RESEARCH PAPER

Effects of Graded Backward Treadmill Training on Functional Knee Outcomes and Quality of Life Following Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial

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ABSTRACT

Background

Anterior cruciate ligament (ACL) reconstruction is frequently associated with persistent functional deficits, neuromuscular impairments and reduced quality of life. Restoration of functional performance remains a major rehabilitation goal following ACL surgery. Backward treadmill walking has emerged as a promising rehabilitation intervention due to its ability to improve neuromuscular coordination and functional recovery.

Objective

To investigate the effects of graded backward treadmill training on functional knee outcomes and quality of life following ACL reconstruction.

Methodology

Sixty participants aged 18–45 years who underwent ACL reconstruction were randomly assigned into five groups (A–E; n=12 per group). Groups A–D performed backward treadmill walking at inclinations of 0°, 5°, 10° and 15° respectively, while Group E received conventional rehabilitation. Training was conducted for 20 minutes per session, three sessions per week for four weeks. Functional outcomes were assessed using the International Knee Documentation Committee (IKDC) subjective knee evaluation form and quality of life was assessed using the Anterior Cruciate Ligament-Quality of Life (ACL-QOL) questionnaire.

Results

All groups demonstrated improvement in IKDC and ACL-QOL scores following intervention. Group D demonstrated the greatest functional improvement. Significant between-group differences were observed at post-test for IKDC and ACL-QOL scores.

Conclusion

Graded backward treadmill training appears to be an effective rehabilitation intervention for improving functional knee outcomes; however, its effect on quality of life should be interpreted with caution.

Keywords: ACL reconstruction, backward treadmill walking, functional recovery, rehabilitation, quality of life

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INTRODUCTION

Anterior cruciate ligament injuries are among the most common ligament injuries of the knee joint, particularly among young and physically active individuals [1,2]. ACL reconstruction is commonly performed to restore joint stability; however, many individuals continue to experience functional limitations following surgery [3,4].

Functional recovery following ACL reconstruction depends on restoration of neuromuscular control, proprioception, quadriceps strength and psychological readiness [5–7]. Persistent deficits may delay return to sports and negatively affect quality of life [8,9].

Closed kinetic chain exercises are widely recommended following ACL reconstruction due to their functional relevance and safety [10,11]. Backward walking has gained attention as a rehabilitation strategy due to its ability to enhance quadriceps activation while minimizing anterior knee stress [12–14].

Backward walking differs biomechanically from forward walking due to altered muscle activation patterns and increased proprioceptive demand [15,16]. These adaptations may improve neuromuscular coordination and functional recovery [17].

Studies suggest backward walking improves balance, mobility and neuromuscular coordination [18–20]. Backward walking training has also been shown to improve knee proprioception following ACL reconstruction [21].

Patient-reported outcome measures such as International Knee Documentation Committee (IKDC) and Anterior Cruciate Ligament-Quality of Life (ACL-

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QOL) provide important insight into functional recovery and rehabilitation success [22–24].

Although previous research has examined effects on muscle strength and morphology, limited research has examined functional recovery following graded backward treadmill training.

Therefore, this study aimed to determine the effects of graded backward treadmill training on functional knee outcomes and quality of life following ACL reconstruction.

METHODOLOGY

This study was designed as a randomized controlled trial to investigate the effects of graded backward treadmill training on functional knee outcomes and quality of life following anterior cruciate ligament (ACL) reconstruction. This manuscript reports functional outcome data from this randomized controlled trial, while other outcomes from the trial are reported separately to address different research objectives. The study was conducted in hospitals affiliated with the Padmashree Institute of Physiotherapy after obtaining ethical approval (Ref No: NU/CEC/2023/359). A total of 60 subjects who had undergone arthroscopic ACL reconstruction using a semitendinosus graft were recruited for the study. All 60 participants completed the study, and no dropouts occurred. The study design followed standard randomized trial methodology to ensure internal validity and minimize bias. The sample size was determined based on feasibility and similar previous studies in ACL rehabilitation, as no prior data were available for precise power calculation. [42]. Due to the nature of the intervention, blinding of participants was not feasible; however, outcome assessment was conducted using standardized self-reported measures to minimize bias.

Participants aged between 18 and 45 years who were between 3 and 6 months post-surgery, able to walk independently, and having knee range of motion between 0° and 110° were included in the study. Subjects with revision ACL surgery, inflammatory joint diseases, neurological disorders, recent lower limb fractures, associated ligament injuries, or any other condition affecting gait were excluded from the study. These criteria were selected based on commonly reported eligibility standards in ACL rehabilitation research [4,7].

Eligible participants were randomly allocated into five groups (n = 12 per group) using an opaque envelope method. Group A performed backward treadmill walking at 0° inclination, Group B at 5° inclination, Group C at 10° inclination, and Group D at 15° inclination. Group E served as the control group and received conventional physiotherapy rehabilitation.

The backward treadmill walking intervention was performed at a constant speed of 1.3 km/h. Each session lasted 20 minutes and was conducted three times per week for a duration of four weeks. All participants also continued their standard rehabilitation exercises including range of motion exercises, strengthening exercises, and functional training as prescribed. Similar rehabilitation progression protocols have been recommended in ACL rehabilitation literature [4,30].

Functional knee outcomes were assessed using the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, a valid and reliable measure of knee function following ACL injury [22,24]. Quality of life was assessed using the ACL Quality of Life (ACL-QOL) questionnaire, which is widely used to assess patient-perceived functional recovery following ACL reconstruction [23]. Outcome measures were recorded before the intervention and after completion of the four-week training program.

Statistical analysis was performed using SPSS software. Descriptive statistics were used to summarize demographic variables. Within-group comparisons were performed using the Wilcoxon signed-rank test, while between-group comparisons were performed using the Kruskal–Wallis test. The level of statistical significance was set at $p < 0.05$. These statistical approaches are commonly used in clinical rehabilitation trials involving non-parametric outcome data [26].

RESULTS

Sl. No.	Background variables	Group-A(n1=12)		Group-B(n2=12)		Group-C(n3=12)		Group-D(n4=12)		Group-E(n5=12)		F-Test
		Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	
1	Age (yrs)	18-45	32.06±11.12	18-38	29.75±6.49	22-45	37.00±11.37	20-45	33.17±8.04	19-42	31.50±8.56	F=1.007,p=0.412, NS
2	Weight (kg)	46-67	57.76±6.24	45-79	62.97±10.49	48-69	61.74±5.90	51-92	66.77±10.72	52-90	62.69±9.82	F=1.631, p=0.180, NS
3	Height (m)	1.49-1.69	1.61±0.05	1.54-1.75	1.65±0.07	1.57-1.71	1.64±0.04	1.55-1.72	1.62±0.06	1.57-1.67	1.62±0.03	1.261, p=0.296, NS

4	BMI (kg/m^2)	19.38-25.85	22.23±2.20	18.49-26.89	22.84±2.71	17.83-26.62	22.81±2.49	21.23-31.10	24.54±2.47	20.57-32.27	23.66±3.18	1.383, p=0.243,NS
5	Gender (Male / Female)	6(50.0) / 6(50.0)		11(91.7)/ 1(8.30)		11(91.7)/ 1(8.30)		9(75.0)/ 3(25.0)		9(75.0)/ 3(25.0)		Chi-square=7.826 df=4, p=0.098, NS
6	Side affected (left /right)	6(50.0)/ 6(50.0)		7(58.3)/ 5(41.7)		5(41.7)/ 7(58.3)		6(50.0)/ 6(50.0)		4(33.3) / 8(66.7)		Chi-square=6.17 df=4, p=0.783, NS

Table 1: Baseline demographic characteristics of subjects following ACL reconstruction

Table 1 presents the baseline demographic characteristics of the study participants. The mean age, weight, height, and BMI were comparable across all five groups with no statistically significant differences observed (p>0.05). Gender distribution and side affected were also similar among the groups, with no significant differences noted (p>0.05). These findings indicate that the groups were homogeneous at baseline, confirming successful randomization and ensuring that post-intervention changes can be attributed to the treatment effects rather than baseline differences.

Groups	Pre test		Post test		Wilcoxon test for within groups
	Range	Mean ± SD	Range	Mean ± SD	
Group-A	17.20-61.0	27.99±12.42	36.00-62.00	47.52±7.78	z=2.982, p=0.003,S
Group-B	20.60-49.00	27.74±7.77	42.50-67.81	52.32±8.33	z=3.059, p=0.002,S
Group-C	18.30-51.00	30.14±9.02	41.30-82.00	51.72±10.99	z=3.001, p=0.002,S
Group-D	22.98-43.67	30.20±5.91	45.00-75.86	62.08±11.56	z=3.059, p=0.002,S
Group-E	18.39-40.00	27.11±6.42	34.00-65.00	50.33±7.55	z=3.062, p=0.002,S
Kruskal Wallis Test for between groups	Chi-square=3.952, df=4, p=0.411,NS		Chi-square=10.494, df=4, p=0.033,S		

Table 2: Within and between group comparison of IKDC scores(%) among subjects with post anterior cruciate ligament reconstruction

Table 2 presents the within-group and between-group comparison of IKDC scores among subjects following ACL reconstruction. Within-group analysis showed statistically significant improvement in IKDC scores in all five groups following the intervention period. The mean IKDC score in Group A improved from 27.99 ± 12.42 to 47.52 ± 7.78 (p=0.003). Similarly, Group B improved from 27.74 ± 7.77 to 52.32 ± 8.33 (p=0.002), Group C from 30.14 ± 9.02 to 51.72 ± 10.99 (p=0.002), Group D from 30.20 ± 5.91 to 62.08 ± 11.56 (p=0.002), and Group E from 27.11 ± 6.42 to 50.33 ± 7.55 (p=0.002). Between-group comparison using Kruskal–Wallis test showed no statistically significant difference at baseline (χ^2=3.952, p=0.411), indicating group comparability. However, post-intervention comparison demonstrated a statistically significant difference between groups (χ^2=10.494, p=0.033), indicating variation in functional improvement among the groups.

Groups	Pre test		Post test		Within groups
	Range	Mean ± SD	Range	Mean ± SD	
Group-A	14.51-26.12	18.95±3.92	24.67-33.54	29.24±2.74	z=3.061, p=0.002,S
Group-B	14.10-38.70	19.39±7.49	20.32-67.09	35.00±12.41	z=3.059, p=0.002,S
Group-C	13.22-28.06	18.96±4.92	26.77-34.19	31.26±2.20	z=3.059, p=0.002,S

Group-D	13.87-41.67	23.21±7.64	27.41-79.67	49.59±16.94	z=2.981, p=0.003,S
Group-E	13.87-51.80	19.58±10.36	25.15-46.45	30.71±6.07	z=2.275, p=0.023, S
Kruskal Wallis Test for between groups	Chi-square=5.493, df=4, p=0.0240,S		Chi-square=12.200, df=4, p=0.016, S		

Table 3: Within and between group comparison of ACL-QOL scores of subjects with post ACLR

Table 3 presents the within-group and between-group comparison of ACL-QOL scores among subjects following ACL reconstruction. Although significant improvements in ACL-QOL scores were observed across all groups, the presence of a statistically significant baseline difference between groups indicates that these findings should be interpreted with caution. The mean ACL-QOL score in Group A improved from 18.95 ± 3.92 to 29.24 ± 2.74 (p=0.002). Similarly, Group B improved from 19.39 ± 7.49 to 35.00 ± 12.41 (p=0.002), Group C from 18.96 ± 4.92 to 31.26 ± 2.20 (p=0.002), Group D from 23.21 ± 7.64 to 49.59 ± 16.94 (p=0.003), and Group E from 19.58 ± 10.36 to 30.71 ± 6.07 (p=0.023).

Between-group comparison using Kruskal–Wallis test showed a statistically significant difference at baseline (χ^2 = 5.493, p = 0.024) as well as at post-test (χ^2 = 12.200, p = 0.016), indicating variation in quality-of-life scores among the groups following intervention.

There were no adverse events reported during the intervention period.

DISCUSSION

The present study demonstrated that graded backward treadmill training improves functional recovery following ACL reconstruction with IKDC used as the primary functional outcome measure. All groups showed improvement in functional outcomes following the intervention period. Similar improvements in functional recovery have been reported following structured neuromuscular rehabilitation programs [25–28]. Backward walking may contribute to functional improvement by enhancing proprioception, neuromuscular coordination and muscle activation patterns, which are essential components of ACL rehabilitation [29–31].

Between-group comparison showed that Group D demonstrated the greatest improvement in functional outcomes. This finding may be attributed to the increased neuromuscular demand associated with higher treadmill inclination, which may have resulted in greater functional adaptation. Previous studies suggest that progressive rehabilitation intensity and task-specific loading improve functional outcomes following ACL reconstruction [32–35].

All groups demonstrated improvement in ACL-QOL scores following the intervention. However, the presence of significant baseline differences between groups suggests that these improvements may not be solely attributable to the intervention. Therefore, the observed changes in quality of life should be interpreted with caution [36–39]. Patient-reported outcome measures such as IKDC and ACL-QOL remain important indicators of rehabilitation success as they reflect the patient's perception of recovery and functional ability [40–42].

From a clinical perspective, the findings of this study suggest that graded backward treadmill training may be incorporated into ACL rehabilitation programs to improve functional recovery. Backward walking provides a safe closed kinetic chain rehabilitation strategy that may enhance neuromuscular recovery while minimizing excessive joint loading [43,44].

The present study had certain limitations including small sample size, short intervention duration, lack of long-term follow-up and absence of blinding. Future studies should include larger sample sizes and longer follow-up periods to evaluate long-term functional outcomes and return-to-sport outcomes following backward walking rehabilitation.

CONCLUSION

Graded backward treadmill training appears to be an effective rehabilitation intervention for improving functional knee outcomes following ACL reconstruction. However, improvements in quality of life should be interpreted with caution due to baseline differences between groups. Higher treadmill inclinations demonstrated superior improvements suggesting the importance of progressive rehabilitation intensity.

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