ORIGINAL SCIENTIFIC PAPER

Effects of Adaptive Riding on Children with Cerebral Palsy

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Abstract

This study investigated the effects of adaptive riding exercise on specific physical parameters in children with cerebral palsy (CP). Twenty children with CP (ages 8–12 years) were randomly assigned to an experimental group (n=10) or a control group (n=10). The intervention involved a 12-week adaptive riding program, consisting of 30–45 minute sessions, three times per week, led by a certified instructor and supported by specially trained horses and volunteer university students. Data collection, executed via pre- and post-intervention assessments, focused on parameters including leg-back strength, unilateral-bilateral flexibility, accuracy, linearity, maximal grip force, and the rate of grip force development. Data were analyzed using a mixed-model ANOVA. The experimental group demonstrated statistically significant improvements over the control group in several measures, including hand-eye coordination, maximal grip strength, flexibility, and muscle strength. The findings suggest that adaptive riding exercise provides a supportive therapeutic effect for children with CP, specifically those classified as GMFCS Levels II and III. Therefore, it is recommended that children with CP who are GMFCS levels 2 and 3 participate in adaptive riding programs.

Keywords: *adaptive horseback riding, cerebral palsy, equine-assisted exercise, equine-assisted services, motor performance, disabled sport*

Introduction

Cerebral palsy (CP) is an umbrella term that describes permanent movement and posture disorders causing activity limitations. These conditions are attributed to non-progressive disturbances that occur in the developing fetal or infant brain (Sadowska, Sarecka, & Kopyta, 2020). Motor impairments resulting from cerebral palsy frequently induce disturbances in sensation, perception, cognition, communication, and behavior (Paul, Nahar, Bhagawati, & Kunwar, 2022). These impairments can also result in epilepsy and secondary musculoskeletal problems (Ruiz Brunner & Cuestas, 2019). The condition is characterized by numerous risk factors, specific etiologies, symptoms, the degree of functional limitations, and the development and severity of associated and secondary conditions (Sadowska et al., 2020). The treatment options for this condition are numerous, and the course of the condition can evolve over time (Patel et al., 2024).

The overarching objective of CP therapeutic strategies is twofold: first, to mitigate the impact of disability, and second, to enhance physical, cognitive, and communicative abilities. Conventional treatment modalities, including physical therapy, orthopedic interventions, and neurological care, remain integral to the management of these conditions. However, their efficacy in achieving long-term functional outcomes is often constrained (Booth et al., 2018; Kousar, Sultana, Sultana, Banu & Begum, 2023). According to Liptak's (2005) findings, children diagnosed with CP frequently exhibit a multitude of symptoms for which there is no known curative treatment. Consequently, these families often seek alternative treatments and therapeutic interventions from various sources. In the aforementioned study, "equine-assisted therapy" is identified as one of a series of methods classified within the domain of Complementary and Alternative Medicine (CAM).

Equine-related human services have undergone significant diversification and expansion in recent decades (Wood et al., 2021). Following extensive deliberations on terminology and subsequent revisions, a comprehensive consensus has been achieved regarding the categorization of equine-related human services. Within this framework, a total of 12 distinct service types have been identified and classified under the subcategories of "therapy," "learning," and "horsemanship," collectively referred to as Equine-Assisted Services (EAS) (Wood et al., 2021).

Within this classification, the term adaptive riding is included under the "Equestrian" category and is used to describe horseback riding activities that are modified to accommodate the physical, cognitive, or emotional needs of individuals with diverse abilities. This terminology is consistent with the language used in the fields of adaptive recreation and sport, emphasizing that the activity is adapted to the rider rather than requiring the rider to conform to a standardized form of riding (Lassell, Wood, Schmid & Cross, 2021; Wood et al., 2021). Additionally, the literature reveals a paucity of studies examining the relationship between adaptive riding and cerebral palsy, indicating a clear need for further research in this area.

Given all these information, the aim of this study was to investigate the effects of adaptive riding exercises on specific parameters in children with cerebral palsy.

Methods

This study employed an experimental, pretest-posttest design with two-time repeated measurements applied to both the experimental and control groups.

Participants

A request for participation was extended to children diagnosed with cerebral palsy (CP) in the Nevşehir province. The determination of eligibility was based on the following inclusion and exclusion criteria:

Inclusion criteria included: age 8–12 years; under physician/therapist supervision; classification at GMFCS Level II or III; ability to follow verbal instructions; and no prior horse experience.

Exclusion criteria included: severe visual or hearing impairment; animal phobia (especially horses); allergies; uncontrollable epileptic seizures; or surgery within the last year.

Interviews were conducted with families, physicians, and teachers of potential participants. Children who met all inclusion criteria and whose families provided written informed consent were enrolled in the study. Participants were randomly assigned to either the experimental group (EG) or the control group (CG) using a fishbowl draw method. The experimental group consisted of six female participants (mean age: 9.83 (±1.60) years) and four male participants (mean age: 10.50 (±1.29) years). The control group consisted of five female participants (mean age: 10.00 (±1.58) years) and five male participants (mean age: 10.60 (±1.14) years). Ethics Committee approval was secured from Erciyes University (Decision No: 2016/180, March 4, 2016).

Participant Characteristics: All participants exhibited mild intellectual disability. The experimental group (EG) comprised six girls and four boys, while the control group (CG) included five girls and five boys. Gross Motor Function Classification System (GMFCS) levels were distributed as follows: the EG included four children classified as GMFCS level II and six as level III, whereas the CG included five children classified as level II and five as level III (Palisano et al., 1997).

Horses: Five horses were selected based on criteria including temperament, strength, health, and size. The horses underwent a 12-week preparatory training program to enhance tolerance and desensitize them to sudden noises, foreign objects, and mobility aids (walkers, crutches). Training also ensured mounting/dismounting capability from both sides. Horses participated in a maximum of four sessions per day, though typically trained three times, representing a light workload.

Intervention

Adaptive Riding Program: The intervention spanned 12 weeks, with the experimental group (EG) participating in 30–45 minute adaptive riding sessions, three days per week. The program was designed based on general principles of adaptive riding and equine-assisted interventions described in the literature, incorporating individualized progression and professional supervision (Sterba, 2007; Wood et al., 2021). Sessions were conducted individually by a certified adaptive riding instructor and supported by relevant specialists (e.g., motor control specialist, physiotherapist), who were either present during sessions or provided professional consultation.

Equestrian equipment (saddle, reins, stirrups, mounting platform) was individually adapted for each child. Session plans were tailored to each participant, taking into account ongoing rehabilitation and school schedules. In addition, children were encouraged to participate in up to 10 minutes of preparatory and horse care activities before and after each session, under supervision of the instructor or trained volunteers.

Control Group Condition: The control group (CG) did not participate in any form of hippotherapy, adaptive riding, equine-assisted activities, or other horse-related interventions during the study period. Participants in the CG continued their standard rehabilitation programs, which typically consisted of conventional physiotherapy and/or occupational therapy sessions prescribed by their healthcare providers. These programs were maintained at their usual frequency and duration (2–3 sessions per week, approximately 30–45 minutes per session) throughout the 12-week study period.

Importantly, the CG did not engage in any additional structured physical activity or exercise programs beyond their routine rehabilitation and school-based activities during the intervention period.

Measurement tools and procedures

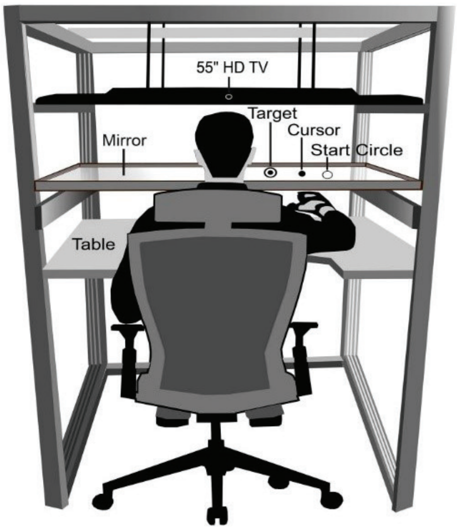
Data were collected during pre-test and post-test assessments using specialized equipment to measure key physical parameters.

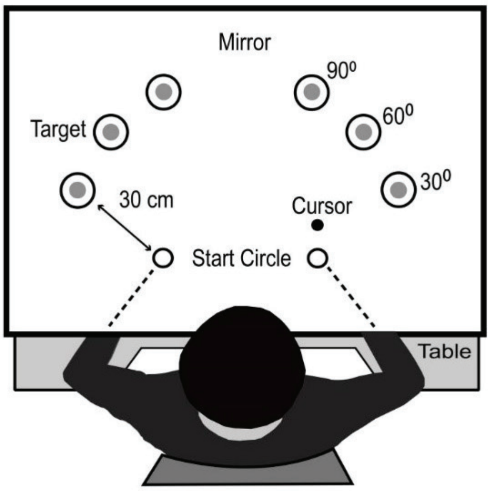
Arm-Reaching Movement Performance (Accuracy and Linearity):

The KineReach system (EZ Kinetics, State College, PA), a custom-developed experimental setup originally described by Przybyla et al. (2013) and subsequently used in later studies (e.g., Cortes et al., 2017), was used to evaluate arm extension movements in a virtual environment (Figure 1).

Participants sat in a custom chair, with an electromagnetic sensor (TrackSTAR Ascension Technology, USA) attached to the index finger (Sainburg & Wang, 2002). Visual targets were displayed on an HD television reflected in a mirror (Figure 1a). A MATLAB R2013a program (MathWorks Inc., Natick, USA) provided visual feedback and recorded data at 100 Hz. The task required children to reach for three randomly located targets (positioned at 30°, 60°, and 90° from the starting point, 20 cm away) with both the right and left hands to measure accuracy and linearity (Figure 1b). Movement onset was signaled visually and audibly after maintaining contact with the starting point for 300 ms (Beyaz, Akpınar, & Demirhan, 2024).

Figure 1. a: KineReach system; b: Targets distribution.





Maximal Grip Force (Max. GF) and Rate of Grip Force Development (RGFD): A SML-900N force transducer (Interface, Scottsdale, Arizona, USA) was used to measure both maximum grip force and the maximal rate of grip force development (RGFD). Participants were seated with their forearms supported and elbows flexed at 90°. For Max. GF, subjects squeezed the device maximally for 5–6 seconds. For Max. RGFD, subjects squeezed as forcefully and rapidly as possible for 5–6 seconds, with the RGFD value recorded within the initial 0–300 ms (Akpinar, 2016; Beyaz, Akpınar & Demirhan, 2024; Sainburg & Wang, 2002). Three trials were performed for each hand, separated bya one-minute rest, and the highest value was used.

Back – Leg Strength: The Takei (Japan) digital leg-back dynamometer (Takei Instruments Ltd, Tokyo, Japan) was used. Participants stood on the platform with knees bent, grasping the bar, and were instructed to pull vertically upwards using maximal back and leg effort. The best result from three trials was recorded in kilograms (Coldwells, Atkinson, & Reilly, 1994).

Flexibility: The experimental apparatus utilized was a portable Baseline Sit-And-Reach Flexibility Box (Baseline®, New York, USA). The measurement of unilateral flexibility (right and left hands separately) and bilateral flexibility (standard two-hand reach) was conducted. The optimal outcome of three successive trials was documented in centimetres (Hartman & Looney, 2003).

Data analysis

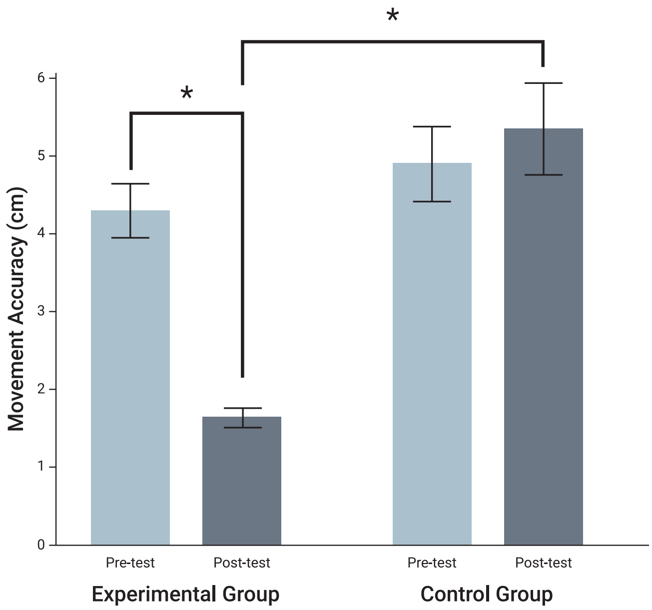
Statistical analysis was performed using the JMP Statistics program (JMP®, Cary, NC, USA). The significance level was set at $p<0.05$. Three-way interactive mixed-model ANOVA was employed to determine differences across groups (EG vs. CG), hands (Right & Left), and tests (Pre-test vs. Post-test) for maximum grip force, RGFD, unilateral flexibility, accuracy, and linearity. Two-way interactive mixed-model ANOVA was used for leg-back strength and bilateral flexibility variables (Groups-times-Tests). Assumptions were tested prior to analysis. Tukey's HSD post-hoc test was used to examine specific differences when significant interactions were found.

Results

Statistical analyses for all variables utilized a three-way or two-way interactive mixed-model ANOVA. Post-hoc analyses were performed using Tukey's Honestly Significant Difference (HSD) test when significant interactions were detected.

Accuracy: Figure 2 presents the results of a mixed-model ANOVA examining accuracy across three interacting factors. The analysis yielded a significant Group × Test interaction, $F(1, 18)=9.41$, $p=0.006$, with a large effect size ($\eta^2=0.34$). Tukey's HSD post hoc comparisons indicated no significant difference between the experimental group (M=4.29±0.56 cm) and the control group (M=4.90±0.52 cm) at pretest, demonstrating comparable baseline performance. In contrast, the experimental group showed a substantial improvement at posttest (M=1.63±0.24 cm), differing significantly from both its own pretest values and the control group's posttest scores (M=5.34±0.35 cm). These findings reflect a robust intervention effect, indicating that the adaptive riding program produced a meaningful enhancement in accuracy performance (Figure 2).

Figure 2. Changes in accuracy values across groups and tests



Linearity: The results of the mixed-model ANOVA examining the linearity parameter are presented in Table 1. The analysis examined the effects of Group (experimental vs. control), Hand (right vs. left), Test (pre-test vs. post-test), and their interactions. A significant main effect of Tests was observed (F(1,18)=11.83, p=0.002, ηp²=0.40), indicating that linearity improved from pre-test to post-test, primarily in the experimental group. No significant main effects were found for Groups or Hands, and the three-way interaction (Groups × Hands × Tests) was non-significant with a negligible effect size (ηp²≈0.0001). Two-way interactions showed medium-to-large effects: Groups × Hands (ηp²=0.15) and Groups × Tests (ηp²=0.17), while Hands × Tests showed a medium effect (ηp²=0.07); none of these reached statistical significance.

Table 1. Pretest and posttest linearity scores and mixed-model ANOVA results

Variables		N	X̄±SD	F	p	Partial ηp²
Group	EG	10	0.16±0.02	0.58	0.455	0.03
	CG	10	0.18±0.02			
Hand	RH	10	0.17±0.01	0.82	0.376	0.04
	LH	10	0.17±0.01			
Test	Pretest	10	0.19±0.02	11.83	0.002*	0.40
	Posttest	10	0.15±0.01			
Group * Hand	EG – RH	10	0.17±0.01	3.18	0.091	0.15
	EG – LH	10	0.16±0.02			
	CG – RH	10	0.17±0.02			
	CG – LH	10	0.19±0.01			
Group * Test	EG – Pretest	10	0.20±0.02	3.77	0.067	0.17
	EG – Posttest	10	0.13±0.02			
	CG – Pretest	10	0.19±0.02			
	CG – Posttest	10	0.17±0.02			
Hand * Test	RH – Pretest	10	0.18±0.01	1.40	0.252	0.07
	LH – Pretest	10	0.20±0.01			
	RH – Posttest	10	0.15±0.01			
	LH – Posttest	10	0.15±0.02			

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Table 1. Pretest and posttest linearity scores and mixed-model ANOVA results

Variables		N	X̄±SD	F	p	Partial ηp²
Group * Hand * Test	EG – RH – Pretest	10	0.20±0.02	0.002	0.958	0.01
	EG – LH – Pretest	10	0.20±0.02			
	CG – RH – Pretest	10	0.17±0.01			
	CG – LH – Pretest	10	0.21±0.02			
	EG – RH – Posttest	10	0.14±0.02			
	EG – LH – Posttest	10	0.12±0.02			
	CG – RH – Posttest	10	0.16±0.01			
	CG – LH – Posttest	10	0.18±0.01			

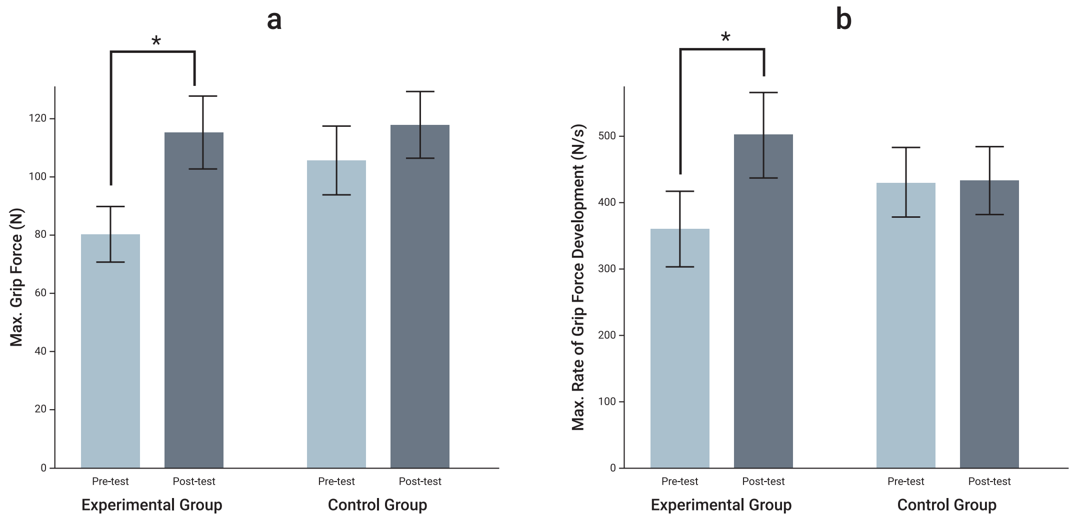
Overall, these results suggest that the primary improvement in linearity was driven by test sessions, with the experimental group showing the most notable gains, while other factors and interactions contributed minimally.

Maximum Grip Force (Max. GF): A three-way interaction mixed model ANOVA statistical analysis of the pretest and posttest data for the maximum grip force of the right and left hands of the EG and CG groups revealed no interaction between groups, tests, and hands. Concurrently, no significant differences were observed between Groups x Hands, and Hands x Tests. However, a substantial difference was identified between the groups (EG and CG) x tests (pre-test and post-test), ($F(1,18)=8.33$, $p<0.05$). As demonstrated in Figure 3a, which reflects the Tukey HSD analysis, a statistically significant difference is evident between the pre-test ($\bar{X}=80.37\pm15.23$ N) and post-test ($\bar{X}=115.48\pm15.04$ N) of the EG group.

Rate of Grip Force Development (RGFD): In order to analyse the pre-test and post-test data on the maximum rate of grip force development (RGFD) of the right and left hand in the experimental and control groups, a three-way interaction mixed model ANOVA was employed. A three-way interaction was not found. In addition, there was an absence of evidence to suggest a group x hands interaction, nor was there any indication of a hands x tests interaction. Nevertheless, a significant difference was found in the groups (EG-CG) x tests (pre-test-post-test) interaction, ($F1, 18)=5.40$, $p<0.05$). Tukey HSD analysis revealed a statistically significant difference in RFGD between the pre-test ($\bar{X}=360.31\pm75.31$ N/s) and post-test ($\bar{X}=501.83\pm74.45$ N/s) results of the EG group (Figure 3b).

Back – Leg Strength: A 2-interactive mixed model ANOVA statistical analysis method was used in the statistical analysis of the Back-Leg Strength variable. Because the device used for the measurement did not provide strength values less than 20 kg, 3 people from the experimental group and 2 people from the control group could not take the measurement. As a result of the analysis, a significant difference was found between groups (experimental - control) x tests (pre-test - post-test), $F(1, 13)=37.2$, $p<0.05$. According to Tukey HSD analysis, the post-test (Mean=48.81±8.11 kg) values of the experimental group were found to be statistically significantly different from its own pre-test values (Mean=33.6±4.08 kg) and from both the pre-test (Mean=29.48±4.78 kg) and post-test (Mean=30.63±5.58 kg) values of the control group (Figure 3c).

Figure 3. Changes in strength measures, a: maximum grip force, b: max. rate of grip force development, and c: back-leg strength in experimental and control groups following the intervention



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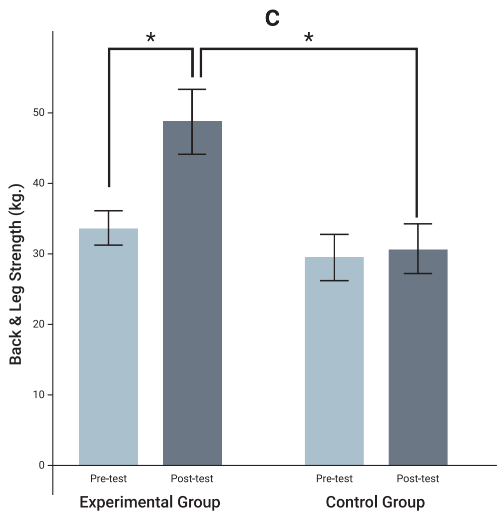
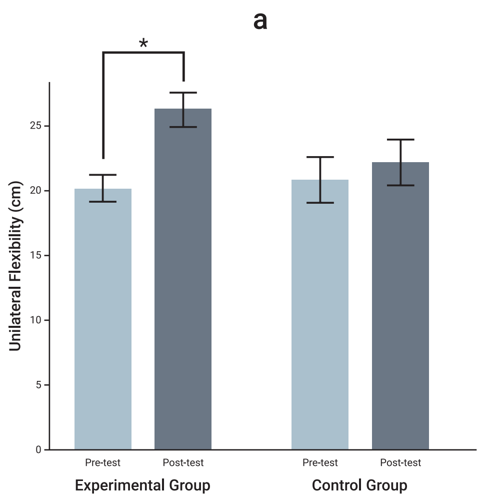
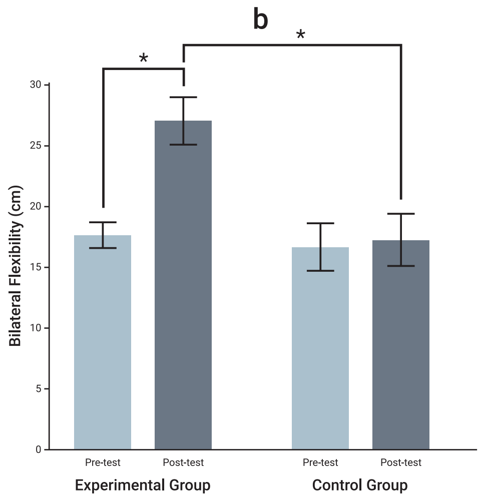


Unilateral Flexibility: Figure 4a shows the pre-test and post-test flexibility values for the right and left hands of the experimental and control groups. The statistical analysis of the three interaction mixed-model ANOVA found a significant difference between the groups (experimental - control) x tests (pre-test - post-test), F(1, 18)=38.29, p<0.05. According to the Tukey HSD analysis, a significantly difference was found only between the pre-test (Mean=20.31±4.77 cm) and post-test (Mean=26.27±4.51 cm) values of the experimental group (Figure 4a).

Bilateral Flexibility: In the statistical analysis of the bilateral flexibility variable, 2 interactive mixed model ANOVA statistical analysis method was used. As a result of the analysis, a significant difference was found between groups (experimental - control) x tests (pre-test - post-test), F(1, 18)=25.33, p<0.05. There was no difference between the pre-test values of the experimental and control groups. According to the Tukey HSD analysis, it was understood that the bilateral flexibility post-test values of the experimental group (Mean=25.2±4.11 cm) were found to be statistically significantly different from its own pre-test values (Mean=17.35±5.70 cm) and from both the pre-test (Mean=18.25±6.21 cm) and post-test (Mean=19.1±4.75 cm) values of the control group (Figure 4b).

Figure 4. Changes in flexibility measures, a: unilateral flexibility and b: bilateral flexibility in experimental and control groups following the intervention.





Discussion

The aim of this study was to determine the effect of a 12-week adaptive horseback riding intervention on specific parameters in children with Cerebral Palsy (CP) classified as GMFCS Levels II and III. Our findings indicate that the intervention significantly improved several core physical and motor competencies in the Experimental Group (EG).

In terms of the accuracy parameter, the post-test values of the Experimental Group (EG) after the intervention showed a statistically significant increase compared to both their pre-test values and the post-test values of the Control Group (CG) ($p<0.05$). This suggests that adaptive riding improves hand-eye coordination and hand stabilization skills, which are critical for the development of gross and fine motor skills in children with CP. Additionally, numerous studies have demonstrated that adaptive riding enhances hand–eye coordination, a crucial element in the development of gross and fine motor skills in children with CP (Angsupaisal, 2015; Champagne, Corriveau & Dugas, 2017; Stergiou et al., 2017; Stergiou et al., 2023). However, there are also studies reporting that horseback riding-based exercise does not affect gross motor function in people with cerebral palsy (Alemdaroğlu et al., 2016; Davis et al., 2009). According to our assessment, most of the studies that yielded such results may be related to the wide age range of the subject groups and the different levels and types of affected, the duration and content of the intervention, and especially the fact that the interventions were mostly interventions other than adapted horse riding (such as hippotherapy).

Unlike the accuracy parameter, no significant difference was found between the EG and CG groups in the linearity tests. While a relative improvement in left-hand performance was noted in the EG group, this difference did not reach statistical significance. Based on this result, we believe that the 12-week period may not be sufficient and that longer-term studies or further research with different age groups is warranted.

The intervention produced significant increases in Maximum Grip Force (MGF) and Rate of Grip Force Development (RGFD) in the experimental group (EG) ($p<0.05$), while no changes were observed in the control group (CG). These results align with previous literature indicating that horseback riding therapy enhances grip strength (Žalienė et al., 2018). A number of studies have underscored the significance of the temporal characteristics of force production as a crucial indicator of health (Aleknavičiūtė-Ablomkė, Savenkovas, Mockevičius, & Miliūnas, 2015) and functionality in daily living (Heyn et al., 2023). Consequently, the enhancement in RGFD values in our experimental group is particularly noteworthy and merits further investigation in subsequent studies.

A substantial enhancement in back and leg strength was observed in the EG group ($p<0.05$). This finding aligns with research indicating that adaptive riding activities enhance lower body strength in children and older adults (Moreau, Falvo, & Damiano, 2012; Scholtes et al., 2010). The observed improvements were attributed to repetitive, moderate-intensity, half-squat-like movements (stirrup stand-ups and controlled crunches) performed in sets and repetitions throughout the sessions. This method bears partial similarity to lower extremity strength exercises recommended for CP (de Araújo et al., 2013; Merino-Andres, Garcia de Mateos-Lopez, Damiano, & Sanchez-Sierra, 2022; Mockford & Caulton, 2008; Ross, MacDonald & Bigouette, 2016) providing a distinctive strengthening technique.

Strengths of the study

This study demonstrates several methodological and conceptual strengths. First, the adaptive riding intervention was individually planned and systematically implemented over a 12-week period, ensuring consistency and adherence to the intervention protocol. Second, the program integrated functional lower extremity strengthening movements within a dynamic postural control environment, which differs from conventional ground-based strength exercises commonly used in rehabilitation for children with cerebral palsy. This approach may provide an alternative means of simultaneously targeting strength, balance, and coordination.

Additionally, the use of objective, instrument-based outcome measures allowed for precise assessment of changes in motor performance. Finally, the inclusion of a control group that continued standard rehabilitation programs strengthens the internal validity of the findings by enabling a clearer attribution of observed effects to the adaptive riding intervention.

Limitations

This study was limited to a small sample size of 20 children (both girls and boys) aged 8-12 years, all diagnosed with mild intellectual disability and cerebral palsy. The focus was on evaluating specific outcomes, including arm extension performance, maximum GF, maximum RGFD, flexibility, and back-leg strength parameters. In addition, the intervention program was limited to a 12-week period and 36 sessions for each child.

Conclusion

In conclusion, based on the aforementioned findings, analyses, conclusions, and evaluations, it can be concluded that 12 weeks of adaptive riding exercise has a positive impact on the development of hand-eye coordination, increased precision in upper extremity movements, increased strength in the lower extremities and hands, increased rate of grip force development, and improved flexibility in children with cerebral palsy (CP). A growing body of evidence demonstrates the positive impact of adaptive riding exercise on children with CP. It is noteworthy that adaptive riding activities offer a unique opportunity to implement a multimodal program that simultaneously trains single- or multi-joint motor skills such as flexibility, strength, and coordination. Because improvements in these parameters are hypothesized to contribute to independence in activities of daily living, adaptive riding exercises are recommended for inclusion in rehabilitation programs for individuals with cerebral palsy.

Acknowledgments
The research, which was derived from a doctoral thesis, was presented as an oral presentation at "The European Conference in Equine Facilitated Therapy" and subsequently published in the conference abstract book by the Czech Equine Facilitated Therapy Association (CEFTA), Prague, Czech Republic, 10–11 September 2021.

Conflict of interest
No potential conflict of interest was reported by the authors.

Funding
The present study received no funding from any organisation.

Received: 13 November 2025 | Accepted: 30 December 2025 | Published: 01 February 2026

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