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Enhancing physical attributes and performance in badminton players: efficacy of backward walking training on treadmill

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Abstract

Background Badminton, a dynamic sport, demands players to display exceptional physical attributes such as agility, core stability, and reaction time. Backward walking training on a treadmill has garnered attention for its potential to enhance physical attributes and optimize performance in athletes while minimizing the risk of injuries.

Objective By investigating the efficacy of this novel approach, we aim to provide valuable insights to optimize training regimens and contribute to the advancement of sports science in badminton.

Methodology Sixty-four participants were randomized into a control group ($n = 32$) and an experimental group ($n = 32$). The control group received routine exercise training, while the experimental group received routine exercise training along with additional backward walking training on the treadmill. Pre- and post-intervention measurements were taken for core stability using the Plank test, balance using the Star Excursion Balance test, reaction time using the 6-point footwork test, and agility using the Illinois Agility test.

Results The results showed that the experimental group demonstrated significant improvements in core stability ($p < 0.001$), balance ($p < 0.001$), reaction time ($p < 0.05$), and agility ($p < 0.001$) compared to the control group. The backward walking training proved to be effective in enhancing these physical attributes in badminton players.

Conclusion Incorporating backward walking exercises into the training regimen of badminton players may contribute to their overall performance.

Keywords Badminton, Backward walking, Trunk stability, Balance, Agility, Reaction time

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Introduction

Badminton is a popular and widely practiced racket sport that has gained immense popularity worldwide [1]. It is a fast-paced and highly dynamic game, requiring players to demonstrate a combination of technical skills, physical fitness, and mental acuity [2]. With its roots in ancient China and India, badminton has grown to become the national sport of several Asian countries, with a strong presence in both professional and recreational circles [3]. In the past few decades, badminton has gained global recognition as one of the fastest racket sports, attracting a diverse and ever-growing community of enthusiasts.

For winning the games and performing better the players must utilize a wide range of shot variations, including smashes, clears, drops, and drives, to outmaneuver their opponents and secure a competitive advantage [4]. The game's rapid and dynamic nature necessitates a high level of physical fitness, making strength, endurance, power, reaction time, agility, speed, adaptability, balance, and coordination essential attributes for successful players [5]. To excel in badminton, athletes need to combine sound technical skills with a strong physical foundation to execute precise and powerful shots while maintaining fluid movement across the court [6].

Agility is a paramount attribute in badminton that significantly affects a player's overall performance on the court [7]. Exceptional agility allows players to cover the court more efficiently, reach the shuttlecock in time, and execute shots accurately from various positions. In the dynamic and fast-paced nature of badminton, players must execute rapid body movements with precision and speed, making agility a critical factor in maintaining a competitive edge [8].

Reaction time is an essential characteristic for badminton players, as it has a significant impact on their ability to respond quickly and effectively to the dynamic and fast-paced nature of the game. Rapid shot return, anticipation, defensive skills, net play, drop shots, net kills, rally control, footwork and court coverage, deception and strategy, competitive edge, and mental agility are indispensable [9]. On the badminton court, training and enhancing reaction time through specific maneuvers and exercises can enhance a player's performance and contribute to their success [10, 11].

Another critical aspect of a badminton player's physical preparation is core strength and stability [12]. Core muscles play a crucial role in stabilizing the spine, transferring force between the upper and lower extremities, and controlling the body's center of gravity. They facilitate fluid movement and efficient power transfer during various game actions, such as lunges, jumps, and swings [13]. Core strength training has been extensively utilized not only to prevent lower back and lower limb injuries but also to optimize player performance in badminton and other sports [14].

Furthermore, posture and balance are key factors contributing to a player's performance on the court. Maintaining proper body control and posture during rapid and complex movements is essential to execute shots accurately and efficiently [15]. The ability to control joint movement and position dynamically is crucial for swift changes in direction, evasive maneuvers, and quick responses to opponent shots. Badminton players with superior agility and balance tend to outperform their peers and are less prone to injuries resulting from incorrect footwork or unstable landing postures [16, 17].

Backward walking, also known as retro walking, has gained popularity as an easy, cost-effective exercise that promotes health and quality of life. In the context of rehabilitation, backward walking training on treadmill has shown promising results in improving muscle action and lower extremity strength through increased motor unit recruitment, benefiting lower limb muscles [18, 19]. Additionally, it has demonstrated positive effects on foot posture and alignment in long-distance runners. Moreover, backward walking has been associated with improvements in body balance and stability in adolescents [20]. Backward walking training has been widely utilized in various sports and has demonstrated its effectiveness in improving balance, stability, agility, coordination, and footwork skills. It has been particularly valuable in sports that require rapid changes of direction [21, 22].

In this context, the present study aims to investigate the efficiency of backward walking training on treadmill on core stability, balance, agility, and reaction time in badminton players. While core strength training has been widely explored, the potential impact of backward walking on these specific aspects of physical performance remains relatively unexplored. Badminton involves quick, explosive movements and shuttlecock tracking which require exceptional lower limb strength, balance, and fast reaction times. Backward walking training is hypothesized to particularly enhance these abilities by improving proprioception and muscular coordination in ways that are directly translatable to badminton's rapid on-court movements.

Understanding the benefits of backward walking on trunk stability, balance, agility, and reaction time can inform coaches and athletes on the optimal integration of this training approach to enhance performance and reduce the risk of injuries. By combining the sport's rich history and global significance with cutting-edge research, this study endeavors to elevate the standard of badminton training and contribute to the development of well-rounded and resilient athletes.

Participants and methods

Study Design

The study design was a two-tailed experimental study. This type of study design was commonly used in scientific research to explore relationships and causality between variables. In this design, two groups were compared, and the hypothesis was formulated as a two-tailed (non-directional) hypothesis. The sampling method employed for participant selection was convenience sampling.

Study participants

The participants were selected based on their easy accessibility and availability to the researchers. The study included participants who were badminton players performing at the district level and above, and who had been actively practicing badminton for a period of more than 6 months in two badminton academies in Delhi NCR. The study focused specifically on participants of the both the genders within the age group of 18 to 26 years. Participants with recent knee and ankle injuries, recent fractures, or those currently on medication or supplements to improve performance were not included in the research. Additionally, individuals with neurological conditions were also excluded to ensure that the study sample comprised individuals without such conditions, thereby maintaining a more homogeneous group for analysis.

Ethical consideration

This study received ethical approval from the Ethical Committee of the Department of Physiotherapy, Faculty of Allied Health Sciences, Manav Rachna International Institute of Research and Studies. The approval reference number is MRIIRS/FAHS/PT/2022-23/S-008 dated 7th January 2023. The study design adhered to the guidelines outlined in the revised Helsinki Declaration of Biomedical Ethics, ensuring the ethical treatment of participants and the protection of their rights. Additionally, to ensure transparency and accountability, the study protocol was registered in the clinical trial registry at https://www.ctri.nic.in/ with the identifier CTRI/2023/05/052750. The registration date was 17th May 2023.

Sample size calculation

G*Power (version 3.1.9.2, Heinrich Heine-University, Düsseldorf, Germany) was used to calculate the sample size. An a priori power analysis using t-test to compare differences between two independent means, with a desired statistical power of 80%, a significance level of 5%, and an effect size of 0.72 resulted in a sample size of 64. The effect size was derived from a previous study [23], where the mean of the outcome variable "dynamic balance following backward walking" was used.

Study Procedure

In this study, 64 participants voluntarily took part after receiving detailed explanations and providing informed consent. The participants were divided into two groups: the control group and the experimental group, based on their eligibility determined by inclusion and exclusion criteria. The control group involved individuals undergoing routine exercise training, while the experimental group received routine exercise training combined with backward walking training. The outcome measures like core stability, balance, reaction time and agility were assessed at both pre- and post-training. To ensure unbiased results, the participants were blinded to their group assignment, while the outcomes assessor remained aware of the groupings for accurate evaluation. The randomization procedure was carried out using a double-blinded trial methodology. This rigorous methodology helps to minimize potential biases and enhances the validity and reliability of the research findings. This study conforms to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for reporting randomized controlled trials. We have included a completed CONSORT checklist as an additional file to provide a comprehensive overview of our trial's design, analysis, and interpretation. Furthermore, a CONSORT flow diagram (Fig. 1.) depicts the study procedures, including enrollment, randomization, pre-assessment, intervention, post-assessment, and data analysis.

Prior to the initiation of the actual study, all participants underwent two familiarization sessions to ensure they were adequately prepared and understood the tests involved in the study. During these sessions, participants were introduced to the equipment and detailed procedures for each test, which included the Plank test, Star Excursion Balance Test (SEBT), 6-point footwork test, and Illinois Agility Test. Each participant had the opportunity to practice under supervision, which helped standardize the test administration and ensure accurate, reliable results. These sessions were not included as the part of intervention and baseline data was collected after these sessions only.

Outcome measures

Agility

The Illinois Agility Test was utilized to assess the agility of badminton players. The methodology was adopted in a previous study [24]. This widely recognized test involves positioning 8 cones in a specific pattern on a flat surface to create a zigzag course. The badminton players were instructed to navigate through the course, executing rapid and accurate directional changes. The test's validity and reliability were established in the study, making it an effective tool for evaluating agility among athletes.

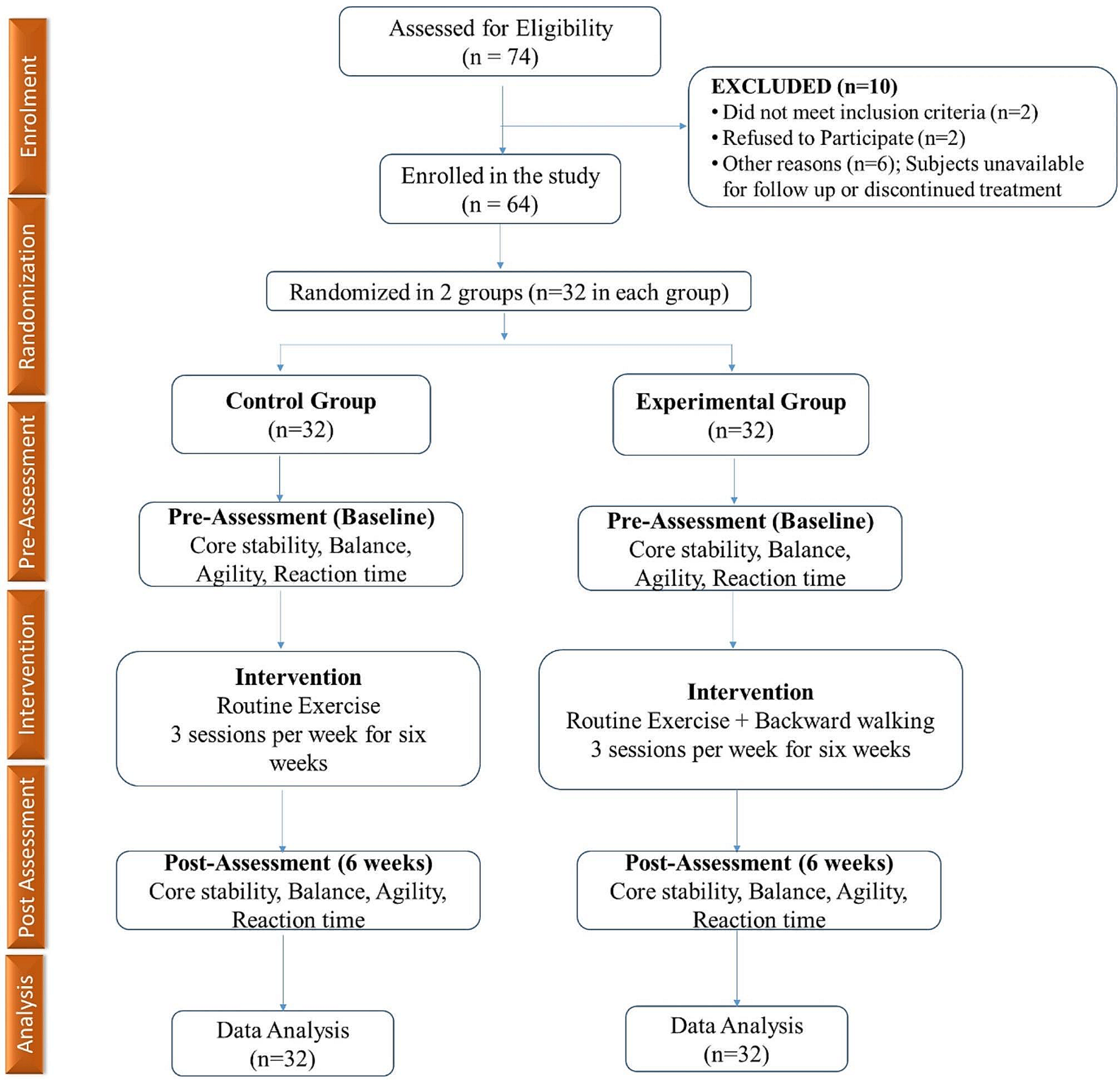

Fig. 1 A CONSORT flow diagram is depicting the study procedures

Core stability and strength

To assess core stability and strength, participants underwent the plank test [25]. Detailed instructions were provided to each participant before the test. The plank test required participants to assume a prone lying position with their elbows supported on the ground, lifting their bodies while keeping their hands pronated and parallel to the floor. Participants were instructed to maintain a straight bodyline off the ground, with their ankles in a neutral position, supported on their toes. A neutral head position, facing the ground, was also emphasized during the test. The stopwatch was started as soon as the subject assumed the correct plank position. Each participant's performance was then measured continuously, recording the time they were able to maintain the plank position until they reached their limit or experienced loss of balance. This process was repeated three times for each participant, and the average of the three readings was used for analysis.

Reaction time

The reaction time of the badminton players was assessed using the randomized six-point footwork drill as describe previously [11]. Results of the reliability analysis indicated the visual reaction system using the stopwatch had excellent Intraclass Correlation Coefficient (ICC) for both tests (ICC=0.95).This drill was conducted on the badminton court, with six cones strategically placed at different locations, including the forehand front corner, backhand front corner, forehand side, backhand side, forehand backcourt corner, and backhand backcourt corner. The purpose of this training exercise was to enhance the players' agility, speed, and footwork by replicating real-game scenarios that require quick reactions and precise foot movements. The players were instructed to move rapidly between these designated points in a random order, simulating the unpredictability of actual game situations. To objectively measure their performance, a stopwatch was used to record the time taken by each player to complete the drill. Each participant performed three repetitions of the test with a resting time of 5 min after every repetition to ensure the best performance every time. The reaction times were recorded for each trial, with data being noted for the best (maximum) times achieved across the trials.

Balance assessment

The study utilized the Star Excursion Balance Test (SEBT) as a clinical tool to evaluate dynamic balance and postural control in participants [26]. The test involved creating a star-like pattern on the floor using tape, with eight distinct directions marked: anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial, and posterolateral. Before commencing the test, participants received clear instructions and a detailed explanation of the procedure. They were asked to stand in a single-leg stance, with the tested limb placed at the center of the star pattern. During the test, participants lifted their non-tested leg and reached as far as possible along each marked direction, maintaining balance throughout each reach and returning to the starting position after each trial. Three trials were conducted for each direction, and the average reach distance achieved was recorded. To account for individual variations in leg length, the reach distance for each direction was normalized by dividing it by the participant's limb length. The utilization of normalized units allowed for standardized measurements of balance performance, ensuring meaningful and comparable assessments across participants [16]. The SEBT was performed in a clockwise direction to maintain consistency in the testing procedure.

Interventions

Routine training

Participants in the control group received routine training, which consisted of three sessions per week for six weeks. The training program included dynamic warm-ups with activities such as jogging, leg swings, and arm circles to prepare the body for more strenuous activities and prevent injuries. Strength training focused on building muscle strength and endurance through exercises like squats, lunges, push-ups, and planks. Agility drills involved ladder drills and cone drills to improve quick directional changes and overall agility. Core stability exercises such as the Russian twist, bird-dog, and bridge were incorporated to strengthen core muscles, vital for balance and efficient movement patterns. Endurance training was performed through longer duration, moderate-intensity cardiovascular activities like running or cycling. Each session concluded with a cool-down phase involving static stretching targeting all major muscle groups to aid in recovery and decrease muscle stiffness. The intensity and repetitions of these exercises were individually adjusted based on each athlete's Perceived Rate of Exertion (PRE), ensuring the training was challenging yet manageable, optimizing the training program's effectiveness tailored to individual fitness levels and recovery needs.

Backward walking training on treadmill

Participants in the experimental group were instructed about the training regimen, which incorporates a ball hanging in front of the treadmill to encourage the participants to maintain a forward-facing gaze during the exercise. The training session began with a 4-minute session of forward walking on the treadmill, followed by a 1-minute rest period. After the rest, the participants switch to backward walking on the treadmill for another 4-minute session, followed by another 1-minute rest period. This sequence was repeated for a total of 12 min of exercise. The training protocol was scheduled to be performed three times a week, continuously for a duration of 6 weeks [27]. Throughout the training period, participants maintain a constant walking speed of 3 km/hr. Backward training regimen aimed to enhance participant's walking skills and proprioception, promoting balance and coordination during backward movement.

Statistical analysis

The statistical analysis was performed using SPSS (version 24.0, IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean and standard deviation (SD), were calculated to summarize the characteristics of the study variables. The normal distribution of the data was assessed by, the Shapiro-Wilk test. To calculate within-group comparisons, paired t-tests was used to examine the differences between pre and post-intervention measurements for trunk stability, balance, reaction time, and agility. Independent t-tests was used to compare the control and experimental groups at the baseline. To see the effects of the intervention over time, repeated measures analysis of variance (ANOVA) was used, considering the factors of time (pre and post) and group (control and

Table 1 Demographic of participants in the control and experimental group

Participant Characteristic	Control Group ($n=32$)		Experimental Group ($n=32$)	
	Male	Female	Male	Female
Gender	22 (68.75%)	10 (31.25%)	24 (75%)	8 (25%)
Age (years)	22.69 ± 2.13	21.56 ± 0.26	21.83 ± 3.12	21.48 ± 0.40
Height (cm)	169.0 ± 5.48	160.0 ± 6.38	170.0 ± 3.56	161.75 ± 3.50
Weight (kg)	63.50 ± 5.0	49.63 ± 2.06	62.90 ± 4.44	55.25 ± 2.50
Body Mass Index (BMI)	22.26 ± 1.85	19.41 ± 0.86	21.33 ± 1.07	18.35 ± 1.72
Dominance				
Right Hand	19/22 (59.4%)	8/10 (21.9%)	20/24 (83.3%)	5/8 (62.5%)
Left Hand	3/22 (12.5%)	2/10 (6.3%)	4/24 (16.7%)	3/8 (37.5%)
Badminton Experience (years)				
> 5 years	16/22 (72.73%)	6/10 (60%)	18/24 (75%)	3/8 (37.5%)
< 5 years	6/22 (27.27%)	4/10 (40%)	6/24 (25%)	5/8 (62.5%)

Table 2 Independent t-test comparing the Illinois agility test, Plank test, and 6-point forward test between pre and post measurements of the control and experimental groups

Group	Time	Mean ± SD	t	*p*	d	MD	95% CI	
							Lower	Upper
(Agility) Illinois test								
Control	**Pre**	17.01 ± 2.87	-0.13	0.89	-0.03	-0.06	-1.09	0.95
Experimental		17.08 ± 0.43						
Control	**Post**	16.54 ± 0.57	10.25	< 0.001	2.56	1.21	0.97	1.45
Experimental		15.32 ± 0.34						
Core stability (Plank test)								
Control	**Pre**	3.35 ± 0.27	-0.98	0.32	-0.25	-0.08	-0.26	0.08
Experimental		3.44 ± 0.41						
Control	**Post**	3.59 ± 0.34	-18.51	< 0.001	-4.63	-1.79	-1.99	-1.60
Experimental		5.39 ± 0.42						
Reaction time (6 Point Forward test)								
Control	**Pre**	17.95 ± 1.09	0.05	0.95	0.01	0.01	-0.51	0.54
Experimental		17.93 ± 1.03						
Control	**Post**	17.84 ± 0.94	15.46	< 0.001	3.87	2.81	2.45	3.18
Experimental		15.02 ± 0.41						

t: independent t-statistic, p: level of significance ($p<0.005$), d: Cohen's d for effect size, MD: Mean Difference, 95% CI: 95% Confidence Interval

experimental). The significance level was set at $p<0.05$ for all statistical tests in the thesis.

Results

The study was conducted on 64 badminton players divided equally in control and experimental groups. The control group consisted of a higher proportion of male participants compared to females, while a similar pattern was observed in the experimental group. The average age of participants in the control group was slightly higher than that of the experimental group. Heights were comparable in both groups, with the experimental group showing a slightly higher average. Average weight was similar in both groups, and the control group had a slightly higher BMI compared to the experimental group. Right-hand dominance was prevalent in most participants in both the control and experimental groups. Specifically, in the control group, a larger percentage of participants were right-handed, whereas the experimental group also had a higher number of right-handed participants. In both the control and experimental groups, a higher percentage of male participants had more than 5 years of badminton experience compared to females (Table 1).

Upon reviewing the participant characteristics presented in the provided data, it is clear that conducting a gender-based study for the comparison of outcome variables may not be feasible due to the limited number of female participants in both the control and experimental groups. Additionally, when comparing hand dominances, it is apparent that the majority of participants in both groups were right-hand dominant. As a result, we did not plan to present the results based on gender and hand dominance in the study, as the sample sizes for these subgroups were not sufficient for meaningful statistical comparisons. Instead, our primary focus was on comparing the outcome variables between the control

Table 3 Independent t-test comparing the SEBT (balance) between pre and post measurements of the control and experimental groups

Outcome Variables	Time	Group		t	*p*	d	MD	95% CI	
		Control	Experimental					Lower	Upper
SEBT Right A	**Pre**	92.5 ± 6.39	93.75 ± 5.16	-0.86	0.39	-0.22	-1.25	-4.15	1.65
	Post	92.72 ± 5.28	100.63 ± 3.81	-6.86	< 0.001	-1.72	-7.90	-10.20	-5.60
SEBT Left A	**Pre**	91.81 ± 7.37	89.88 ± 4.42	1.27	0.20	0.32	1.93	-1.10	4.97
	Post	90.88 ± 6.9	98.09 ± 3.33	-5.32	< 0.001	-1.33	-7.21	-9.92	-4.50
SEBT Right AL	**Pre**	92.69 ± 5.69	88.75 ± 4.42	3.08	< 0.001	0.77	3.93	1.38	6.48
	Post	92.84 ± 5.06	99.16 ± 2.5	-6.31	< 0.001	-1.56	-6.31	-8.31	-4.31
SEBT Left AL	**Pre**	91.31 ± 4.7	89.72 ± 3.76	1.49	0.14	0.37	1.59	-0.53	3.72
	Post	90.66 ± 4.79	98.56 ± 2.77	-8.07	< 0.001	-2.02	-7.90	-9.86	-5.94
SEBT Right L	**Pre**	95.59 ± 6.4	90.13 ± 4.21	4.03	< 0.001	1.01	5.46	2.75	8.17
	Post	94.75 ± 3.62	99.59 ± 3.5	-5.42	< 0.001	-1.36	-4.84	-6.62	-3.06
SEBT Left L	**Pre**	92.97 ± 7.19	89.25 ± 4.88	2.42	0.01	0.61	3.71	0.64	6.79
	Post	91 ± 4.35	99.41 ± 2.56	-9.41	< 0.001	-2.35	-8.40	-10.19	-6.62
SEBT Right PL	**Pre**	96.25 ± 6.23	90.91 ± 4.13	4.04	< 0.001	1.01	5.34	2.70	7.98
	Post	94.72 ± 4.45	100.28 ± 4.09	-5.19	< 0.001	-1.30	-5.56	-7.70	-3.42
SEBT Left PL	**Pre**	95.63 ± 7.36	90.41 ± 4.68	3.38	< 0.001	0.85	5.21	2.13	8.30
	Post	93.44 ± 4.41	99.28 ± 3.96	-5.57	< 0.001	-1.40	-5.84	-7.93	-3.74
SEBT Right P	**Pre**	93.16 ± 4.87	92.94 ± 3.88	0.19	0.84	0.05	0.21	-1.98	2.42
	Post	97.88 ± 4.83	101.34 ± 2.82	-3.50	< 0.001	-0.88	-3.46	-5.44	-1.49
SEBT Left P	**Pre**	92.06 ± 3.77	91.53 ± 4.93	0.48	0.63	0.12	0.53	-1.66	2.72
	Post	96.75 ± 4.04	100.16 ± 4.34	-3.24	< 0.001	-0.81	-3.40	-5.50	-1.31
SEBT Right PM	**Pre**	88.16 ± 5.24	89.81 ± 4.61	-1.34	0.18	-0.34	-1.65	-4.12	0.81
	Post	91.03 ± 5.37	98.81 ± 4.42	-6.32	< 0.001	-1.58	-7.78	-10.24	-5.32
SEBT Left PM	**Pre**	90.78 ± 6.03	90.06 ± 4.75	0.52	0.59	0.13	0.71	-1.99	3.43
	Post	92.88 ± 6.22	99 ± 3.69	-4.78	< 0.001	-1.20	-6.12	-8.68	-3.56
SEBT Right M	**Pre**	82.03 ± 8.83	87.13 ± 4.21	-2.94	< 0.001	-0.74	-5.09	-8.55	-1.63
	Post	84.25 ± 6.46	95.63 ± 5.02	-7.86	< 0.001	-1.97	-11.37	-14.26	-8.48
SEBT Left M	**Pre**	83.97 ± 9.68	81.53 ± 7.41	1.13	0.26	0.28	2.43	-1.87	6.74
	Post	85.47 ± 8.02	92.63 ± 6.33	-3.96	< 0.001	-0.99	-7.15	-10.76	-3.54
SEBT Right AM	**Pre**	83.31 ± 5.89	85.22 ± 4.63	-1.43	0.15	-0.36	-1.90	-4.55	0.74
	Post	83.78 ± 6.25	94.41 ± 4.92	-7.55	< 0.001	-1.89	-10.62	-13.43	-7.81
SEBT Left AM	**Pre**	80.78 ± 7.7	79.56 ± 5.71	0.71	0.47	0.18	1.21	-2.17	4.60
	Post	84.53 ± 6.99	90.00 ± 4.06	-3.82	< 0.001	-0.96	-5.46	-8.32	-2.61

SEBT: Star Excursion Balance Test, A: Anterior, AL: Anterolateral, L: Lateral, PL: Posterolateral, P: Posterior, PM: Posteromedial, M: Medial, AM: Anteromedial, t: independent t-statistic, p: level of significance ($p < 0.005$), d: Cohen's d for effect size, MD: Mean Difference, 95% CI: 95% Confidence Interval

and experimental groups and evaluating the impact of the intervention on the specified measures.

Table 2 presents the results of the independent t-test were used to assess differences between two independent groups at each time point—pre and post-intervention for agility, core stability, reaction time and balance. For the agility test, there was a significant improvement in the experimental group from pre (17.08 ± 0.43) to post (15.32 ± 0.34) with a mean difference of 1.75 (t = 21.28, $p < 0.001$, 95% CI [1.58, 1.92]), whereas the control group showed no significant difference (t=-0.13, $p = 0.89$, 95% CI [-1.09, 0.95]). Similarly, for the core stability, the experimental group showed a significant improvement from pre (3.44 ± 0.41) to post (5.39 ± 0.42) with a mean difference of -1.94 (t=-18.51, $p < 0.001$, 95% CI [-2.16, -1.73]), while the control group had no significant change (t=-0.98, $p = 0.32$, 95% CI [-0.26, 0.08]). Finally, for reaction time, the experimental group demonstrated a significant improvement from pre (17.93 ± 1.03) to post (15.02 ± 0.41) with a mean difference of 2.91 (t = 14.09, $p < 0.001$, 95% CI [2.49, 3.33]), while the control group had no significant difference (t = 0.05, $p = 0.95$, 95% CI [-0.51, 0.54]).

The independent t-test results for the SEBT measurements between pre and post-intervention showed significant improvements in the experimental group for various reach directions (Table 3). Notably, the experimental group displayed significant enhancements in anterior reach for both the right (MD= -6.87, $p < 0.001$) and left legs (MD= -8.21, $p < 0.001$), anterolateral reach for the right leg (MD = 10.40, $p < 0.001$), lateral reach for the right leg (MD = 9.46, $p < 0.001$), posterolateral reach for both the right (MD = 9.37, $p < 0.001$) and left legs (MD=

-8.87, $p<0.001$), and posteromedial reach for the right leg (MD=9.18, $p<0.001$). In contrast, the control group had no significant changes in most reach directions. However, both groups showed significant improvements in posterior reach for both legs.

Paired t-tests was conducted to compare the pre and post-intervention measurement within each group for the agility, core stability, reaction time and balance (Fig. 2). For the agility, the experimental group showed a significant improvement from pre (17.08±0.43) to post

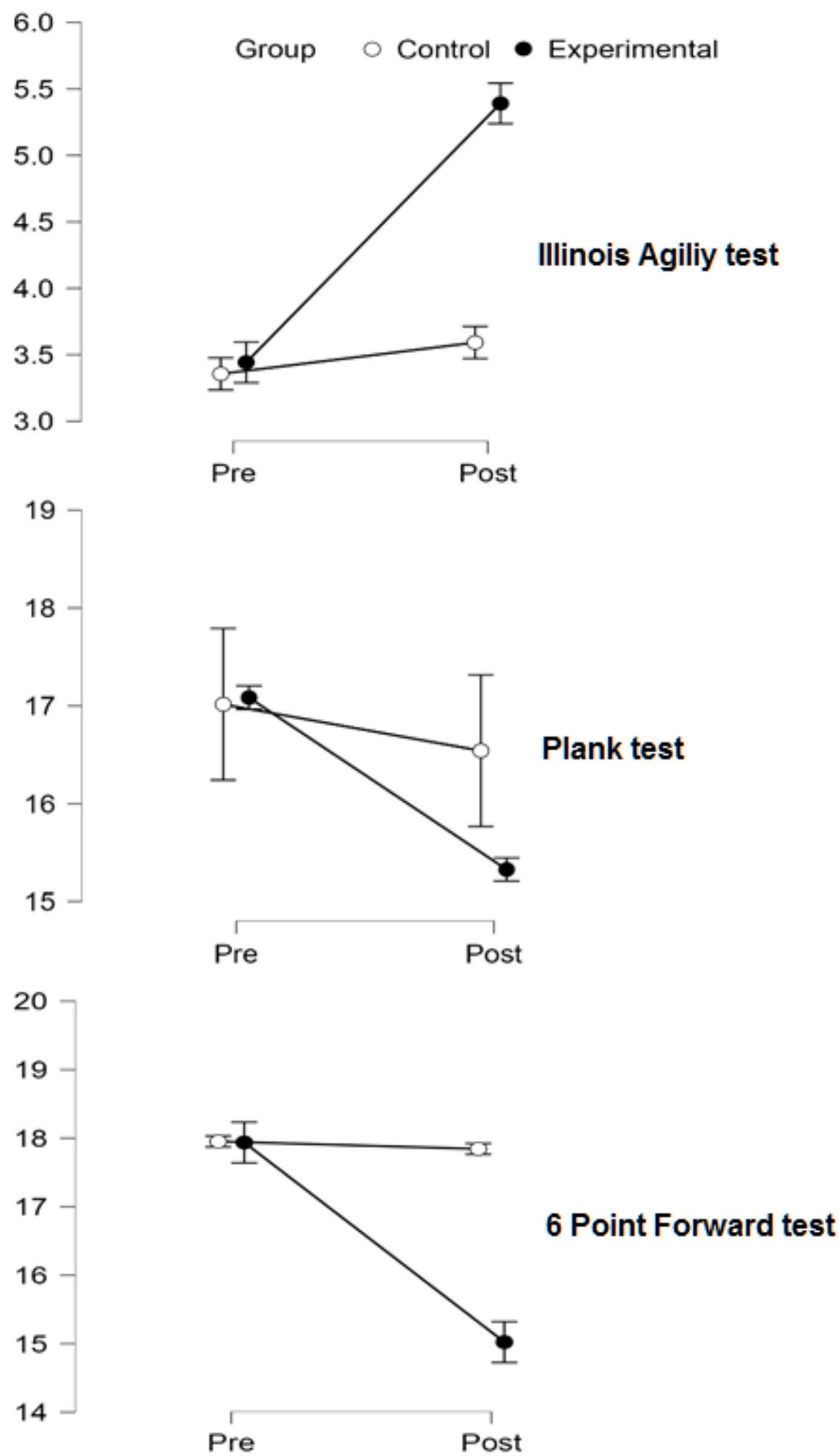

Fig. 2 Pre and Post comparison of illinois agility test, plank test, and 6-point forward test between control and experimental group

(15.32±0.34) with a mean difference of 1.75 (t=21.28, $p<0.001$, 95% CI [1.58, 1.92]), whereas the control group had no significant change (t=0.88, $p=0.38$, 95% CI [-0.62, 1.57]). Further, the core stability in the experimental group demonstrated a significant improvement from pre (3.44±0.41) to post (5.39±0.42) with a mean difference of -1.94 (t= -18.51, $p<0.001$, 95% CI [-2.16, -1.73]), while the control group had no significant change (t= -0.23, $p=0.88$, 95% CI [-0.40, -0.06]). Similarly, for the reaction time, the experimental group showed a significant improvement from pre (17.93±1.03) to post (15.02±0.41) with a mean difference of 2.91 (t=14.09, $p<0.001$, 95% CI [2.49, 3.33]), while the control group had no significant difference (t=0.10, $p=0.92$, 95% CI [-0.51, 0.54]). As a whole, the experimental group showcased significant enhancements in balance, exemplified by marked improvements across diverse reach directions. In contrast, the control group exhibited minimal alterations in SEBT performance, underscoring the distinct disparity between the two groups. (Table 4).

The repeated measures ANOVA was conducted to assess changes in performance measures (agility test, core stability, and the reaction time) over time within each group (Table 5). For the agility, there was a significant time effect (F=16.87, $p<0.001$, $\eta^2 p=0.21$), indicating that performance improved from pre to post within both the experimental and control groups. However, the group effect (F=5.03, $p=0.03$, $\eta^2 p=0.08$) and time x group interaction (F=5.57, $p=0.02$, $\eta^2 p=0.08$) were not significant, suggesting that the improvement in performance did not differ significantly between the two groups. For the core stability and reaction time, there were significant time effects (core stability: F=262.06, $p<0.001$, $\eta^2 p=0.81$; reaction time: F=199.77, $p<0.001$, $\eta^2 p=0.76$), indicating performance improvements from pre to post within both groups. Additionally, significant group effects (core stability: F=220.04, $p<0.001$, $\eta^2 p=0.78$; reaction time: F=49.07, $p<0.001$, $\eta^2 p=0.44$) and time x group interactions (core stability: F=161.15, $p<0.001$, $\eta^2 p=0.72$; reaction time: F=171.9, $p<0.001$, $\eta^2 p=0.73$) were found for both core stability and reaction time, suggesting that the improvement in performance differed significantly between the experimental and control groups.

Discussion

The aim of the study was to investigate the efficiency of backward walking on agility, core stability, reaction time, and balance in badminton players. To assess these variables, the researchers employed specific outcome measures, including the Illinois agility test for agility, Plank test for core stability, the 6-point footwork test for reaction time, and the Star Excursion Balance Test (SEBT) for balance in the badminton players. The study included a total of 64 participants, with 32 individuals in each group (control and experimental).

Badminton is physically demanding, requiring athletes to possess high levels of aerobic and anaerobic fitness [28]. The ability to swiftly change direction, accelerate, and decelerate is essential for reaching the shuttlecock and maintaining court coverage effectively. The aerodynamics of a shuttlecock play a crucial role in badminton. Researchers investigate the factors influencing shuttlecock trajectory, spin, and speed, taking into account factors such as air resistance, drag, and shuttlecock design [29]. This knowledge helps players anticipate and react to shots more effectively. Backward walking training on treadmill offers a unique and innovative approach to enhancing the physical performance of athletes. By incorporating such exercises into their training regimen, players can improve their agility, balance, and proprioception, which are crucial attributes in badminton. By adding backward training to their training routines, badminton players can enhance their physical attributes, ultimately contributing to improved performance and reduced injury risk during competitive play [30].

In the present study, the control group received routine exercise training focusing on improving sports performance, whereas the experimental group received routine exercise training along with backward walking training. Pre and post-intervention assessment were taken to measure core stability using plank test, balance using the SEBT, reaction time using the 6-point footwork test and agility using the Illinois agility test. The experimental group demonstrated significant improvement in core stability, balance, reaction time, and agility as compared to the group following only regular exercise protocol.

There were significant difference in stability between the control and experimental groups. The improved core strength enhances dynamic balance, and agility in adolescent badminton players [14]. The six weeks of backward walking training leads to enhanced core strength, as evidenced by the outcomes of the plank test. This improvement in core strength could potentially contribute to the observed enhancements in agility and balance. These findings align with findings of previous studies which demonstrated that backward walking has the potential to enhance balance and stability among badminton players [31]. Notably, their study revealed the most significant improvements within the short-term duration of 4 weeks of training.

Backward training targets specific muscle groups involved in maintaining stability and generating power during quick movements on the court, such as the quadriceps, hamstrings, and calf muscles. Strengthening these muscles through backward training can help prevent injuries and improve overall lower body strength and stability. Additionally, backward training challenges players'

Table 4 Paired t test used to compare the pre and post-intervention measurements within each group for the SEBT (Star Excursion Balance Test) in both the right and left legs

SEBT Reach	Group	Pre	Post	MD	SD	95% CI		t	*p*	d
						Lower	Upper			
Anterior										
Right	**Control**	92.5 ± 6.39	92.72 ± 5.28	-0.21	5.01	-2.02	1.58	-0.24	0.80	-0.44
	Experimental	93.75 ± 5.16	100.63 ± 3.81	-6.87	3.85	-8.26	-5.48	-10.08	< 0.001*	-1.78
Left	**Control**	91.81 ± 7.37	90.88 ± 6.9	0.93	6.01	-1.22	3.10	0.88	0.38	0.16
	Experimental	89.88 ± 4.42	98.09 ± 3.33	-8.21	3.17	-9.36	-7.07	-14.66	< 0.001*	-2.59
Anterolateral										
Right	**Control**	92.69 ± 5.69	92.84 ± 5.06	0.15	5.52	-1.83	2.14	0.16	0.87	0.28
	Experimental	88.75 ± 4.42	99.16 ± 2.5	10.40	3.18	9.25	11.55	18.50	< 0.001*	3.27
Left	**Control**	91.31 ± 4.7	90.66 ± 4.79	0.65	4.07	-0.81	2.12	0.91	0.37	0.16
	Experimental	89.72 ± 3.76	98.56 ± 2.77	-8.84	3.22	-1001	-7.68	-15.51	< 0.001*	-2.74
Lateral										
Right	**Control**	95.59 ± 6.4	94.75 ± 3.62	-0.84	7.21	-3.44	1.75	-0.66	0.51	-0.12
	Experimental	90.13 ± 4.21	99.59 ± 3.5	9.46	3.97	8.03	10.90	13.47	< 0.001*	2.38
Left	**Control**	92.97 ± 7.19	91.00 ± 4.35	1.96	5.63	-0.06	3.99	1.97	0.05	0.35
	Experimental	89.25 ± 4.88	99.41 ± 2.56	-10.15	4.45	-11.76	-8.54	-12.88	< 0.001*	-2.28
Posterolateral										
Right	**Control**	96.25 ± 6.23	94.72 ± 4.45	-1.53	6.88	-4.01	0.95	-1.25	0.21	-0.22
	Experimental	90.91 ± 4.13	100.28 ± 4.09	9.37	3.96	7.94	10.80	13.37	< 0.001*	2.36
Left	**Control**	95.63 ± 7.36	93.44 ± 4.41	2.18	5.46	0.21	4.15	2.26	0.03	0.40
	Experimental	90.41 ± 4.68	99.28 ± 3.96	-8.87	4.42	-10.46	-7.28	-11.36	< 0.001*	-2.01
Posterior										
Right	**Control**	93.16 ± 4.87	97.88 ± 4.83	4.71	3.49	3.45	5.97	7.64	< 0.001*	1.35
	Experimental	92.94 ± 3.88	101.34 ± 2.82	8.40	3.48	7.15	9.66	13.65	< 0.001*	2.42
Left	**Control**	92.06 ± 3.77	96.75 ± 4.04	-4.68	2.65	-5.64	-3.72	-9.97	< 0.001*	-1.76
	Experimental	91.53 ± 4.93	100.16 ± 4.34	-8.62	3.93	-10.04	-7.20	-12.40	< 0.001*	-2.19
Posteromedial										
Right	**Control**	88.16 ± 5.24	91.03 ± 5.37	2.87	2.35	2.02	3.72	6.91	< 0.001*	1.22
	Experimental	89.81 ± 4.61	98.81 ± 4.42	9.00	4.04	7.54	10.45	12.57	< 0.001*	1.21
Left	**Control**	90.78 ± 6.03	92.88 ± 6.22	-2.09	1.99	-2.81	-1.37	-5.95	< 0.001*	-1.05
	Experimental	90.06 ± 4.75	99.00 ± 3.69	-8.93	3.67	-10.26	-7.61	-13.77	< 0.001*	-2.43
Medial										
Right	**Control**	82.03 ± 8.83	84.25 ± 6.46	2.21	8.14	-0.71	5.15	1.54	0.13	0.27
	Experimental	87.13 ± 4.21	95.63 ± 5.02	8.50	4.00	7.05	9.94	12.02	< 0.001*	2.13
Left	**Control**	83.97 ± 9.68	85.47 ± 8.02	-1.50	9.13	-4.79	1.79	-0.92	0.36	-0.16
	Experimental	81.53 ± 7.41	92.63 ± 6.33	-11.09	3.13	-12.22	-9.96	-20.01	< 0.001*	-3.54
Anteromedial										
Right	**Control**	83.31 ± 5.89	83.78 ± 6.25	0.46	6.12	-1.74	2.67	0.43	0.66	0.08
	Experimental	85.22 ± 4.63	94.41 ± 4.92	9.18	2.48	8.29	10.08	20.94	< 0.001*	3.70
Left	**Control**	80.78 ± 7.7	84.53 ± 6.99	-3.75	7.71	-6.53	-0.96	-2.75	0.01	-0.49
	Experimental	79.56 ± 5.71	9 < 0.001 ± 4.06	-10.43	3.70	-11.77	-9.10	-15.93	< 0.001*	-2.82

SEBT: Star Excursion Balance Test, A: Anterior, AL: Anterolateral, L: Lateral, PL: Posterolateral, P: Posterior, PM: Posteromedial, M: Medial, AM: Anteromedial, t: paired t-statistic, p: level of significance ($p < 0.005$), d: Cohen's d for effect size, MD: Mean Difference, 95% CI: 95% Confidence Interval

motor skills by requiring them to perform movements in reverse, leading to increased motor unit recruitment and improved coordination [32]. The focus on core stability during backward training can also benefit badminton players in maintaining a strong and balanced stance while executing shots and moving swiftly on the court [16].

Further, the control group did not show a significant difference in agility, whereas the experimental group of backward training exhibited a significant improvement in agility. These findings suggest that incorporating backward walking training can be effective in enhancing agility. Studies in the past shows that repeated backward running training (RBRT) can have positive effects on various measures of physical fitness in youth male soccer players and netball players [17, 21, 22]. Within-group analysis revealed that RBRT improved all performance

Table 5 Repeated measure ANOVA showing how performance measures changed over time within each group

Group	Pre	Post	Time Effect			Group Effect			Time x Group Interaction		
			F	*p*	η^2p	F	*p*	η^2p	F	*p*	η^2p
Agility (Illinois test)											
Control	17.01 ± 2.87	16.54 ± 0.57	16.87	< 0.001*	0.21	5.03	0.03*	0.08	5.57	0.02*	0.08
Experimental	17.08 ± 0.43	15.32 ± 0.34									
Core stability (Plank test)											
Control	3.35 ± 0.27	3.59 ± 0.34	262.06	< 0.001*	0.81	220.04	< 0.001*	0.78	161.15	< 0.001*	0.72
Experimental	3.44 ± 0.41	5.39 ± 0.42									
Reaction time (6 Point Forward test)											
Control	17.95 ± 1.09	17.84 ± 0.94	199.77	< 0.001*	0.76	49.07	< 0.001*	0.44	171.9	< 0.001*	0.73
Experimental	17.93 ± 1.03	15.02 ± 0.41									

F: F-statistic, p: level of significance ($p < 0.005$), η^2p: Partial Eta Squared

variables, including speed, agility, power and other physical fitness measures.

In this study, there was no significant difference in the control group of the six-point footwork test, whereas there was a significant difference in the experimental group that underwent backward training. The backward training helped improve backward running when the shuttle was behind and helped maintain balance with control. A previous study reported discovered that a twelve-week intervention focused on agility training, utilizing the Visual Reaction Time technique with a foundation in six-point footwork and T-footwork, yielded significant differences in the recorded reaction and action times for the fixed-light-mode six-point footwork test [11]. Additional research has corroborated the notion that engaging in recurrent backward running exercises can enhance diverse aspects of physical fitness among adolescent male football players and netball players. These improvements encompass enhanced speed, agility, power, and other pertinent physical fitness indicators. The inclusion of backward training in conditioning and skills training regimens has the potential to yield positive outcomes in terms of improving physical fitness among adolescent male football and netball athletes [21, 22].

The improved balance improves footwork performance in adolescent competitive badminton players also the visual reaction training improves the six-point footwork [15]. The improved footwork has also been associated with enhanced reaction time and agility [11]. Another study has shown the significant differences in short-sprint speed and power measures were observed in adolescent athlete after backward running training shows the effectiveness of backward training [17]. Balance training has been identified as an effective approach to mitigate the risk of falls during backward running, offering benefits during gameplay when players need to respond to the shuttle being behind them, thereby preventing potential falls and enhancing performance.

Backward walking training on treadmill offers a unique and innovative approach to enhancing the physical performance of athletes. By incorporating such exercises into their training regimen, players can improve their agility, balance, and proprioception, which are crucial attributes in badminton. By adding backward training to their training routines, badminton players can enhance their physical attributes, ultimately contributing to improved performance and reduced injury risk during competitive play.

While this study provides valuable insights into the effects of backward walking on trunk stability, balance, agility, and reaction time in badminton players, there are some limitations to consider. The six-week duration of the intervention may not fully capture the long-term effects. The study did not control for external factors that could influence the outcomes, such as participants' training regimens or nutrition. Additionally, the lack of long-term follow-up limits our understanding of the durability of the observed improvements. There may also be unaccounted confounding variables that could influence the results. Future research should address these limitations to enhance the validity and broader applicability of the findings.

Despite the limitations, this study opens avenues for future research. Firstly, investigations could focus on exploring the optimal duration and frequency of backward walking training to maximize its effectiveness in improving trunk stability, balance, agility, and reaction time. Additionally, further studies could examine the underlying mechanisms through which backward walking influences these physical attributes, such as changes in muscle activation patterns or proprioceptive feedback. Moreover, investigations could extend beyond laboratory settings and explore the real-world application of backward walking training in badminton players during their actual game performance. Lastly, future research could explore the potential benefits of combining backward walking with other training modalities or interventions to enhance overall athletic performance in badminton players.

Conclusion

This study demonstrates that a six-week intervention of backward walking has the potential to improve trunk stability, balance, agility, and reaction time in badminton players. The experimental group showed significant and clinically relevant improvements as compared to the control group. The findings suggest that incorporating backward walking into training regimens may be an effective strategy for enhancing athletic performance in badminton players. However, further research is needed to validate the results in larger and more diverse populations, consider longer intervention duration, and address potential confounding factors to establish the full benefits and applicability of backward walking as a training modality.

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Author contributions
O.S.G. M.R.R. A.S. S.H. F.A. A.H.A. and A.I. proposed the study concept and design. O.S.G. M.R.R. and A.S. planned the methodology. O.S.G. and A.S. collected data. H.J.A. A.I., A.H.A., and F.A. contributed to the data analysis. F.A. S.H. A.R.S. M.K.S. S.U. S.N. A.H.A. and A.I. contributed to the data interpretation. O.S.G. A.S. M.R.A. F.A. S.H. and A.I. prepared the manuscript's initial draft. O.S.G. M.R.R. A.S. F.A. S.H. A.R.S. M.K.S. S.U. S.N. A.H.A. and A.I. critically reviewed and edited the manuscript for intellectual content. All authors have read, understood, reviewed, and approved the manuscript's final version to be submitted or published and take responsibility for the intellectual content of the same manuscript.

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Data availability
All data generated or analyzed during this study will be available upon a reasonable request from the corresponding author.

Declarations

Ethics statement and consent to participate
This study received ethical approval from the Ethical Committee of the Department of Physiotherapy, Faculty of Allied Health Sciences, Manav Rachna International Institute of Research and Studies. The approval reference number is MRIIRS/FAHS/PT/2022-23/S-008 dated 7th January 2023. The study design adhered to the guidelines outlined in the revised Helsinki Declaration of Biomedical Ethics, ensuring the ethical treatment of participants and the protection of their rights. Additionally, to ensure transparency and accountability, the study protocol was registered in the clinical trial registry at https://www.ctri.nic.in/ with the identifier CTRI/2023/05/052750. The registration date was 17th May 2023.

Consent for publication
Not applicable.

Completing interest
The authors declare that they have no competing interests, either financial or non-financial in this study.

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