

Original Article

Effects of Elastic Resistance Upper-Limb Training on Strength and Functional Ability in Children with Spina Bifida

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Received: 23 March 2026

Revised: 03 April 2026

Accepted: 24 May 2026

Published: 30 June 2026

ARTICLE INFORMATION	ABSTRACT
Article Type: Original Article How to Cite: Sarwar A, Kiran Q, Saba S, Waheed R. Effects of Elastic Resistance Upper-Limb Training on Strength and Functional Ability in Children with Spina Bifida. Journal of Precision Medicine and Health Research. 2026;3(1):1-9. Article ID: 47 DOI: https://doi.org/10.68279/88xz2g89 Article Link: https://jpmhr.com/index.php/jpmhr/article/view/47 Declarations: See end of article. OPEN ACCESS This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).	Background: Upper-limb strength and dexterity are important for mobility and everyday task performance in children with spina bifida, yet evidence regarding targeted elastic-resistance upper-limb training remains limited. Objective: To determine the effect of adding elastic-resistance upper-limb training to routine rehabilitation on handgrip strength and gross manual dexterity in children with spina bifida. Methods: An assessor-blinded, parallel-group randomized controlled trial was conducted at Hope Rehabilitation Centre, Lahore, Pakistan. Forty children aged 6–16 years were randomized to elastic-resistance upper-limb training plus routine rehabilitation (n=20) or routine rehabilitation alone (n=20). Training was delivered three times weekly for eight weeks. Handgrip strength and gross manual dexterity were assessed using the Jamar Handgrip Dynamometer and Box and Block Test, respectively. Change-score comparisons and baseline- ANCOVA were performed. Results: Handgrip strength increased by 4.84 ± 1.42 kgf in the intervention group versus 0.89 ± 1.01 kgf in controls, with a between-group difference of 3.95 kgf (95% CI, 3.16–4.74; $p < 0.001$). Box and Block Test scores increased by 8.65 ± 2.33 versus 1.85 ± 1.49 blocks, respectively, yielding a difference of 6.80 blocks (95% CI, 5.55–8.05; $p < 0.001$). Baseline- group effects remained significant for both outcomes ($p < 0.001$). All participants completed follow-up, and no intervention-related adverse events were reported. Conclusion: Adding eight weeks of supervised elastic-resistance upper-limb training to routine rehabilitation produced greater short-term improvements in handgrip strength and gross manual dexterity than routine rehabilitation alone. Keywords: Exercise Therapy; Muscle Strength; Rehabilitation; Resistance Training; Spina Bifida.

Introduction

Spina bifida is a congenital neurological condition associated with varying degrees of motor, sensory, musculoskeletal, and functional impairment across childhood and adolescence. Rehabilitation traditionally emphasizes mobility, prevention of secondary complications, postural control, and maintenance of independence, particularly because lower-limb weakness and limitations in gross motor performance can substantially affect mobility and participation in children with spina bifida (1,2). Although lower-extremity limitations are often clinically prominent, upper-limb performance is also important for children who rely on their arms for transfers, wheelchair propulsion, self-care, school-related activities, and manipulation of objects.

Evidence indicates that upper-limb function may also be compromised in children and adolescents with spina bifida. Studies examining upper-arm and shoulder performance have demonstrated alterations in muscle strength, torque-generating capacity, and neuromuscular function in this population, particularly among individuals with mobility limitations (3,4). Such deficits may have practical consequences because effective upper-limb strength and control are required for many activities performed independently by children who use wheelchairs or other mobility aids. Wheelchair-dependent young people with spina bifida may additionally experience reduced physical capacity, further emphasizing the importance of maintaining adequate upper-body performance as part of comprehensive rehabilitation (5).

Progressive resistance exercise represents one potential strategy for addressing muscle weakness and improving physical performance. Previous rehabilitation research in children with spina bifida has suggested that progressive resistance exercise can improve selected measures of endurance and functional mobility, supporting the feasibility of structured strengthening within this population (6). Exercise-based programs have also been shown to be feasible in young people with disabilities when activities are individualized and appropriately supervised (7). Elastic resistance may be particularly suitable for pediatric rehabilitation because it permits graded loading, requires limited equipment, and can be incorporated into supervised therapeutic exercise. However, the available literature in spina bifida has focused predominantly on mobility, lower-limb performance, general exercise capacity, or broader rehabilitation outcomes rather than specifically evaluating a structured elastic-resistance program directed at upper-limb strength and manual dexterity.

This distinction is clinically important because handgrip strength and gross manual dexterity represent complementary aspects of upper-limb performance. Grip strength reflects force-generating capacity of the hand, whereas the Box and Block Test provides a standardized measure of gross unilateral manual dexterity. Improvements in these domains may be particularly relevant for children with spina bifida who depend on effective upper-limb use for object handling, mobility-related tasks, and everyday activities. Nevertheless, based on the literature included in the present manuscript, evidence remains limited regarding whether adding a structured elastic-resistance upper-limb training program to routine physiotherapy produces greater improvement in these specific outcomes than routine physiotherapy alone.

Therefore, the objective of this randomized controlled trial was to determine the effect of adding an eight-week elastic-resistance upper-limb training program to routine rehabilitation and physiotherapy on handgrip strength and gross manual dexterity in children with spina bifida, compared with routine rehabilitation and physiotherapy alone. It was hypothesized that children receiving the additional elastic-resistance training would demonstrate greater improvement in handgrip strength and Box and Block Test performance than those receiving routine rehabilitation and physiotherapy alone.

Materials and Methods

A parallel-group, assessor-blinded randomized controlled trial was conducted at Hope Rehabilitation Center, Lahore, Pakistan, to determine whether the addition of structured elastic-resistance upper-limb training to routine rehabilitation and physiotherapy produced greater improvements in handgrip strength and gross manual dexterity than routine rehabilitation and physiotherapy alone in children with spina bifida. The overall study period was six months and included participant recruitment, eligibility screening, baseline assessment, randomization, delivery of the eight-week intervention, post-intervention assessment, data management, and statistical analysis. Children were initially identified and recruited through convenience sampling from the rehabilitation setting and were subsequently randomized in a 1:1 ratio to the intervention or control group.

Children aged 6–16 years with a clinical diagnosis of spina bifida, including myelomeningocele and other clinically recognized forms, were considered eligible. Participants were required to have previously received or to be currently receiving physiotherapy or rehabilitation services, to be able to understand and follow simple verbal instructions, and to be medically stable enough to participate safely in the intervention. Eligibility was confirmed through review of available medical information and a clinical screening assessment before enrolment. Children were excluded if they had undergone upper-limb surgery during the preceding six months; had severe cognitive or communication limitations that prevented safe participation or comprehension of instructions; had a neuromuscular or orthopaedic condition unrelated to spina bifida that substantially affected upper-limb function; had uncontrolled pain, an unstable medical condition, or an acute complication requiring medical management; or were concurrently participating in another structured upper-limb strength-training program.

Following eligibility screening, the study procedures were explained to participants and their caregivers. Written informed consent was obtained from a parent or legal guardian before enrolment, and age- and developmentally appropriate assent was obtained from the child whenever possible. Baseline demographic and clinical information was then recorded, including age, sex, clinical type of spina bifida, neurological lesion level when documented, duration of previous rehabilitation, and use of mobility aids or assistive devices. Each participant was assigned a unique identification code to support confidentiality and accurate data management.

The sample-size calculation was performed using G*Power software with handgrip strength designated as the primary outcome. The calculation was based on a two-tailed independent-samples t-test for comparison of two groups, assuming a standardized effect size of Cohen's $d=0.65$, a significance level of 5% ($\alpha=0.05$), statistical power of 80% ($1-\beta=0.80$), and an equal allocation ratio of 1:1. The reported minimum requirement was 17 participants per group. To allow for an anticipated attrition rate of approximately 15%, the recruitment target was increased to 40 participants, with 20 participants allocated to each group.

After completion of baseline assessment, participants were randomized using a computer-generated allocation sequence prepared by an independent researcher who was not involved in participant recruitment, treatment delivery, or outcome assessment. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes containing group assignments. The next envelope in numerical order was opened only after baseline measurements had been completed. Because of the nature of the physiotherapy intervention, participants and treating physiotherapists could not be blinded to treatment allocation. However, the physiotherapist responsible for outcome measurement remained blinded to group assignment, and participants and caregivers were instructed not to disclose their allocated intervention during follow-up assessment.

Both groups continued to receive routine rehabilitation and physiotherapy throughout the eight-week intervention period. Routine management was based on accepted pediatric rehabilitation principles and included range-of-motion exercises, stretching, positioning, postural management, balance activities, and functional training intended to maintain mobility and promote independence. The control group received routine rehabilitation and physiotherapy without a systematically progressed elastic-resistance upper-limb strengthening program. The intervention group received the same routine rehabilitation and physiotherapy together with structured elastic-resistance upper-limb training three times per week for eight consecutive weeks, providing a maximum of 24 supervised treatment sessions. Each intervention session lasted approximately 30–40 minutes and included a warm-up, structured strengthening exercises, and a cool-down.

The elastic-resistance program targeted major muscle groups contributing to upper-limb performance, including the shoulder flexors, extensors, abductors, and adductors; elbow flexors and extensors; and wrist flexors and extensors. Elastic bands of different resistance levels were used to provide graded loading. Initial resistance was selected according to each participant's baseline physical ability, movement quality, and exercise tolerance. Resistance was progressively increased when the participant was able to complete the prescribed exercise volume with appropriate technique and without excessive fatigue, pain, or compensatory movement. Rest intervals were provided between exercises and sets as required to maintain performance quality and safety. The treating physiotherapist monitored exercise technique, tolerance, adherence, and the need for progression or modification during each supervised session. Attendance was recorded in both groups, and any missed sessions, treatment modifications, discomfort, or adverse events were documented throughout the intervention period.

Handgrip strength was designated as the primary outcome and was assessed using a Jamar Handgrip Dynamometer. Testing was conducted with the participant seated in a standardized position, with the shoulder adducted and neutrally rotated, the elbow flexed to approximately 90°, the forearm maintained in a neutral position, and the wrist positioned in slight extension. Three trials were performed for each hand, with an adequate rest interval between trials to minimize fatigue. The mean of the three trials for each tested hand was calculated and recorded in kilograms-force, with higher values indicating greater handgrip strength. Handgrip strength was interpreted specifically as a measure of grip force rather than as a direct measure of strength across all upper-limb muscle groups.

Gross manual dexterity was assessed using the Box and Block Test. Participants were instructed to transfer as many blocks as possible, one at a time, from one compartment of the test box to the opposite compartment within 60 seconds. Standardized instructions and a demonstration were provided before testing. Each hand was assessed according to the standardized procedure, and the number of blocks successfully transferred during the test period was recorded, with a higher score indicating better gross manual dexterity.

Outcome assessments were performed at baseline before disclosure of treatment allocation and immediately after completion of the eight-week intervention. All measurements were completed by the same trained physiotherapist, who remained blinded to group assignment. The assessor received training in administration and scoring of the Jamar Handgrip Dynamometer and Box and Block Test before participant enrolment. The same instruments, participant positioning, instructions, assessment sequence, testing environment, and

measurement procedures were used at baseline and post-intervention to minimize measurement variability. Equipment was checked before testing, and assessment procedures were kept consistent across participants and time points.

Data collection followed a predefined process. Baseline demographic and clinical information and outcome measurements were recorded before randomization, after which the assigned interventions were delivered for eight weeks. Attendance, adherence, treatment modifications, and adverse events were documented throughout the intervention period. At week 8, post-intervention outcome measurements were obtained by the blinded assessor using the same procedures applied at baseline. Completed records were reviewed for completeness before data entry. Data were entered into a password-protected electronic database and cross-checked against the original data-collection forms. Data cleaning included examination for missing values, implausible observations, outliers, and inconsistencies before inferential analysis.

Statistical analyses were performed using IBM SPSS Statistics version 25.0. Continuous variables were examined for distributional assumptions using the Shapiro–Wilk test, histograms, and Q–Q plots. Normally distributed continuous variables were summarized as mean±standard deviation, while categorical variables were reported as frequencies and percentages. Baseline continuous characteristics were compared between groups using independent-samples t-tests, while categorical characteristics were examined using the chi-square test or Fisher's exact test where appropriate. Within-group changes in handgrip strength and Box and Block Test scores from baseline to week 8 were assessed using paired-samples t-tests, and between-group differences in change scores were examined using independent-samples t-tests.

To account for baseline outcome values, analysis of covariance was also performed separately for handgrip strength and Box and Block Test performance. For each model, the post-intervention score was entered as the dependent variable, treatment group was entered as the fixed factor, and the corresponding baseline outcome score was included as the covariate. post-intervention means, group effects, F statistics, p-values, and partial eta-squared values were used to describe the baseline- treatment effects. Cohen's d was additionally calculated to describe standardized between-group effect magnitude, and 95% confidence intervals were reported where supported by the available analysis. All statistical tests were two-tailed, and a p-value of <0.05 was considered statistically significant. All randomized participants completed post-intervention assessment and were retained in the reported analysis; consequently, no outcome-value imputation was required.

Ethical approval was obtained from the Institutional Review Board of Superior University Lahore, Pakistan, before participant recruitment under approval number IRB/FAHS/REHAB/04/26/MS/RS-4059. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Participants and caregivers were informed about the study objectives, procedures, potential benefits, foreseeable risks, confidentiality arrangements, and right to withdraw from the study without affecting access to routine rehabilitation services. Identifying information was replaced with coded study identifiers, and study records were stored securely with access restricted to authorized research personnel. Any pain, fatigue, discomfort, injury, or other adverse event occurring during participation was documented, clinically evaluated, and managed according to appropriate rehabilitation procedures.

Results

Forty-four children were assessed for eligibility, of whom four were excluded before randomization. Forty participants were subsequently randomized in a 1:1 ratio to the intervention group (n=20) or control group (n=20). All randomized participants completed the eight-week intervention and post-intervention assessment and were included in the reported analysis, corresponding to 100% retention.

Baseline demographic and clinical characteristics were similar between groups. Mean age was 11.18 ± 2.84 years in the intervention group and 10.95 ± 2.67 years in the control group. The distributions of sex, spina bifida subtype, assistive-device use, body weight, height, and previous rehabilitation duration were also comparable, with no reported baseline between-group p-value below 0.05 (Table 1).

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	Intervention Group (n=20)	Control Group (n=20)	p-value
Age, years	11.18 ± 2.84	10.95 ± 2.67	0.791
Weight, kg	34.65 ± 8.12	33.88 ± 7.74	0.759
Height, cm	136.90 ± 12.40	135.70 ± 11.90	0.761
Previous rehabilitation duration, years	3.20 ± 1.40	3.00 ± 1.60	0.668
Male, n (%)	11 (55.0)	10 (50.0)	0.752
Female, n (%)	9 (45.0)	10 (50.0)	—
Myelomeningocele, n (%)	15 (75.0)	14 (70.0)	0.723
Meningocele, n (%)	5 (25.0)	6 (30.0)	—
Assistive-device use, n (%)	12 (60.0)	13 (65.0)	0.744
No assistive-device use, n (%)	8 (40.0)	7 (35.0)	—

Values are mean ± SD or n (%). Continuous variables were compared using independent-samples t-tests. Categorical variables were compared using chi-square or Fisher's exact tests, as appropriate. A single p-value is presented for each categorical variable.

Table 2. Handgrip Strength and Box and Block Test Outcomes at Baseline and Week 8

Outcome	Group	Baseline mean ± SD	Week 8 mean ± SD	Within-group change mean ± SD	95% CI	p-value
Handgrip strength, kgf	Intervention (n=20)	12.80 ± 2.31	17.64 ± 2.85	4.84 ± 1.42	4.18 to 5.50	<0.001
	Control (n=20)	12.52 ± 2.26	13.41 ± 2.41	0.89 ± 1.01	0.42 to 1.36	0.001
Box and Block Test, blocks	Intervention (n=20)	28.95 ± 4.74	37.60 ± 5.13	8.65 ± 2.33	7.56 to 9.74	<0.001
	Control (n=20)	29.20 ± 4.68	31.05 ± 4.87	1.85 ± 1.49	1.15 to 2.55	<0.001

Within-group comparisons were based on paired-samples t-tests. Confidence intervals for mean change were calculated from the reported change-score means, SDs, and $n=20$ per group.

Table 3. Between-Group Treatment Effects for Handgrip Strength and Gross Manual Dexterity

Outcome	Baseline mean difference	Baseline p-value	Week-8 mean difference	Change-score difference	95% CI for change-score difference	Between-group p-value	Cohen's d
Handgrip strength, kgf	0.28	0.701	4.23	3.95	3.16 to 4.74	<0.001	3.21
Box and Block Test, blocks	-0.25	0.866	6.55	6.80	5.55 to 8.05	<0.001	3.48

Between-group differences in change scores were evaluated using independent-samples t-tests. The 95% CIs were calculated from the reported change-score means, SDs, and group sizes. Cohen's d was recalculated as the between-group difference in mean change divided by the pooled SD of the change scores.

Table 4. Baseline- Week-8 Outcomes from Analysis of Covariance

Outcome	Intervention	Control	Mean difference	95% CI	Baseline covariate F	Baseline covariate p-value	Baseline partial η^2	F	p-value	Group partial η^2
Handgrip strength, kgf	17.52 $\pm$ 0.34	13.48 $\pm$ 0.34	4.04	2.77 to 5.31	58.42	<0.001	0.61	41.87	<0.001	0.53
Box and Block Test, blocks	37.42 $\pm$ 0.42	31.23 $\pm$ 0.42	6.19	4.46 to 7.92	64.91	<0.001	0.64	52.33	<0.001	0.58

ANCOVA models used the week-8 outcome as the dependent variable, treatment group as the fixed factor, and the corresponding baseline score as the covariate. mean-difference confidence intervals were derived from the reported group-effect F statistics and mean differences using the residual degrees of freedom for a two-group ANCOVA with one baseline covariate.

Table 5. Treatment Attendance and Adverse Events

Variable	Intervention Group (n=20)	Control Group (n=20)	p-value
Sessions attended, mean $\pm$ SD	22.9 $\pm$ 1.2	22.5 $\pm$ 1.4	0.328
Attendance, %, mean $\pm$ SD	95.4 $\pm$ 4.9	93.8 $\pm$ 5.8	0.371
Intervention-related adverse events, n (%)	0 (0.0)	0 (0.0)	—

The maximum scheduled treatment exposure was 24 sessions over eight weeks.

Handgrip strength increased from 12.80 $\pm$ 2.31 kgf at baseline to 17.64 $\pm$ 2.85 kgf at week 8 in the intervention group, corresponding to a mean within-group increase of 4.84 $\pm$ 1.42 kgf (95% CI, 4.18 to 5.50; $p<0.001$). The control group increased from 12.52 $\pm$ 2.26 kgf to 13.41 $\pm$ 2.41 kgf, with a mean change of 0.89 $\pm$ 1.01 kgf (95% CI, 0.42 to 1.36; $p=0.001$) (Table 2). The between-group difference in mean change was 3.95 kgf (95% CI, 3.16 to 4.74; $p<0.001$), with a standardized change-score difference of Cohen's $d=3.21$ (Table 3).

Gross manual dexterity demonstrated a similar pattern. Mean Box and Block Test performance increased from 28.95 $\pm$ 4.74 to 37.60 $\pm$ 5.13 blocks in the intervention group, yielding a mean increase of 8.65 $\pm$ 2.33 blocks (95% CI, 7.56 to 9.74; $p<0.001$). The control group increased from 29.20 $\pm$ 4.68 to 31.05 $\pm$ 4.87 blocks, corresponding to a mean change of 1.85 $\pm$ 1.49 blocks (95% CI, 1.15 to 2.55; $p<0.001$). The between-group change-score difference was 6.80 blocks (95% CI, 5.55 to 8.05; $p<0.001$), with Cohen's $d=3.48$ (Table 3).

Baseline- analyses were consistent with the change-score comparisons. After adjustment for baseline handgrip strength, the estimated week-8 mean was 17.52 $\pm$ 0.34 kgf in the intervention group and 13.48 $\pm$ 0.34 kgf in the control group, corresponding to an mean difference of 4.04 kgf (95% CI, 2.77 to 5.31). The treatment-group effect was statistically significant ($F=41.87$, $p<0.001$, partial $\eta^2=0.53$). For the Box and Block Test, week-8 means were 37.42 $\pm$ 0.42 and 31.23 $\pm$ 0.42 blocks, respectively, producing an mean difference of 6.19 blocks (95% CI, 4.46 to 7.92). The corresponding group effect was $F=52.33$ ($p<0.001$, partial $\eta^2=0.58$) (Table 4).

Treatment exposure was high in both groups. Participants receiving elastic-resistance training attended a mean of 22.9 $\pm$ 1.2 of 24 scheduled sessions, compared with 22.5 $\pm$ 1.4 sessions in the control group. Mean attendance percentages were 95.4 $\pm$ 4.9% and 93.8 $\pm$ 5.8%, respectively, with not statistically significant between-group differences in attendance. No intervention-related injuries, excessive fatigue, medical complications, or other adverse events were reported during the eight-week intervention period (Table 5).

Discussion

The present randomized controlled trial showed that adding an eight-week supervised elastic-resistance upper-limb training program to routine rehabilitation produced greater gains in handgrip strength and gross manual dexterity than routine rehabilitation alone in children with spina bifida. The direction of the findings was consistent across both the un change-score analyses and the baseline- ANCOVA models, while treatment attendance remained high and no intervention-related adverse events were reported. These findings support the potential value of incorporating structured, progressively loaded upper-limb exercise into rehabilitation programs for appropriately selected children with spina bifida, while the magnitude and clinical significance of the observed effects require confirmation in larger studies.

The improvement in handgrip strength is clinically relevant to the rehabilitation needs of children with spina bifida because upper-limb muscle performance can be important for transfers, mobility-related tasks, wheelchair propulsion, and manipulation of objects. Previous work has demonstrated measurable impairments in upper-arm muscle strength, torque production, and neuromuscular performance among children and adolescents with spina bifida, particularly in those with limitations in mobility (3,4). These observations provide a plausible context for the response observed in the present trial, because children with reduced upper-limb capacity may have substantial potential to benefit from appropriately dosed strengthening exercise. The present findings also broadly agree with previous rehabilitation research reporting favorable changes in endurance and functional mobility following progressive resistance exercise in children with spina bifida (6). Although that previous work did not evaluate the same upper-limb outcomes or elastic-resistance protocol, both studies support the feasibility of structured resistance exercise within this population.

Gross manual dexterity, assessed using the Box and Block Test, also showed a greater increase in the intervention group than in the control group. This finding suggests that the effects of the intervention were not limited to grip-force production but were also reflected in performance of a standardized gross hand-manipulation task. Upper-limb function is particularly relevant in children with spina bifida because many daily and mobility-related activities depend on repeated and coordinated use of the arms and hands. Previous studies describing reduced upper-limb muscular performance in this population indicate that limitations may extend beyond lower-limb mobility alone (3,4). Similarly, work examining wheelchair-related physical capacity in young people with spina bifida highlights the functional demands placed on the upper body among children who rely substantially on their arms for mobility (7).

Several plausible mechanisms may explain the observed changes. The intervention provided repeated, supervised loading of the shoulder, elbow, and wrist musculature with progressive increases in elastic resistance according to individual tolerance and movement quality. Such repeated loading may enhance force-generating capacity through training-related muscular and neuromuscular adaptation. Repeated performance of controlled upper-limb movements may also have contributed to improved task execution during the Box and Block Test. However, these mechanisms were not directly measured in the present study, and the observed improvement in dexterity should not be interpreted as evidence of specific neuroplastic or motor-control adaptations. Previous studies demonstrating measurable upper-limb neuromuscular characteristics in children with spina bifida provide biological plausibility for responsiveness to targeted training, but mechanistic confirmation would require direct physiological assessment (8,9,10).

The high treatment attendance observed in both groups suggests that the intervention schedule was feasible within the studied rehabilitation setting. Exercise programs for young people with disabilities have previously demonstrated that structured, supervised, and individually adapted physical activity can be implemented with acceptable participation (11). Elastic resistance may be particularly practical in rehabilitation environments because the exercises can be individually progressed and incorporated into supervised therapeutic sessions without requiring large exercise equipment. Nevertheless, feasibility in the present study should be interpreted within the context of a single rehabilitation setting and a relatively small group of participants. The absence of reported intervention-related adverse events is reassuring but does not establish safety across the broader population of children with spina bifida.

The findings may have practical implications for pediatric rehabilitation. Children with spina bifida may rely considerably on their upper limbs for mobility and daily tasks, particularly when lower-limb function is limited. Incorporating structured upper-limb strengthening into routine rehabilitation could therefore complement interventions directed primarily toward lower-limb mobility, postural control, and prevention of secondary complications (12,13).

However, the present outcomes were restricted to handgrip strength and gross manual dexterity. The study did not directly assess self-care, wheelchair performance, school participation, quality of life, independence in activities of daily living, or long-term participation. Consequently, improvements in the measured outcomes should not be interpreted as direct evidence of broader functional independence or improved quality of life (14,15).

The study has several strengths. Random allocation, concealed group assignment, and blinded outcome assessment reduced important sources of selection and measurement bias. Both groups received routine rehabilitation, allowing the study to evaluate the additional contribution of elastic-resistance training rather than comparing treatment with no rehabilitation. Standardized procedures were used for handgrip strength and Box and Block Test assessment, participant retention was complete, adherence was high, and the treatment effect remained evident after adjustment for corresponding baseline outcome values. Reporting both absolute between-group differences and standardized effect estimates also allows the magnitude of the observed group differences to be considered alongside statistical significance (16,17).

Several limitations should nevertheless be considered. The sample consisted of only 40 participants recruited through convenience sampling from a single rehabilitation setting in Lahore, which limits the precision and external generalizability of the findings. Although randomization supports internal comparison between treatment groups, convenience recruitment does not ensure that the study population is representative of all children with spina bifida. The sample also included children with different clinical forms of spina bifida and varying use of assistive devices, and the study was not powered to determine whether treatment response differed according to neurological lesion level, mobility status, or clinical subtype. The intervention lasted eight weeks and outcomes were measured immediately after treatment; therefore, persistence of the observed gains beyond the treatment period remains unknown (18,19).

Further limitations relate to outcome scope and intervention characterization. Handgrip strength reflects grip force rather than strength across all upper-limb muscle groups, while the Box and Block Test measures gross manual dexterity rather than comprehensive hand function or everyday participation. No patient-reported or caregiver-reported measures of independence, quality of life, or participation were included. In addition, the large, standardized change-score effects observed in this relatively small sample should be interpreted cautiously, particularly because a population-specific threshold for clinically important change was not established in the study. Future investigations using larger and more diverse samples, longer follow-up, and broader functional outcomes would be useful for determining the durability and practical relevance of the observed treatment effects (20).

Overall, the findings indicate that structured elastic-resistance upper-limb training may provide additional benefit when incorporated into routine rehabilitation for children with spina bifida. The consistency of the treatment effect across handgrip strength, gross manual dexterity, and baseline- analyses strengthens the internal interpretation of the findings, while the study's sample size, recruitment method, short follow-up, and restricted outcome set require cautious interpretation regarding broader clinical effectiveness and generalizability.

Conclusion

Among the children with spina bifida included in this randomized controlled trial, adding eight weeks of supervised elastic-resistance upper-limb training to routine rehabilitation resulted in greater improvement in handgrip strength and gross manual dexterity than routine rehabilitation alone. The findings indicate that structured upper-limb resistance training may be a useful adjunct to routine pediatric rehabilitation for improving these specific aspects of upper-limb performance, although the results should be interpreted within the context of the small single-setting sample and short-term follow-up.

DECLARATIONS

Author Contributions:	Concept: AS; Design: AS; Data Collection: AS; Analysis: AS; Drafting: AS, SS, RW.
Ethical Approval:	Ethical approval for the study was granted by the Research Ethical Committee, Faculty of Allied Health Sciences, Superior University, Lahore, Pakistan, under reference number IRB/FAHS/REHAB/04/26/MS/RS-4059. The committee reviewed and approved the study protocol titled "Effects of Elastic Resistance Upper Limb Training on Strength and Functional Ability Among Children with Spina Bifida: A Randomised Controlled Trial" on 24 April 2026. The formal ethical approval letter was issued on 24 August 2026.
Informed Consent:	Written informed consent was obtained from a parent or legal guardian before participant enrolment. Age- and developmentally appropriate assent was also obtained from participating children whenever possible.
Conflict of Interest:	The authors declare no conflict of interest.
Funding:	No external funding was received for this study.
Data Availability:	Data are available from the corresponding author on reasonable request.
Acknowledgments:	None.
AI Declaration:	Generative AI tools were used solely for language and grammatical refinement. The authors verified the final manuscript and remain fully responsible for its accuracy, integrity, and scientific content.

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