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Effect of upper body plyometric training on fitness and trunk balance in wheelchair athletes – an experimental study

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Abstract
Introduction. **From the Paralympics in the 1960s to the 2020 Games wheelchair sports have seen a surge in participation. Athletes heavily rely on their upper extremities and trunks for strength and power, yet optimizing these aspects, particularly in terms of sprint efficiency, remains a gap. Plyometric training, known for enhancing power, is underutilized in wheelchair athlete programs. This study investigates upper extremity plyometrics' impact on wheelchair athletes' fitness and balance, addressing the gap.** Aim of Study. **To evaluate the effect of upper extremity plyometrics in wheelchair athletes by evaluating their fitness components and balance.** Material and Methods. **Data for this experimental study was collected from wheelchair athletes aged 18-45 from various locations, with a sample size of 22 subjects determined by using purposive sampling. Tools included a stopwatch, a dynamometer, cones, and tape. Inclusion criteria were two years of experience, excluding certain health conditions. The study, approved by the Institutional Ethical Committee, evaluated upper extremity plyometrics' effects on athletes' fitness and balance.** Results. **The plyometric training program led to significant improvements in all five parameters in 22 elite wheelchair athletes ($p < 0.001$). The participants, with a mean age of 30.5 ± 4.31 years, of whom 59.1% were male and 41% were female, showed notable gains. Handgrip strength increased in both hands, and medicine ball throw distances extended significantly. A biceps curl-up test showed a significant increase in curl-ups. Sprint times improved, and trunk balance enhanced in forward, bilateral, and lateral reaches. These results were statistically validated by a paired t-test [$t(21) = 21.0$, $p < 0.001$], confirming the program's effectiveness.** Conclusions. **The study indicates that a 4-week upper extremity plyometric intervention significantly boosts wheelchair athletes' fitness and trunk balance, enhancing overall performance and potentially sustaining sports participation. The recommendation is to incorporate upper body plyometrics into wheelchair athletes' routines to enhance performance and prevent injuries, focusing on strength, power, and balance. Further research is needed to explore long-term effects and optimal implementation strategies.**

KEYWORDS: athletes, wheelchairs, plyometrics, postural balance, sports for persons with disabilities, accident prevention.

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Introduction

In the dynamic landscape of wheelchair sports, where athletes use their upper limbs to propel themselves through rigorous competition, prevalence of injuries looms large as a significant concern in the 2020 Games. Wheelchair athletes heavily rely on their upper extremities and trunks for propulsion, passing, and balance, placing substantial demands on their strength and power [1]. The nature of wheelchair sports, whether it is intense propulsion in basketball or physical contact in rugby, exposes athletes to unique stresses, particularly on their shoulders, wrists, and hands [2, 3]. This can lead to injuries, ranging from ailments resulting from overuse, like tendonitis and carpal tunnel syndrome, to acute strains, sprains, and fractures, which are all very common among wheelchair athletes.

Studies have shown that shoulder injuries are widespread among wheelchair athletes, with prevalence rates ranging from 30% to 73%, depending on a sport and level of competition. Wheelchair basketball and rugby players often experience the highest incidence of shoulder injuries due to demands of pushing, reaching, and blocking during gameplay [4, 8]. This reliance, combined with physiological adaptations observed in response to wheelchair sports, underscores a critical need for understanding unique requirements for optimal athletic performance [9]. Despite advancements in wheelchair designs tailored to individual athletes and specific sports disciplines, a concerning trend of increased musculoskeletal injuries persists, particularly affecting the shoulder complex [10]. Acknowledging these challenges, it becomes evident that addressing the specific needs of wheelchair athletes is paramount. Upper limb plyometric training is a targeted approach aimed at enhancing strength, power, and coordination through rapid muscle contractions. By incorporating plyometric exercises such as medicine ball throws and resistance band work tailored to wheelchair propulsion biomechanics, athletes can not only improve performance, but also reduce injury risks.

However, despite the evident benefits, a gap persists in understanding and optimizing upper extremity function and stability in wheelchair athletes. Shoulder complaints are prevalent, underscoring urgency for interventions that improve upper body strength and balance. While trunk function is recognized as pivotal, much remains to uncover regarding its role in sprint efficiency and overall athletic performance [11, 12]. To address the specific needs of wheelchair athletes and mitigate a risk of injury, incorporating upper limb plyometric training into their conditioning regimen is essential. Plyometric exercises focus on rapid muscle contractions, improving power, speed, and coordination. For wheelchair athletes, plyometric training can enhance upper limbs strength and endurance, improving performance while reducing the risk of injury [12-15].

Implementing a structured plyometric training program requires careful consideration of an individual athlete's needs, including their sport, functional abilities, and injury history [15, 16]. Working with experienced coaches and rehabilitation professionals can help to tailor a program that addresses specific strengths and weaknesses while minimizing a risk of overtraining or exacerbating existing injuries [17]. Our study delves into an impact of upper extremity plyometrics on fitness and balance of wheelchair athletes, an area that has not been thoroughly explored.

The present study aims to make a significant contribution to advancement of injury prevention and performance enhancement in wheelchair sports, thereby elevating a level of care and support provided to athletes in this community. Through introduction and refinement of preventive measures and performance enhancing techniques, the aim is to safeguard well-being of wheelchair athletes while facilitating their attainment of peak performance levels. Investigating a response of wheelchair athletes to an upper body plyometric intervention is aimed to optimize performance outcomes and have an impact on development of rehabilitation strategies specifically tailored to this unique population. These efforts will hopefully bridge the existing gaps in understanding and address the specific needs of wheelchair athletes, thereby promoting inclusivity and excellence in adaptive sports on a broader scale.

Aim of Study

To evaluate the effect of upper extremity plyometrics in wheelchair athletes by assessing their fitness components and balance.

Material and Methods

Participants

The study received the ethical approval from the University's Institutional Ethical Committee (Research Code: 752/29.06.2022) and was registered in the Clinical Trials Registry of India (CTRI Number: CTRI/2022/09/045474). A total of 22 wheelchair athletes (13 males and 9 females) from different areas of Belagavi participated in this 4-week experimental study, with data collection taking place at various locations including cricket academies, basketball courts, and a district ground of Belagavi. The participants, aged between 18 and 45 years (mean age 30.5 ± 4.31 years), were included if they had at least 2 years of experience in wheelchair sports, trained at least three times a week, and expressed willingness to participate. Exclusion criteria ensured that individuals with systemic diseases, mental or cognitive impairments, upper limb disabilities, shoulder joint pathologies, or a history of upper limb surgery were not included. This rigorous selection process was designed to create a diverse, yet homogeneous group of participants that would provide meaningful insights into an impact of upper body plyometric training on wheelchair athletes. Screening was conducted by a single investigator, with dominance considered during evaluation. Informed consent was obtained from all participants according to ethical guidelines. A sample size calculation, based on previous research by Ferreira et al. [5], determined that a minimum of 22 participants was necessary to achieve a statistical power of 0.8 at a bilateral α level of 0.05.

Procedures

Measurements were consistently taken by the same investigator throughout the study to ensure reliability. The participants engaged in a 4-week upper body plyometric training program consisting of a total of 12 sessions. Each session involved a series of exercises, with the participants performing 10 repetitions in 3 sets for a total of 4 prescribed exercises per session. Various tools, instruments, and equipment were utilized, including a stopwatch, a Jamar dynamometer, marking cones, a measuring tape, dumbbells (2.5 kg, 5 kg), and medicine balls (2 kg, 3 kg). During the first 2 weeks of the intervention, the participants used 1 kg and 2 kg medicine balls, progressing to a 3 kg medicine ball in subsequent weeks to increase intensity. Additionally, battle rope activities and dumbbell exercises were integrated into the training regimen to provide diverse stimuli.

Outcome measures were assessed both before and after the intervention and included a handgrip test, medicine ball throw test, biceps curl-up test, sprint test, and trunk balance test. A comprehensive training protocol detailing exercise selection, repetitions, sets, and equipment utilization is provided in Tables 1 and 2. This meticulously structured upper body plyometric training protocol was designed to enhance the participants' upper extremity strength, power, and balance, with an overarching goal of improving their overall fitness and performance levels.

Table 2. Recommended intervention parameters

Recommended parameters	Plyometric training program
frequency	3 times a week
intensity	80-100%
type	isolated to multijoint exercises
duration	4 weeks, 40-60 minutes/session
repetitions	5-10 repetition/set
sets	3 sets/exercise
pattern	minimum 4 different exercises/session
rest interval	48 hours between workout sessions

Handgrip test

The Jamar dynamometer was utilized to conduct the handgrip test, a reliable and valid measure of upper extremity strength. Test-retest reliability, with an Intraclass Correlation Coefficient (ICC) ranging from 0.90 to 0.98, and intrarater reliability exceeding 0.90, were established. The participants were comfortably seated in their wheelchairs, maintaining proper posture with shoulders adducted and neutrally rotated, elbows flexed at 90 degrees, and forearms in a neutral position. They were instructed to grip the dynamometer with

Table 1. Exercise protocol for plyometric intervention

	Session 1	Session 2	Session 3
Week 1	medicine ball chest pass 90-90 throw biceps curl-ups one-hand sidearm throw	overhead throw one-hand ball throw triceps push-ups wrist flexor flips	two-hand overhead rotations trunk rotation trunk flexion wrist extensor flips
Week 2	medicine ball chest pass 90-90 throw biceps curl-ups one-hand sidearm throw	overhead throw one-hand ball throw triceps push-ups wrist flexor flips	two-hand overhead rotations trunk rotation trunk flexion wrist extensor flips
Week 3	overhead slams static chest pass rotational slams battle rope forward slams	underhand throw rotational scoop throw one-hand sidearm throw battle rope sideways slams	biceps curl-ups battle rope crossover slams wrist flexor flips wrist extensor flips
Week 4	overhead slams static chest pass rotational slams battle rope forward slams	overhead slams static chest pass rotational slams battle rope forward slams	biceps curl-ups battle rope crossover slams wrist flexor flips wrist extensor flips

maximal force for approximately three seconds. Each participant underwent three trials for each hand, with short rest intervals in between to minimize fatigue. The highest recorded value of each hand was used for analysis. This standardized protocol ensured consistency and accuracy in assessing handgrip strength in the wheelchair athletes, providing valuable insights into their upper extremity capabilities [7].

Medicine ball throw test
The medicine ball throw test serves as a valuable assessment of upper extremity power in wheelchair athletes. The participants were seated in a wheelchair with their backs against a backrest and were instructed to throw a medicine ball as far as possible. A minimum rest period of 30 seconds was applied between each trial to minimize fatigue. Distances covered by the thrown ball were measured using a standard measuring tape, and the best distances from two trials were recorded for analysis. This standardized protocol ensured a reliable evaluation of upper extremity power, providing meaningful insights into performance capabilities of the wheelchair athletes [12].

Biceps curl-up test
The biceps curl-up test was employed to evaluate upper extremities endurance in the wheelchair athletes. The participants were seated, grasping a weight in their palm using a suitcase grip, with their arms hanging vertically down alongside the wheelchair. The subjects were directed to perform a curling motion, bringing their arm up through its full range of motion until the palm was facing upward. A number of repetitions completed to a point of maximum effort was meticulously recorded during the assessment. This standardized protocol provided a reliable measure of upper extremity endurance, offering valuable insights into capabilities of the wheelchair athletes in this aspect of physical fitness [14].

Sprint test
The sprint test serves as a key measure for evaluating speed of wheelchair athletes. A designated distance of 20 meters was demarcated on a floor to serve as a sprinting track. Before the test, the subjects were positioned behind a starting line. The subjects were instructed to initiate sprint on a command "GO", exerting maximum effort to cover the distance and cross a finish line as quickly as possible. The time taken to complete the sprint was accurately recorded using a stopwatch or a timing device. This standardized procedure ensured a reliable assessment of sprint speed in the wheelchair athletes, providing valuable data for research and performance evaluation purposes [11].

Trunk balance test
To evaluate trunk balance in the wheelchair athletes, a comprehensive procedure consisting of a modified functional reach test, bilateral reach test, and lateral reach test was employed. Firstly, in the modified functional reach test, the participants were seated comfortably in their wheelchairs with a marker placed at shoulder height on a nearby wall. Instructed to extend their arm forward while maintaining contact with the wheelchair, the participants aimed to achieve maximal reach without any trunk movement. A distance between the initial hand position and the marker represents functional reach. Subsequently, in the bilateral reach test, the participants were seated in their wheelchairs and instructed to reach out with both arms simultaneously, aiming for maximal extension without trunk displacement. Measurements of distances between the initial hands' positions and the markers on each side determine bilateral reach. Finally, in the lateral reach test the seated participants reached laterally with one arm, maintaining contact with the wheelchair to assess lateral reach. Each test was repeated three times, and average scores were computed for analysis. This meticulous protocol (Tables 1 and 2) facilitated a thorough evaluation of trunk balance in the wheelchair athletes, offering valuable insights into their postural control and stability [10].

Statistical analysis
Statistical analysis was conducted using the SPSS 28.0 software (IBM® Armonk, NY, USA), with data entry and tabulation performed in Microsoft Excel. Visual methods, including pie charts, histograms, and probability graphs, along with analytical methods, such as the Kolmogorov–Smirnov and Shapiro–Wilk's tests, were employed to assess a normal distribution of variables. Descriptive statistics, including means ("mean") and standard deviations ("SD"), were utilized to analyze and present raw data from both pre- and post-tests. Additionally, effect sizes were computed by converting partial eta squared values to Cohen's d values. A significance level of 5% ($p < 0.05$) was established for all two-tailed tests. Paired t-tests were employed to assess improvements between the pre- and post-test measurements across all variables. This rigorous statistical approach facilitated a comprehensive evaluation of the impact of upper body plyometric training on fitness and trunk balance of the wheelchair athletes, providing valuable insights into the efficacy of the intervention.

Results

The results of the study are summarized as follows: a total of 22 subjects, with a mean age of 30.5 ± 4.31 years, and gender distribution of 13 (59.1%) males and 9 (41%) females (Figures 1 and 2), met the inclusion criteria. After four weeks of plyometric training, significant enhancements in all five outcome measures were observed in the 22 elite wheelchair athletes (p < 0.001). Notable improvements were evident in handgrip strength, with significant post-intervention increases compared to the pre-test values (Table 3). Similarly, the medicine ball throw test demonstrated the significant post-intervention improvement (Table 4). Additionally, the biceps curl test revealed the significant rise in the number of arm curl-ups completed in 30 seconds following the intervention (Table 5). The sprint test showed faster post-intervention sprint times compared to the pre-intervention assessments (Table 6). Trunk balance, assessed through the forward reach, bilateral reach, and lateral reach tests, also displayed the significant post-intervention improvement (Table 7). These findings underscore the efficacy of the intervention in enhancing various fitness components in the study cohort. The paired t-test revealed a significantly large difference between the pre- and post-intervention scores (t(21) = 21.0, p < 0.001), further confirming the effectiveness of the plyometric intervention. Overall, the results demonstrate the positive impact of upper extremity plyometrics on various fitness components and balance in the elite wheelchair athletes.

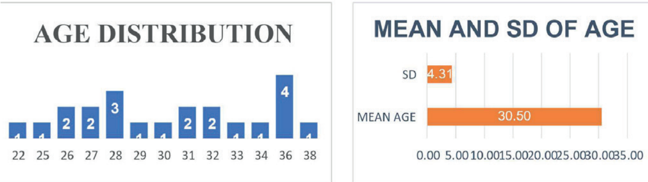

Figure 1. Age distribution

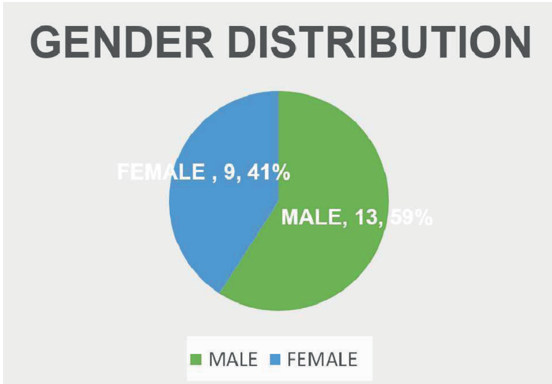

Figure 2. Gender distribution

Table 3. Comparison of handgrip strength tests

Side	Pre-intervention		Post-intervention		Difference		Effect size	t-value	p-value
	Mean	SD	Mean	SD	Mean	SD			
Right	29	7.9	34	9.65	5	4.10	1.22	4.550	0.001*
Left	27.68	8.17	33.09	9.96	5.40	4.48	4.24	4.183	0.001*

* p < 0.05

Table 4. Comparison of medicine ball throw tests

Pre-intervention		Post-intervention		Difference		Effect size	t-value	p-value
Mean	SD	Mean	SD	Mean	SD			
193.8	84.2	200.2	86.2	6.4	5.7	1.11	–7.33	0.0001*

* p < 0.05

Table 5. Comparison of right and left arm biceps curl-up tests

Side	Pre-intervention		Post-intervention		Difference		Effect size	t-value	p-value
	Mean	SD	Mean	SD	Mean	SD			
Right	31.2	7.3	35.4	7	4.18	0.90	4.61	–3.77	0.0001*
Left	30.6	7.6	35.5	6.8	4.95	2.96	1.67	–3.63	0.0001*

* p < 0.05

Table 6. Comparison of wheelchair sprint times (sec.)

Pre-intervention		Post-intervention		Difference		Effect size	t-value	p-value
Mean	SD	Mean	SD	Mean	SD			
11.2	1.4	7.7	0.9	3.5	0.9	0.7	21.0	<0.001*

* p < 0.05

Table 7. Comparison of pre- and post-intervention modified sit and reach test values

	Pre-intervention		Post-intervention		Difference		Effect size	t-value	p-value
	Mean	SD	Mean	SD	Mean	SD			
Forward right	10.7	2.4	10.9	2.5	0.2	0.1	1.07	0.287	0.777
Forward left	10.1	1.9	10.5	2.2	0.4	0.3	1.04	4.89	<0.001*
Bilateral	10.3	1.4	10.8	1.5	0.5	0.1	0.94	4.42	<0.001*
Lateral right	10	1.2	10.4	1.4	0.4	0.2	1.19	5.58	<0.001*
Lateral left	9.8	1	10.2	1.1	0.4	0.1	0.92	4.33	<0.001*

* p < 0.05

Discussion

The findings of this study demonstrate the significant enhancement in fitness components and trunk balance in the elite wheelchair athletes after the 4-week upper body plyometric training intervention. Sports such as wheelchair basketball, cricket, rugby and throw ball were all included in this comprehensive investigation. The purpose of implementing strength training in the wheelchair athletes was twofold: to aid in injury recovery and to address daily challenges faced by these athletes, with a primary focus on maintaining fitness levels and enhancing functional independence. Plyometric training, commonly employed to increase strength and power output in athletes, emerged as a promising intervention in this context [4, 13]. Previous research has underscored the effectiveness of upper body plyometrics in enhancing performance and muscle power [15, 16]. Specifically, the medicine ball throw test demonstrated notable improvements in power generation following plyometric training, supporting the findings of the current study [8]. Additionally, the increase in muscle endurance, as evidenced by greater repetitions in the biceps curl-up test, suggests that plyometric training contributes to improved muscular endurance over sustained periods of activity.

The reduction in wheelchair sprint time following plyometric training indicates the notable increase in upper extremity strength and power, consistent with previous studies reporting enhanced sprint speed after plyometric strength training [1]. Trunk balance, crucial in wheelchair sports, was a focal point of this study. Plyometric training aimed at improving trunk balance resulted in the peak improvements, as assessed through the modified trunk balance tests. This improvement may be attributed to alterations in proprioception and neuromuscular control, particularly in a direction-specific manner, following the plyometric intervention [6, 17]. This study represents a novel approach to using upper extremity plyometric interventions to enhance fitness and trunk balance in wheelchair athletes. The demonstrated safety and efficacy of plyometric training, when properly supervised and executed, underscore its potential as a valuable training technique for elevating performance levels of wheelchair athletes. Based on these results, it is recommended to incorporate upper body plyometric training programs into regular practice routines of wheelchair athletes. Such training not only enhances quality of athletic performance, but also aids in injury prevention. By focusing on improving upper extremity strength, power, and balance, athletes may experience greater success and longevity in their sporting endeavors. In conclusion, integrating upper extremity plyometric exercises into training regimens can be a valuable strategy for optimizing athletic abilities and well-being of wheelchair athletes. Further research is warranted to explore long-term effects and optimal implementation strategies of such training programs.

Conclusions

This study demonstrates that a 4-week upper extremity plyometric training intervention significantly enhances fitness and trunk balance in wheelchair athletes.

Additionally, the program improves overall performance levels and potentially supports sustained participation in sports over a prolonged period.

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Conflict of Interest
The authors declare no conflict of interest.

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