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Effect Of Plyometric Exercises On Lower Limb Functions Following Pediatric Burn

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Abstract
Background: *Burn injuries rank among the most devastating traumas and represent a major global public health crisis.* ***Objectives****: This study was conducted to evaluate the effects of a plyometric exercise program on lower-limb range of motion (ROM), muscle strength, and overall lower-limb function in pediatric burn patients.* ***Patients and Methods****: Sixty-eight patients (aged 7–15 years) with second-degree leg burns covering 3–10% of total body surface area were enrolled and randomly assigned to two equal groups. Group A (n = 34) received plyometric exercises in addition to a traditional physical therapy program; Group B (n = 34) received only the traditional program and served as the control. All participants underwent 20–30-minute sessions, 2–3 times weekly, over eight weeks. Measurements were taken at baseline and following the final treatment session. Quadriceps and hamstring strength were assessed with a handheld dynamometer, knee-extension ROM was measured using a standard goniometer, and lower-limb function was evaluated via the Lower Extremity Functional Scale (LEFS).* ***Results****: Group A demonstrated significantly greater improvements than Group B (p < 0.001). Quadriceps strength rose by 61.9% in Group A compared to 32.58% in Group B; hamstring strength increased by 60.88% versus 41.59%. Knee-extension ROM improved by 80.96% in Group A and 47.27% in Group B. LEFS scores increased by 196.21% in Group A versus 92.59% in Group B.* ***Conclusion:*** *It was concluded that the plyometric exercises was effective in improving lower limb strength, ROM and functions.*

Keywords: *Burn, Plyometric Exercises, Pediatric.*

INTRODUCTION

Pediatric burn injuries represent a great worldwide health problem, typically increase in low- and middle-income countries, where children are frequently exposed to hazards such as scalds from hot liquids, open flames, and electrical sources. Burns affecting the lower extremities are particularly impactful, often resulting in prolonged immobility, scar formation, and muscle atrophy, which collectively impair functional mobility and hinder the child's independence. Since children are in the critical stages of physical and motor development, early and targeted rehabilitation interventions are essential to support recovery, reduce long-term complications, and promote normal growth and functional reintegration.(1)(2)

Conventional rehabilitation programs for pediatric burn survivors often emphasize range-of-motion exercises, passive stretching, and basic muscle strengthening to preserve joint flexibility and prevent contractures. While these methods are effective in supporting foundational recovery, they may fall short in restoring dynamic motor abilities such as jumping, running, and balance control, which are essential for age-appropriate mobility, play, and social engagement. Consequently, there is a growing recognition of the need for more intensive and developmentally tailored interventions that target higher-level functional skills and promote full reintegration into daily physical and recreational activities among children recovering from lower limb burn injuries.(3)

Plyometric training, characterized by rapid and explosive movements that engage the muscle stretch-shortening cycle, has been shown to enhance muscle strength, motor coordination, and neuromuscular control in both typically developing children and those with motor impairments. Incorporating such exercises into pediatric burn rehabilitation may offer additional benefits by targeting power generation, balance, and agility domains that conventional therapy may not fully address. However, given the sensitivity of healing tissues and the distinct developmental and psychological considerations in children, the application of plyometric exercises in this population must be approached with caution. Rigorous evaluation is necessary to ensure these interventions are both safe and effective for burn-injured pediatric patients. (4)(5)

This study aimed to investigate the effectiveness of a structured plyometric exercise program in improving lower limb function among pediatric patients recovering from burn injuries. By evaluating pre- and post-intervention changes in muscle strength, range of motion (ROM), and functional mobility, the research seeks to determine whether plyometric training offers added benefits beyond those achieved through conventional rehabilitation protocols. The findings are expected to provide valuable evidence to inform clinical practice in pediatric burn rehabilitation, supporting the incorporation of dynamic, developmentally appropriate, and play-based exercises that may enhance quality of life and promote long-term physical development in children affected by lower limb burns.

SUBJECTS, MATERIAL AND METHODS

Subjects

A total of sixty-eight pediatric patients, aged between 7 and 15 years and diagnosed with lower limb burns, were participated in the study. All patients had the right to go out from the study at any time. Eligible children and their parents received comprehensive oral and written information regarding the study's objectives, procedures, and duration. Informed consent was obtained from patent or their parents. Patients were then randomly assigned into two equal sized groups. The study was conducted from April to June 2025 in the Departments of Physical Therapy and Rehabilitation at Mansoura International Hospital, Mansoura, Egypt, and Zefta General Hospital, Zefta, Egypt.

Group A (plyometric exercises):

This group composed of 34 pediatric patient and received plyometric exercise for 20 to 30 minutes in addition to traditional physical therapy programs in the form of ROM exercises, stretching, and strengthing exercise for 20 to 30 minutes, eight successive weeks, three sessions per week.

Group B (control):

This group composed of 34 pediatric patient and received a traditional physical therapy program in the form of ROM exercises, stretching, and strengthening exercises for 20 to 30 minutes, eight successive weeks, and three sessions per week.

Inclusion criteria

1- Age ranged from 7 to 15 years old.
2- Patients with posterior lower limb burn affecting hamstring and quadriceps strength.
3- Total surface area affected equals 3 to 10 percent.
4- Healed Second degree burn child.
5- Knee joint ROM was affected.

Exclusion criteria

1. Concomitant Psychiatric disorders including major depression, anxiety, or personality disorders.
2. Patients with fractures and joint injuries .
3. Patients with neurological problems .
4. Orthopedic deformities of lower limb
5. Sever Cardiac diseases.

6. Lymphedema .
7. Patients who had previous surgical procedures which may affect the results of the study.

Ethical considerations :
This study was conducted according to the ethical principles and was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University with number P.T.REC/012/005681. The study was also registered on ClinicalTrials.gov with the identifier NCT06932913. Informed consent was assigned from the parents of all patients prior to starting the study. Confidentiality and the right to withdraw from the research at any time were ensured for all participants.

- **Sample size calculation:**
- Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) based on data of knee extensors strength derived from Abd Elsabour et al., 2025 and revealed that the required sample size for this study was 34 subjects in each group. Calculation was made with α=0.05, power = 90% and effect size = 0.8.

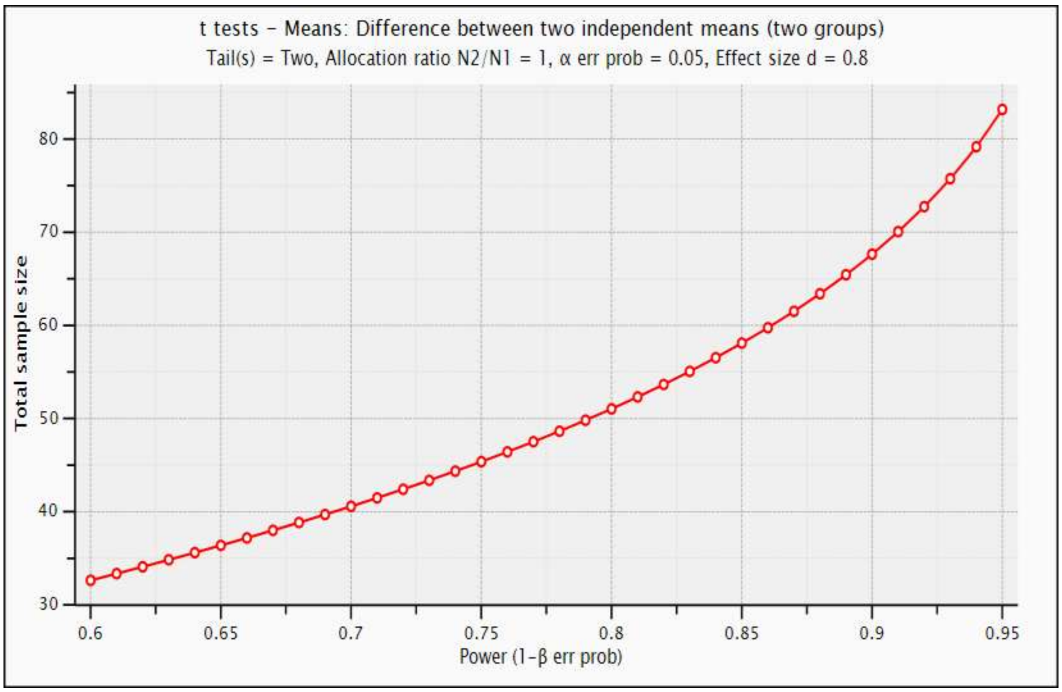

Figure (1). Chart for sample size calculation.

THE MEASURING EQUIPMENT:

Goniometer: for measuring knee extension ROM :
The universal goniometer (Whitehall Manufacturing, City of Industry, CA, USA) has a transparent plastic 360° face, two movable arms, and a 1° gradation.
Hand held dynamometer :
Ser.n.01165 Lafayette manual muscle tester (made in the USA) that was used for muscle strength evaluation.
Lower Extremity Functional Scale (LEFS)
LEFS is a commonly applied questionnaire that was used to measure the degree of physical limitation in patients. Recognized for its strong psychometric properties, including reliability, validity, and

responsiveness, the LEFS consists of 20 tasks, each rated on a scale from 0 (unable to perform) to 4 (no difficulty). The total score, ranging from 0 to 80, reflects the individual's overall level of lower limb function, with higher scores indicating better performance and function. The final score is calculated by summing the responses to all items, with a maximum score of 80 representing full functional ability. (6)(7)(8)

THERAPEUTIC PROCEDURES:

Group A:

Patients in Group A underwent a combined intervention consisting of traditional physiotherapy followed by a plyometric training program. Each session lasted approximately 40 to 60 minutes, with 20–30 minutes dedicated to standard physical therapy and an additional 20–30 minutes focused on plyometric exercises. This regimen was administered two to three sessions per week over a total period of eight weeks.

a)Wall jumps :the child was asked to stand up facing the wall with both hands supported on the wall and asked to try to jump upward as he could while the therapist proximal hand support knee joint and the other hand support the ankle joint. Then he asked to try to jump in different directions forward, backward and side to side.

b) **Bounding in place** : From position of exercise (a) the child was asked to alternate raise lower limbs and increase speed of till reach Jump from one leg to the other straight up and down .

c) **Squat jumps**: From position of exercise (a) the child was asked to jump upward as he could then land in squat position.

d) **Stairs jump;** started with the child stand on a stair and encourage him to jump on the ground

e) **Single leg jump distance**: the child was asked to stand up on one leg facing the wall with both hands supported on the wall then the child try to jump upward as he can, starting with the non-affected leg to encourage the affected one.

f) **Tuck jumps**: From position of exercise (a) the child was asked to jump and bring both knees up to chest as possible as he can. (9)(10)

Table (1): Progression of plyometric exercise.

weeks	exercises	Duration
1-2	wall jump, horizontal jump, forward-backward jumps	5-8 reps for each task
3-5	Week one to two exercise + Squat jump, Bounding in place, Stairs jump	6-10 reps for each task
6-8	Week 3 to five exercises + Tuck jump , Single leg jump distance	4-10 reps for each task

GROUP B: TRADITIONAL PHYSIOTHERAPY PROGRAM

Patients in Group B received a standardized traditional physiotherapy protocol, administered three times per week over a period of eight consecutive weeks. Each session lasted approximately 20 to 30 minutes and was designed to improve knee mobility and hamstring flexibility and strength. The intervention included the following components:

1. **Active Range of Motion (AROM) Exercises for the Knee Joint**

These exercises were performed to enhance dynamic mobility and joint function:

A. Knee Flexion: From a prone lying position, the child was instructed to bend the knee by drawing the heel toward the buttocks to the extent possible, creating a gentle stretch across the anterior thigh and knee. The child then returned to the starting position.
B. Knee Extension: While seated at the edge of a plinth, the child extended the knee by lifting the foot upward toward the ceiling, stretching the hamstring muscles, and then returned to the initial position.

C. Hip and Knee Bend: The child was asked to point the toes upward, bend the knees toward the chest as much as tolerated, and then straighten the legs to return to a supine position on the bed.

2. Hamstring Stretching

In a long-sitting position with knees fully extended, the child was encouraged to reach forward and touch the toes, maintaining the stretch for as long as possible to promote flexibility of the hamstring muscles.

3. Strengthening Exercises

Targeted exercises were used to build hamstring and quadriceps strength:

A. Straight Leg Raise: While lying supine, with one leg bent and the other straight, the child was asked to point the toes toward the ceiling, maintain a straight knee, and lift the leg to approximately 45 degrees, then lower it slowly without allowing it to drop.
B. Resisted Knee Extension: From a seated position on the edge of a plinth, the child performed knee extension against mild to moderate manual resistance applied to the anterior shaft of the tibia.
C. Resisted Knee Flexion: In the prone position, the child was instructed to flex the knee while manual resistance was applied to the posterior aspect of the lower leg.

DATA ANALYSIS

Unpaired t-tests were utilized to compare the baseline characteristics of participants between the two groups, while the Chi-squared test was employed to analyze differences in sex distribution. The normality of the data was assessed using the Shapiro–Wilk test, and Levene's test was applied to evaluate the homogeneity of variances between groups. A mixed-design multivariate analysis of variance (MANOVA) was conducted to examine both within-group and between-group effects on knee extensor and flexor strength, knee extension range of motion (ROM), and Lower Extremity Functional Scale (LEFS) scores. When significant effects were detected, post-hoc analyses were performed using the Bonferroni correction to adjust for multiple comparisons. A p-value of less than 0.05 was considered statistically significant for all tests. Data analysis was carried out using IBM SPSS Statistics version 25 for Windows (IBM Corp., Armonk, NY, USA).

RESULTS

Subject characteristics:

sixty-eight children with lower limb burns participated in this study. Table (2) shows the subject characteristics of group A and B. There was no significant difference between groups in age, TBSA, and gender distribution ($p > 0.05$).

Table 2. Subject characteristics.

	Group A	Group B	MD	t- value	p-value
	Mean ± SD	Mean ± SD			
Age (years)	10.12 ± 2.31	10.44 ± 2.22	-0.32	-0.59	0.56
TBSA of lower limb (%)	6.09 ± 1.83	5.97 ± 1.45	0.12	0.29	0.77
Sex, n (%)					
Girls	16 (47%)	14 (41%)		$\chi^2 = 0.23$	0.63
Boys	18 (53%)	20 (59%)			

SD, standard deviation; MD, mean difference; χ^2, Chi squared value; p-value, level of significance

EFFECT OF TREATMENT ON KNEE EXTENSORS AND FLEXORS STRENGTH, KNEE EXTENSION ROM AND LEFS:

WITHIN GROUP COMPARISON

There was a significant increase in extensors and flexors strength in both groups post treatment compared with that pre treatment ($p < 0.001$). (table 2).

There was a significant increase in knee extension ROM and LEFS in both groups post treatment compared with that pre treatment ($p < 0.001$). (table 3).

BETWEEN GROUPS COMPARISON:

There was no significant difference between groups pre-treatment ($p > 0.05$). Comparison between groups post treatment revealed a significant increase in strength of extensors (ES = 0.98) and flexors (ES = 1.45), knee extension ROM (ES = 3.63) and LEFS (ES = 4.4) of group A compared with that of group B ($p < 0.001$). (Table 2-3).

Table 3. Mean extensors and flexors peak torque pre and post treatment of group A and B:

Strength (lb)	Group A	Group B			
	Mean ±SD	Mean ±SD	MD (95% CI)	P value	ES
Extensors					
Pre treatment	22.65 ± 3.60	23.06 ± 3.02	-0.41 (-2.02: 1.20)	0.61	
Post treatment	36.44 ± 3.60	32.65 ± 4.10	3.79 (1.93: 5.66)	0.001	0.98
MD (95% CI)	-13.79 (-15.32: -12.26)	-9.59 (-11.12: -8.05)			
% of change	60.88	41.59			
	p = 0.001	*p = 0.001*			
Flexors					
Pre treatment	15.31 ± 1.50	15.56 ± 1.85	-0.25 (-1.07: 0.57)	0.54	
Post treatment	24.79 ± 2.68	20.63 ± 3.06	4.16 (2.77: 5.56)	0.001	1.45
MD (95% CI)	-9.48 (-10.13: -8.83)	-5.07 (-5.72: -4.42)			
% of change	61.92	32.58			
	p = 0.001	*p = 0.001*			

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Level of significance; ES, Effect size

Table 4. Mean knee extension ROM and LEFS pre and post treatment of group A and B:

	Group A	Group B			
	Mean ±SD	Mean ±SD	MD (95% CI)	P value	ES
Knee extension ROM (degrees)					
Pre treatment	21.38 ± 4.88	19.97 ± 4.96	1.41 (-0.97: 3.79)	0.24	
Post treatment	4.07 ± 1.72	10.53 ± 1.83	-6.46 (-7.31: -5.60)	0.001	3.63
MD (95% CI)	17.31 (15.70: 18.91)	9.44 (7.83 to 11.05)			
% of change	80.96	47.27			
	p = 0.001	*p = 0.001*			
LEFS					
Pre treatment	25.32 ± 4.23	26.59 ± 3.77	-1.27 (-3.20: 0.67)	0.19	
Post treatment	75.00 ± 5.94	51.21 ± 4.82	23.79 (21.17: 26.41)	0.001	4.4
MD (95% CI)	-49.68 (-51.49: -47.86)	-24.62 (-26.43: -22.81)			
% of change	196.21	92.59			
	p = 0.001	*p = 0.001*			

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Level of significance; ES, Effect size

DISCUSSION

This research evaluated the effectiveness of a plyometric exercise program in enhancing lower limb function among pediatric burn patients during rehabilitation. The intervention resulted in significant improvements in hamstring and quadriceps strength, alongside noticeable gains in functional mobility, as measured by the Lower Extremity Functional Scale (LEFS). These improvements highlight the potential of plyometric training as a therapeutic modality capable of mitigating the muscle weakness and functional impairments that are commonly observed in children following burn injuries.

Pediatric burn injuries, especially those involving the lower limbs, are frequently associated with extended periods of immobilization, contributing to muscle wasting, joint stiffness, and disruption of neuromuscular control (11)(12). Key muscle groups such as the quadriceps and hamstrings are particularly at risk due to their crucial role in weight-bearing and locomotion. The observed improvements in strength within these muscle groups in the current study may be explained by the physiological principles underlying plyometric training, particularly the stretch-shortening cycle, which facilitates increased motor unit activation, storage of elastic energy, and improved neuromuscular efficiency. (13)

Previous research has reported comparable findings regarding the benefits of plyometric training. For example, **Lee et al. (2020)** demonstrated that a six-week plyometric intervention led to significant gains in knee extensor strength and neuromuscular control in children with cerebral palsy (16). Although the underlying condition differs from burn-related injuries, both groups share common deficits in muscle strength and functional movement, supporting the general effectiveness of plyometric exercise in pediatric populations. Moreover, a meta-analysis conducted by **Hammami et al. (2020)** involving athletic and clinical pediatric cohorts confirmed that plyometric interventions consistently enhance lower limb muscle strength, particularly in the quadriceps and hamstrings, findings that align closely with those of the present study (15).

In another relevant study, **Al-Mohrej et al. (2019)** observed significant improvements in balance and lower extremity performance among children recovering from thermal burns after undergoing plyometric training. These functional gains were attributed to enhanced proprioception, improved motor coordination, and increased activation of fast-twitch muscle fibers. Such results further reinforce the current study's conclusions and emphasize the value of integrating plyometric exercises into rehabilitation protocols for pediatric burn survivors (16).

Fergason et al. (2020) reported that incorporating explosive functional movements like jumps and hops into rehabilitation improved muscular power and neuromuscular control in pediatric burn survivors. Their findings showed significant gains in lower extremity strength and agility after a structured plyometric program, which align with the improvements observed in the current study.(17)

Plyometric exercises offered a dynamic and engaging method to improve functional recovery in pediatric patients with burn-related lower limb impairments. These exercises utilize the stretch-shortening cycle, promoting powerful muscular contractions that enhance neuromuscular efficiency, muscle strength, and explosive power. Pediatric burn patients, who often exhibit reduced muscle mass, restricted joint mobility, and poor balance due to prolonged inactivity and scar formation, may particularly benefit from such interventions. Plyometric movements encourage active joint loading, stimulate neuromuscular pathways, and improve balance and proprioception all of which are crucial for regaining independent mobility. When systematically introduced within a broader rehabilitation framework, plyometric training has the potential to accelerate functional gains and support reintegration into age-appropriate physical activities, including climbing stairs, jumping, and active play.

The improvements in LEFS scores provide further evidence of the clinical relevance of these functions gained. LEFS is a validated patient-reported outcome measure that assessed the child's ability to perform functional tasks such as climbing stairs, walking, and squatting activities that are critically dependent on adequate quadriceps and hamstring functions. The post-intervention improvements in LEFS scores suggest that the gains in muscle strength translated into tangible improvements in daily function and participation, which is a central goal of pediatric rehabilitation.

Moreover, this study supports the integration of plyometric training into rehabilitation protocols not only for its physical benefits but also for its potential to enhance motivation and engagement in pediatric patients. Plyometric drills are often perceived as more dynamic and enjoyable compared to traditional resistance exercises, which may contribute to better adherence and long-term functional gains. (18)

While the findings of this study are encouraging, several limitations must be acknowledged. Firstly, the relatively short intervention period (approximately 6–8 weeks) restricts the ability to draw conclusions regarding the long-term retention of strength gained and functional improvements. Secondly, although handheld dynamometry provided objective measures of muscle strength, future research may benefit from employing isokinetic testing, which offers more detailed and precise strength assessment. Lastly, the lack of extended follow-up prevents evaluation of whether the observed improvements in LEFS scores are sustained over time, or whether they contribute to a lower risk of re-injury and better reintegration into daily activities, such as school or play.

In summary, the findings of this study support the use of plyometric training as a safe and effective intervention for enhancing quadriceps and hamstring strength and improving lower extremity function in children recovering from burn injuries. The results underscore the value of integrating dynamic, neuromuscular-focused exercises into pediatric rehabilitation programs to facilitate faster recovery and achieve functional gains that are meaningful to daily activities. Future investigations should focus on examining the long-term effects of plyometric interventions, identifying the optimal training parameters, and evaluating their efficacy in comparison to other conventional or advanced rehabilitation strategies.

CONCLUSION:

This study concludes that plyometric training is an effective intervention for enhancing lower limb flexibility and functional performance in children with burn injuries affecting the lower extremities. The significant improvements observed in knee extension range of motion (ROM) and Lower Extremity Functional Scale (LEFS) scores provide strong evidence of the program's therapeutic benefit. These findings contribute to the development of a scientifically grounded rehabilitation protocol that can assist physical therapists and surgeons in managing hamstring tightness and mobility restrictions commonly encountered post-burn. Implementing such an approach may support the design of targeted care plans aimed at preventing complications such as pain, functional decline, and knee stiffness, ultimately enhancing the quality of life for pediatric burn survivors.

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