurance[20]. Exercise adherence was calculated as the percentage of attended sessions, with reasons for missed sessions documented. Finally, participant satisfaction and experience were evaluated post-intervention using an 8-item questionnaire with 5-point Likert responses, covering satisfaction, benefits, convenience, and willingness to continue; it showed good internal consistency (Cronbach's α=0.83) in this sample.

Statistical Analysis: The analysis of data was completed using the Statistical Package for the Social Sciences (SPSS) version 26.0. The normality of the data was confirmed using the Shapiro-Wilk Test, and descriptive statistics were calculated. The researchers used T-tests and chi-square tests to compare baseline measures between groups as appropriate. The primary analysis was conducted using a 2×2 mixed-model ANOVA to assess all main effects and interactions across groups over time. Effect sizes were determined using partial eta squared, and Bonferroni corrections were applied to control for multiple testing across 9 planned comparisons: 6 within-group pre-post comparisons (3 outcomes × 2 groups) and 3 between-group comparisons of change scores (adjusted $\alpha<0.05$). the researchers conducted a secondary per-protocol analysis that only included participants that completed 80% or more of all sessions. For all statistical analyses, the researchers adhered to a threshold of $p<0.05$ for statistical significance.

RESULTS

At baseline, the overall sample (n=60) had a mean age of 43.3±8.8 years, with 27(45.0%) males and 33(55.0%) females. The average BMI was 27.1±3.9 kg/m², and the mean pain duration was

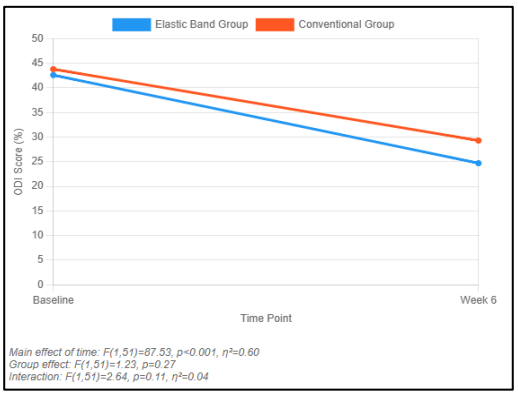
https://doi.org/10.52567/trehabj.v9i03.109

18.9±7.8 months. In terms of employment status, 36(60.0%) participants were employed, 17(28.3%) were unemployed, and 7(11.7%) were retired. Regarding previous treatment history, 23(38.3%) participants reported medication only, 22 (36.7%) had undergone physical therapy, and 15 (25.0%) reported no prior treatment. For baseline outcomes, the mean ODI score was 43.2±10.9, the VAS pain score was 6.4±1.5, and the plank time was 34.8±17.9 seconds. (Table 2)

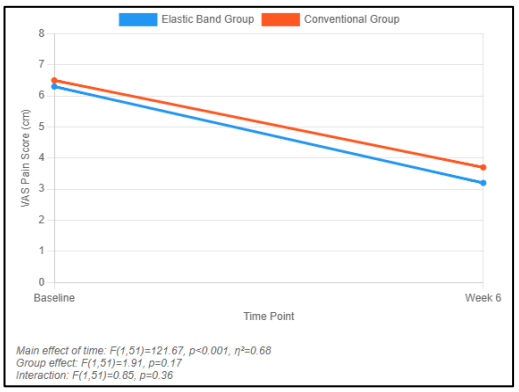
Table 2: Participants characteristics at baseline

Characteristic	Group A (n=30)	Group B (n=30)	p-value
Age (years), mean±SD	42.7 ± 8.5	43.9 ± 9.2	0.59
Gender, n (%)			
Male	13 (43.3)	14 (46.7)	0.78
Female	17 (56.7)	16 (53.3)	
BMI (kg/m²), mean±SD	26.8 ± 3.7	27.3 ± 4.1	0.62
Pain duration (months), mean±SD	18.3 ± 7.1	19.5 ± 8.4	0.54
Employment status, n (%)			
Employed	19 (63.3)	17 (56.7)	0.81
Unemployed	8 (26.7)	9 (30.0)	
Retired	3 (10.0)	4 (13.3)	
Previous treatment, n (%)			
Medication only	12 (40.0)	11 (36.7)	0.78
Physical therapy	10 (33.3)	12 (40.0)	
None	8 (26.7)	7 (23.3)	
Baseline outcome measures, mean±SD			
ODI score (%)	42.6 ± 11.2	43.8 ± 10.7	0.67
VAS pain (cm)	6.3 ± 1.5	6.5 ± 1.4	0.59
Plank time (seconds)	35.7 ± 18.3	33.9 ± 17.5	0.70

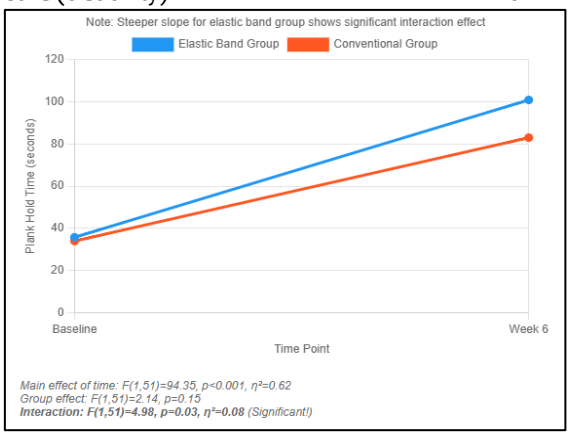
SD-Standard deviation; BM- Body mass index; OD- Oswestry Disability Index; VAS-Visual Analog Scale



a. ODI Score (disability)



b. VAS (pain)



c. Plank (core endurance)

Figure 2: Mixed ANOVA (interaction, group and main effects)

Statistical analysis demonstrated significant improvements across both intervention groups. For the Oswestry Disability Index (ODI), there was a strong effect of time {F(1,58)=87.53, p<0.001, partial η^2=0.60}, with no significant interaction between treatments {F(1,58)2.64, p=0.11, partial η^2=0.04}, indicating comparable effectiveness. Mean ODI gains were 17.9±8.7 points with elastic resistance

https://doi.org/10.52567/trehabj.v9i03.109

and 14.5±9.2 points with standard methods, both exceeding the 10-point threshold for clinical significance. Pain intensity (VAS) also decreased significantly over time {F(1,58)=121.67, p<0.001, partial η^2=0.68} without a main effect of treatment {F(1,58)=1.91, p=0.17, partial η^2=0.03}, with reductions of 3.1±1.2 cm and 2.8±1.4 cm respectively, both surpassing the 2 cm criterion for clinical relevance. For plank endurance, a significant time effect {F(1,58)=94.35, p<0.001, partial η^2=0.62}nd a treatment-time interaction {F(1,58)=4.98, p=0.03, partial η^2=0.08} favoured elastic resistance, which improved endurance by 65.2±24.7 seconds compared with 49.1±22.3 seconds using conventional training (p=0.03), confirming superior effects on core stabilization capacity. (Figure 2 & Table 3)

Table 3: Pre-post and between group comparisons

Outcome Measure	Group A (n=27)		With-in	Group B (n=26)		With-in	MD(95%CI)	Between p-value
	Baseline	Post-Intervention	p-value	Baseline	Post-Intervention	p-value		
ODI score (%)	42.6±11.2	24.7±9.6	0.00***	43.8±10.7	29.3±11.3	0.00***	-4.6 (-10.1 to 0.9)	0.11
VAS pain (cm)	6.3±1.5	3.2±1.3	0.00***	6.5±1.4	3.7±1.5	0.00***	-0.5 (-1.2 to 0.2)	0.17
Plank time (sec)	35.7±18.3	100.9±32.4	0.00***	33.9±17.5	83.0±29.7	0.00***	17.9 (1.7 to 34.1)	0.03*

*MD -Mean difference; *p<0.05**; p<0.01***; p<0.001; ns-not significant*

The elastic band group demonstrated higher adherence rates compared to the conventional group. Participants in the elastic band group attended a median of 16(2.5) out of 18 prescribed sessions (92.2% adherence), while those in the conventional group attended a median of 15.1±2.3 sessions (83.9% adherence), a statistically significant difference (p=0.01). Post-intervention satisfaction ratings were high in both groups, with 85% of participants in the elastic band group and 80% in the traditional resistance training group reporting being "satisfied" or "very satisfied" with their intervention. Notably, 93% of participants in the elastic band group expressed intention to continue with the exercises beyond the study period, compared to 76% in the conventional group (p=0.04) (Table 4).

Table 4: Adherence and satisfaction outcomes

Outcome	Elastic Band Group (n=27)	Conventional Group (n=26)	Test Statistic	p-value
Sessions attended, median (IQR)	16(2.5)	15 (3)	U=2.67	0.010*
Satisfied/Very satisfied, n (%)	23 (85%)	21 (81%)	χ^2=0.23	0.631
Intention to continue, n (%)	25 (93%)	20 (77%)	χ^2=4.12	0.042*

*Statistical significance: *p<0.05**, p<0.01***, p<0.001; χ^2-Chi square*

No serious adverse events were reported in either group. Minor adverse events included, temporary, increase in muscle soreness (7 participants in the elastic band group, 8 in the conventional group) and mild joint discomfort (2 participants in the elastic band group, 3 in the conventional group), all of which resolved spontaneously within 24-48 hours without requiring intervention modification or cessation.

DISCUSSION

This randomized controlled trial compared the effectiveness of elastic resistance band exercise with standard weight-based resistance training in alleviating chronic non-specific low back pain. Our hypothesis that elastic resistance band training would be at least as effective as traditional resistance training for enhancing CNSLBP outcomes was supported, with additional benefits observed in adherence and convenience. Both treatments resulted in clinically significant benefits on functional disability and pain level according to our findings, as well as superior outcomes by elastic resistance training for core endurance, retention rates, and patient-intended long-term continuation.

The similar gains in functional disability and pain severity between both interventions are consistent with earlier studies indicating that resistance exercise, independent of the form of resistance, can alleviate CNSLBP symptoms [22,23,24]. This supports the hypothesis that mechanical loading and neuromuscular adaptations secondary to resistance exercise, more than the particular equipment utilized, are responsible for clinical improvement. Our results agree with Iversen et al. [23], who reported no differences in pain-related disability between general physical exercise and progressive resistance band training in a multidisciplinary rehabilitation program for non-specific low back pain.

The much larger improvement in core endurance seen in the elastic band group is an unexpected finding that requires further research. This can be explained by the specific properties of elastic resistance, which delivers variable resistance along the range of motion, with maximum

https://doi.org/10.52567/trehabj.v9i03.109

resistance at the end range where traditional weights offer decreased mechanical advantage [25,26]. Also, elastic resistance requires more neuromuscular control to stabilize against the multidirectional forces created by the bands, which may better develop trunk stabilization ability than traditional resistance [27, 28].

The improved adherence levels of the elastic band group are a key finding, especially in those with chronic pain conditions where exercise adherence over extended periods is notoriously problematic, typically ranging from 50-70% in chronic pain populations [11]. The greater adherence likely attests to increased accessibility and ease of elastic resistance training, as it requires less equipment and can be carried out in varied settings. Home-based exercise programs demonstrate 15-30% higher adherence rates compared to facility-based interventions [10]. The much greater percentage of the elastic band group participants indicated they would continue to do the exercises after the study ended (93% vs. 76%), implying that elastic resistance training can benefit long-term self-management of CNSLBP.

Our results have significant clinical relevance, especially for low-resource settings. While formal cost-effectiveness analysis was not conducted, the lower equipment costs of elastic bands ($15-30 USD) compared to gym equipment (hundreds to thousands of dollars), coupled with clinical outcomes' non-inferiority and better adherence rates, suggest potential economic advantages that warrant future investigation. This potential economic benefit, coupled with clinical outcomes' non-inferiority and better adherence rates, makes elastic resistance training a worthy choice for managing CNSLBP across various settings.

Strengths and Limitations; Our investigation benefits from its robust methodology, blinded outcome assessment, multifaceted outcome evaluation, and good retention rates (88.3%). The inclusion of both subjective and objective outcome measures, combined with assessment of adherence and satisfaction, enhances external validity across demographic variations.

Notable constraints include the brief six-week duration, which prevents assessment of long-term effects future research should incorporate extended follow-up periods. The age range (18-45 years) represents a limitation as treatment response may vary across different age groups. Despite protocol standardization efforts, the inherent mechanical differences between resistance modalities may have independently influenced outcomes. Additionally, the single-centre urban Pakistani setting may limit generalizability to other contexts.

CONCLUSION

Elastic band resistance exercises achieve similar reductions in pain intensity and functional limitations as conventional weight-based training for patients with CNSPLBP. Notably, the elastic band approach demonstrated superior outcomes for core muscle endurance, program adherence rates, and overall participant satisfaction. The elastic resistance training can be as a viable, cost-effective, and accessible intervention for CNSLBP rehabilitation, particularly valuable in resource-constrained environments. Healthcare providers should consider implementing elastic resistance programs when developing treatment plans for CNSLBP patients, especially when emphasizing independent management skills and overcoming common exercise compliance challenges.

DECLARATIONS & STATEMENTS

Author's Contribution

AK: Substantial contributions to the conception and design of the study.
AK and DF: Acquisition of data for the study.
DF and FW: Interpretation of data for the study.
AK: Analysis of the data for the study.
DF and FW: Drafted the work.
AK, DF and FW: Revised it critically for important intellectual content.
AK, DF and FW: Final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

This study was approved by the Institutional Review Board of Hamdard College of Medicine & Dentistry, Faculty of Health & Medical Sciences, Hamdard University (Reference No. HCM&D/415/2025). The study was conducted in accordance with the Declaration of Helsinki, and all participants provided written informed consent prior to participation.

AI Use Statement

The authors used Grammarly to improve language, clarity during manuscript preparation. All final content was reviewed and approved by the authors.

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

The authors acknowledge the support of the physiotherapy department at Hamdard University and the participating healthcare facilities in Karachi for their assistance in participant recruitment and data collection.

https://doi.org/10.52567/trehabj.v9i03.109

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

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