

Immediate Effect of Soft Lumbosacral Orthosis on Trunk Stability and Upper-Limb Functionality in Children with Cerebral Palsy

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ABSTRACT

Introduction: Lumbar lordosis is important for the spine and pelvis to work in harmony in providing trunk control and maintaining sagittal balance. Children with cerebral palsy (CP) have difficulties in providing trunk postural control and balance, which is critical for independence in daily living activities. This study was planned to examine the immediate effect of a lower-trunk orthosis supporting physiological lumbar lordosis on trunk control and upper-limb functionality in children with CP.

Objectives and Methods: A total of 30 children with CP, 13 diparetic, 11 hemiparetic, and 6 ataxic, 21 ambulatory (GMFCS I/II), and 9 nonambulatory (GMFCS III/IV) aged 3–16 years were included in the study. The Pediatric Functional Reach Test (PFRT) and the Seated Postural Control Measure (SPCM) were used to assess trunk control; the Pediatric Berg Balance Scale (PBBS) was used to assess balance; and the Box and Block Test (BBT) and the Nine-Hole Peg Test (9HPT) were used to evaluate upper-limb functions. All tests were performed with and without a soft lumbosacral brace. The braces were made of soft, elastic fabric with steel, and were made by the orthotic technician in four different sizes. The angle of lordosis was adjusted with steel underwires according to each child. The existing physiological lordosis of the child is supported by the brace. It is not intended to increase or decrease.

Results: In the study, the results of all evaluations with a brace were better than those without a brace ($P < 0.05$). No significant difference was found only in the functional part of the SPCM test ($P > 0.05$).

Conclusions: Our study revealed that soft lumbosacral orthosis, which supports physiological lordosis, has a positive effect on trunk stability and upper-limb functionality in children with CP.

Clinical Relevance: In children's trunk stability and upper-limb functionality studies, the use of soft lumbosacral orthosis that supports physiological lordosis can be added to rehabilitation programs and daily living activities as a support. (*J Prosthet Orthot.* 2024;36:59–66)

KEY INDEXING TERMS: cerebral palsy, trunk control, trunk brace, lumbar lordosis

Cerebral palsy (CP) is a neurodevelopmental disorder in which a group of posture and movement disorders cause limitations in activities of daily living.¹ It adversely affects functional activities such as the use of upper limbs and hands and independent sitting, standing, and walking.^{2–4} Trunk control involves the stability and selective movements of the trunk. This stability is necessary for free and selective movements of the head and limbs.^{5,6}

Studies in the field of postural control in CP show that the degree of trunk control is related to sitting balance, and that trunk control and limb functions are also related. Basic trunk movements are required to maintain mobility and provide postural control during limb movements.^{7–9} The necessity of lumbar

lordosis is important in maintaining trunk control and maintaining sagittal balance. Functions of the joints and muscles in the correct anatomical position reduce the energy consumption for stabilization and increase the motor performance during physical activity.¹⁰ It is also important for effective treatment and rehabilitation approaches to investigate postural control and postural balance problems caused by motor problems that affect motor function and quality of movement in children with CP. Recent studies on this subject have shown the importance of postural balance problems and the necessity of investigating them.¹¹ It is seen in the literature that there are not many studies on the relationship between the mechanisms affecting the postural balance and the stabilization of the lumbosacral region in children with neuromotor problems. Therefore, our study will provide a catalyst effect in revealing the contribution of lumbosacral stability to postural balance.

As a result of the literature review made during the planning phase of the present study, the lack of studies on increasing postural control via any adaptive material for children who can walk independently has highlighted the necessity of examining this subject. Studies have shown that children who cannot sit experience an increase in upper-limb functions with adaptive sitting arrangements.^{12–14} Based on these studies, we thought that providing an upright posture by supporting the musculoskeletal system in the correct anatomical position in children with better

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Disclosures: The authors declare no conflict of interest. Authors declare no funding was received.

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Figure 1. Lumbosacral brace.

GMFCS level would stimulate postural control mechanisms, thus increasing trunk control and upper-limb function and performance. Even in children at the best level of GMFCS 1, trunk control deteriorates in daily life. As a result, performance decreases and energy loss increases.

In this study, it was aimed to increase trunk control and upper-limb functions by externally supporting existing physiological lumbar lordosis in children with CP using a lumbosacral trunk brace.

METHODS

STUDY DESIGN

Participation in the study was on a voluntary basis. Before the study, the child and the family were informed about the study. A

Table 1. Demographic characteristics of study participants

Demographic Characteristics	X ± SD	Minimum	Maximum
Age, y	8.87 ± 3.48	4	16
Length, cm	129.60 ± 19.50	96	165
Weight, kg	27.30 ± 9.78	14	51
Body mass index, kg/m ²	15.78 ± 2.25	12.30	21.70

consent form was signed by the families of the children participating in the study. The study was approved by the Hasan Kalyoncu University Non-Interventional Clinical Research Ethics Committee on March 20, 2017. The work was performed between March 20, 2017 and December 10, 2017.

PARTICIPANTS

Included patients were 13 diparetic, 11 hemiparetic, and 6 ataxic CP types. Twenty-one ambulatory (GMFCS I/II) and 9 nonambulatory (GMFCS III/IV) children were included in this study. A common feature of all the children was sitting independently. They did not use an upper-limb device, but some of them were using ankle-foot orthosis in daily life for spasticity (Figure 1, Figure 2).

Criteria for participation in the study include the following: being in an age range of 3–16 years; being diagnosed with CP at GMFCS levels I, II, III, or IV; not having undergone surgery or botulinum toxin A (BTX-A) application in the previous 6 months; having a good cognitive level and a good level of communication; and presenting a consent form signed by the family. Exclusion criteria include the following: not presenting a

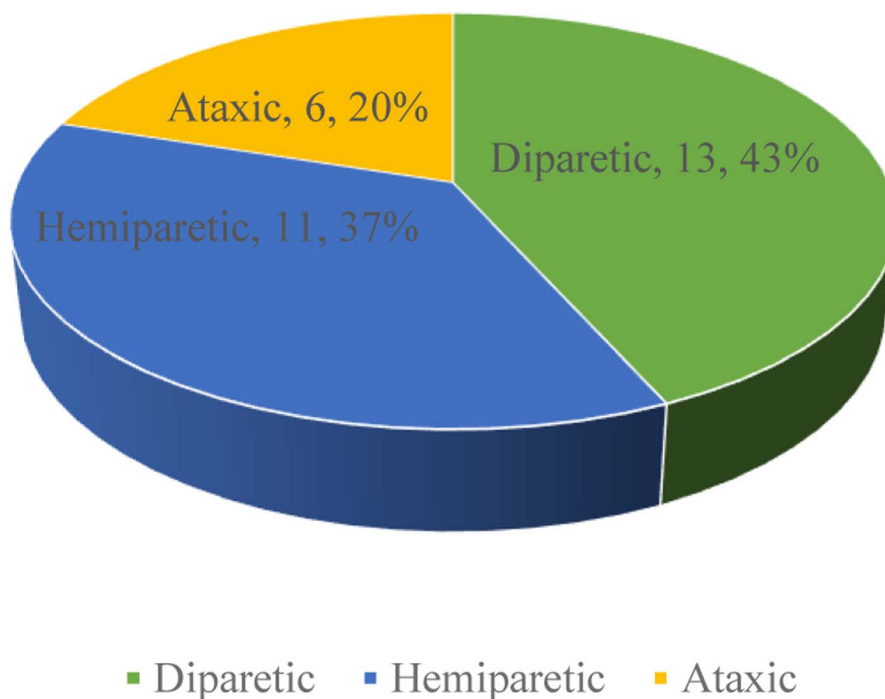


Figure 2. CP clinical types.

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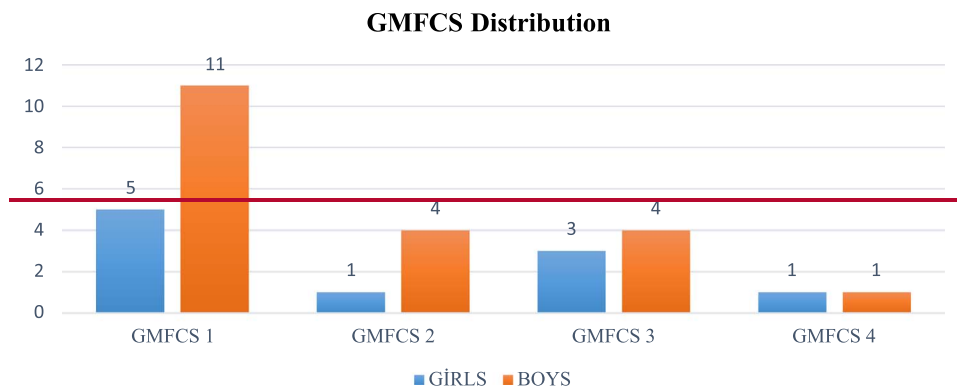


Figure 3. CP GMFCS type.

consent form signed by the family, not completing evaluations, being at GMFCS level V, having cognitive problems, inability to communicate, and having hip dislocation. Demographic findings of 30 children included in our study are presented in Table 1.

Children with CP were evaluated in locations where they received treatment and under conditions that would not interfere with their treatment. Children who were predicted to experience difficulty in their treatment were evaluated at home. Before being included in the study, their families and the authorized person in their institution were informed and permission was obtained. All assessments were performed initially on the same day. However, because fatigue was observed and the children's willingness to participate in the assessments decreased, the subsequent assessments were divided into two parts with and without a brace and performed in two sessions. All assessments were performed by the same physiotherapist.

While deciding on the evaluation methods to be used in our study, we selected tests that are easy and practical to be performed by children, as well as highly valid tests and used in mostly studies, and are not too long and boring.

IMPLEMENTATION PROTOCOL

The soft lumbosacral braces (Figure 3) to be used in the evaluation were made of soft, elastic fabric with steel and were specially made by the orthotic technician in four different sizes according to waist. The angle of lordosis was adjusted with steel underwires to each child by the physiotherapist. The existing physiological lordosis of the child is supported by the brace. It is not intended to increase or decrease. During the study, the children were divided into two groups. We aimed to eliminate the prelearned effect by measuring the first group without a brace

and then with a brace, and the second group, first with a brace and then without a brace.

While determining the lumbar lordosis angle, the patient was asked to bring their arms to full extension. This angle was made in a standing position, the hips and knees were in extended position for children who could stand, and in sitting position, hips and knees were in flexed position for children who could not stand. Patients who could not do it received help to determine the lordosis angle, and the steel underwire of the brace was given a lordosis angle. We did not intend to change the lordosis angle; we only supported lordosis at the current angle. The lordosis angle was adjusted for each patient by creating an angle with steel underwires.

In the first 15 patients, all tests were performed before the brace was fitted. After wearing the brace that supports the physiological lordosis, it took approximately 1 hour for the patient to adapt to the brace. Then, the same tests were applied again, and the results were recorded. In the other 15 patients, a brace with an adjusted lordosis angle was placed, and after 1 hour, the tests were performed, and the first results were recorded. It takes a lot of time to make the evaluations two times in a row and to have a waiting period of 1 hour with the brace. In this case, it causes reluctance and boredom, especially in younger children. Because of the reluctance of the patients and the persistence of the brace effect, the second tests were repeated in another session.

In the evaluation of the trunk control, methods that evaluate static and dynamic balance and postural control and examine posture in detail were preferred. These methods were determined as the Pediatric Functional Reach Test (PFRT), the Seated Postural Control Measure (SPCM), and the Pediatric Berg Balance Scale (PBBS).

The SPCM is a measurement technique that evaluates postural control and functionality in sitting position, developed by

Table 2. Comparison of with and without brace balance assessment results (n = 28)

Pediatric Berg Balance Scale (0–56)	X ± SD	Min-Max	z	P
Without brace	37.68 ± 18.93	3–55	–3.847	<0.001*
With brace	39.46 ± 19.36	4–56		

*Wilcoxon signed rank test, P < 0.05

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Table 3. Comparison of postural control skills with and without brace (n = 30)

Postural Evaluation		X ± SD	Min-Max	z	P
Postural alignment	Without brace	61.23 ± 3.78	53–68	-4.716	<0.001*
	With brace	65.63 ± 2.34	59–68		
Function	Without brace	44.83 ± 4.21	35–48	-1.841	0.066
	With brace	45.07 ± 4.06	36–48		

*Wilcoxon signed rank test, *P* < 0.05.

physiotherapists and occupational therapists at the Sunny Hill Health Centre in Vancouver, Canada. The SPCM also evaluates the effect of sitting on postural control along with the child's postural straightness.¹⁵ During the application of the test, the children were seated on a stool with their feet in full contact with the ground and without back support, and they were asked to sit facing forward. Meanwhile, the second part was observed and scored observationally. In the third part, which examines upper-limb functionality by placing a coffee table in front of the subject in the same position, the test was evaluated between 1 point and 4 points. This test is preferred because it shows instant changes and allows us to examine postural smoothness.

The Box and Block Test (BBT) and the Nine-Hole Peg Test (9HPT), which are time-dependent tests, were used to evaluate upper-limb functions. During the tests, a stool without back support and a table suitable for the child's height were used. Incidences in which the test could not be performed due to spasticity or lack of proximal control were noted.

STATISTICAL ANALYSIS

Our study is strengthened by including a total of 30 children with CP. Power analysis was performed as a result of the pilot study. The power of this study is found to be 0.97 in the power analysis performed with reference to the functional reach test, which is our primary finding (d = 1.73). The Wilcoxon signed rank test, which is one of the nonparametric tests, was used in the comparison of ordinal parameters such as the PBBS, the SPCM, and the BBT with and without braces, and paired sample *t*-test, one of the parametric tests, was used in the analysis of numerical

evaluation methods such as the 9HPT and the PFRT. Significance was accepted as *P* < 0.05.

RESULTS

When the results of the evaluation of trunk control were compared with and without brace, it was seen that dynamic and static balance could be achieved better with brace. A comparison of balance assessment results with and without brace is given in Table 2. According to the PBBS results, the brace increased balance (*P* < 0.05). Balance improved in children with CP at GMFCS levels 1 or 2, but there was no difference in balance in children at levels 3 or 4.

Statistics of the Alignment and Function sections of the SPCM questionnaire applied before (without braces) and after treatment (with braces) to measure the postural control skills of children with CP are given in Table 3. The change in the Alignment section of the children was found to be better in the measurements with braces (*P* < 0.05). In particular, a change in the direction of development was observed in trunk, shoulder girdle, and pelvis asymmetry and indirectly trunk asymmetry, but no difference was observed in the lower-limb part. In the functional part of the test, the results with and without brace were similar (*P* > 0.05).

Functional reach test results with and without braces are given in Table 4 and Figure 4. According to the results of the evaluation, it was seen that the brace was effective in dynamic balance control in all outcome measures except for SPCM Function (*P* < 0.05).

BBT and 9HPT were preferred to evaluate upper-limb functions, but shoulder flexion-extension movements in 1 minute

Table 4. Comparison of with or without brace results of functional reach test (n = 30)

Functional Reach Test		X ± SD	Min-Max	t	P
FRT right anterior	Without brace	19.30 ± 6.69	0–30	-6.100	<0.001*
	With brace	23.60 ± 5.32	15–33		
FRT right lateral	Without brace	13.80 ± 6.05	0–25	-4.421	<0.001*
	With brace	17.53 ± 4.43	9–27		
FRT left anterior	Without brace	17.93 ± 6.93	0–30	-5.998	<0.001*
	With brace	22 ± 6.57	0–34		
FRT left lateral	Without brace	13.30 ± 5.36	0–28	-7.212	<0.001*
	With brace	16.17 ± 5.57	0–28		

*Paired sample *t*-test, *P* < 0.05.
FRT, Functional Reach Test.

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Trunk Stability With and Without Brace

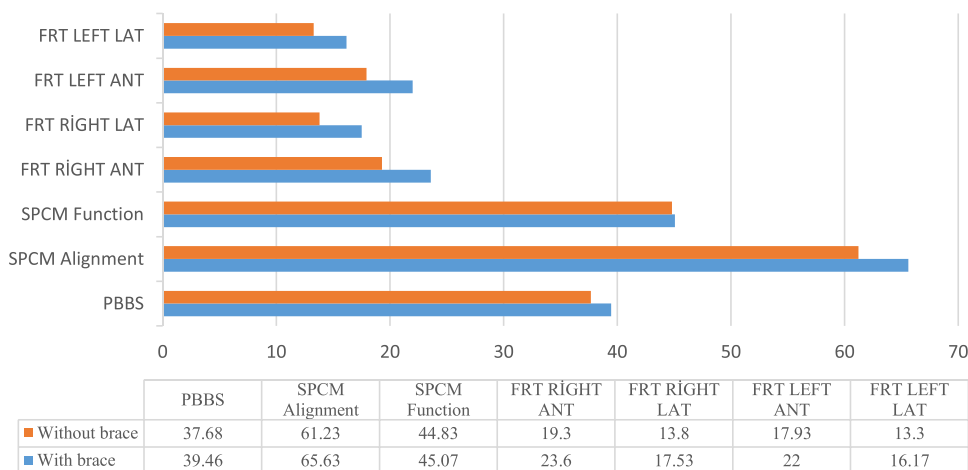


Figure 4. Trunk stability evaluations.

were evaluated in a few children who could not perform both tests. The results of this test were not statistically evaluated, but better movement was observed with braces during the application. In the findings of the BBT and the 9HPT, the statistical results in both limbs showed that upper-limb functions were better with the brace ($P < 0.05$). The results are given in Tables 5 and 6.

DISCUSSION

There are studies in the literature showing that trunk control deficiency is an important motor disorder in CP and that it negatively affects the daily living activities of children with CP.¹⁶ In order to develop more effective physiotherapy approaches in patients with CP, it is important to determine whether treatment programs are sufficiently effective on trunk balance and postural control ability. The importance of this subject and the necessity of researching it have been emphasized in studies on the subject.¹¹

In a study conducted by Şimşek et al.,¹⁷ the relationship between trunk control and balance in children with hemiplegic and diplegic CP was examined, and as a result, they revealed that there was a positive and significant relationship between trunk control and balance. In Özal and Kerem Günel’s study examining the relationship between trunk control and functional mobility and balance in children with spastic CP, limitations in postural control and balance resulted in limitations in the performance

of voluntary skills, including mobility levels. This study showed us that there is a relationship between trunk control and functional movement abilities and balance in children with CP.¹⁸ Curtis et al.¹⁵ examined the relationship between segmental trunk control and gross motor functions, and showed that there was a strong correlation between segmental trunk control and gross motor functions and mobility, and emphasized its clinical importance. During muscle training and in order to develop trunk control and voluntary motor movements, an upright sitting posture should be maintained during physiotherapy sessions.¹⁹ Harrison et al.²⁰ found that sitting position causes posterior rotation of the pelvis, which reduces the lumbar lordosis required for an upright posture. Gavin-Dreschnack,²¹ on the other hand, argued that the supports given to the posterior wall of the sitting systems protect the lumbar lordosis. These studies show that supporting physiological lordosis is necessary for an upright posture. In our study, the soft lumbosacral brace, which supported physiological lordosis with steel underwire, helped children to protect their lumbar lordosis, and thus the pelvis was supported in a neutral position.

In the study by Angelo,²² it was stated that head control was provided for a longer period in a 15° tilt position of the pelvis compared with the evaluation made in sitting position on a plane parallel to the ground. In our study, we evaluated the position of the pelvis and the position of the head with SPCM. In the examinations, it has been observed that pelvic asymmetry

Table 5. Comparison of with or without brace results of the Box and Block Test (n = 29)

The Box and Block Test		X ± SD	Min-Max	z	P
Right	Without brace	26.38 ± 13.66	9–56	–3.577	<0.001*
	With brace	29.45 ± 15.14	10–63		
Left	Without brace	23.97 ± 13.53	0–52	–3.656	<0.001*
	With brace	27.21 ± 12.68	8–59		

*Wilcoxon signed rank test, $P < 0.05$.

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Table 6. Comparison of with or without brace results of Nine-Hole Peg Test

Nine-Hole Peg Test		N	X ± SD	Min-Max	t	P
Right	Without brace	29	78.96 ± 59.98	20.90–233	2.756	0.010*
	With brace	29	67.07 ± 48.25	18.60–222		
Left	Without brace	25	79.65 ± 73.44	0–319	2.069	0.049*
	With brace	26	71.08 ± 57.80	0–206		

* Paired sample t-test, P < 0.05.

may cause lateral flexion and rotational angulation in the head. Because of muscle imbalance and tone changes in children with CP, asymmetry occurs in the pelvis and shoulder girdle, and therefore in the trunk. Both static and dynamic balance are affected due to trunk asymmetry and trunk control weakness. There is difficulty in voluntary motor movements using the upper limbs in the sitting position. We evaluated trunk asymmetry in sitting position and its effect on functions with SPCM. In the evaluations of SPCM-Alignment section with and without a brace, it was observed that the brace provided the body with an anatomical posture in all patients. This shows us the importance of lordosis in terms of the symmetry of the trunk and sitting posture. The SPCM-Function section was easily performed in children with GMFCS levels 1 or 2, and the brace application did not produce any functional changes. There was a difference in this section in children with GMFCS levels 3 or 4, but a statistical evaluation could not be made due to the insufficient number of children involved at this level.

The Functional Reach Test is the most widely used tool to evaluate the reach function of children with CP and normally developing children. In our study, the PFRT, which is a form adapted to pediatrics and evaluates the ability to reach forward, to the right and to the left, was used. Hadders-Algra et al.²³ reported that reaching patterns and postural control differ between children with CP and healthy children in the same age range. In our study, especially in children with diparetic and ataxic CP, reaching was recorded as “more controlled” and “longer distance” with brace (Table 7, Figure 5). However, it was observed that there were no consistent results in the hemiparetic group, and some individuals

had reductions in reach, especially on the unaffected side. It was thought that this was due to the disappearance of compensation mechanisms in the body because of increased pelvic control. Based on the evaluation results, this study is an indication that the body braces increase dynamic and static body control. Especially in children with ataxic CP, the fact that the test parameters, which could never be done without a brace due to excessive sways, could be applied after wearing the brace is an important detail that shows how much the brace is beneficial in these children.

McClenaghan et al.²⁴ conducted a study in 20 children with CP aged 4 to 10 years and evaluated the upper-limb functionality using movements in daily living activities on different inclined sitting surfaces. They reported that they could not find a statistically significant difference between upright, forward-curved, and backward-curved seating surfaces in terms of upper-limb functionality.²⁴ Reid et al.²⁵ conducted a study in six children with CP with a mean age of 10.4 years, and achieved a functional sitting position by providing pelvic stabilization, hip abduction, and foot support using a pelvic belt; and in this position, they tilted the seating surface forward 10° and compared it with an ordinary wheelchair. They measured upper-limb functionality with the Canadian Occupational Performance Measure. As a result, they found that upper-limb functionality was better in the featured chair.²⁵ In our study, we evaluated upper-limb functions with and without braces in general with the BBT and the 9HPT, and also with the SPCM-Function section.

Based on the above information, in this study, we tried to create a treatment model that would contribute to trunk control. In

Table 7. Comparison of with or without brace results of cerebral palsy types of Functional Reach Test (n = 30)

Functional Reach Test of Cerebral Palsy Types		Diparetic (n = 13), X ± SD	Hemiparetic (n = 11), X ± SD	Ataxic (n = 6), X ± SD
FRT right anterior	Without brace	20.84 ± 5.64	19.82 ± 6.57	15 ± 8.22
	With brace	25.46 ± 5.16	23.64 ± 4.84	19.5 ± 4.93
FRT right lateral	Without brace	13.08 ± 3.75	16.64 ± 5.03	10.17 ± 5.34
	With brace	17.54 ± 4.94	19.18 ± 3.60	14.5 ± 3.51
FRT left anterior	Without brace	19.08 ± 4.57	19.27 ± 6.03	13 ± 10.92
	With brace	24.62 ± 4.33	21.27 ± 5.22	17.67 ± 10.46
FRT left lateral	Without brace	13.46 ± 3.48	15.27 ± 5.95	9.33 ± 6.25
	With brace	16.77 ± 4.83	17.82 ± 4.96	11.83 ± 6.71

FRT, Functional Reach Test.

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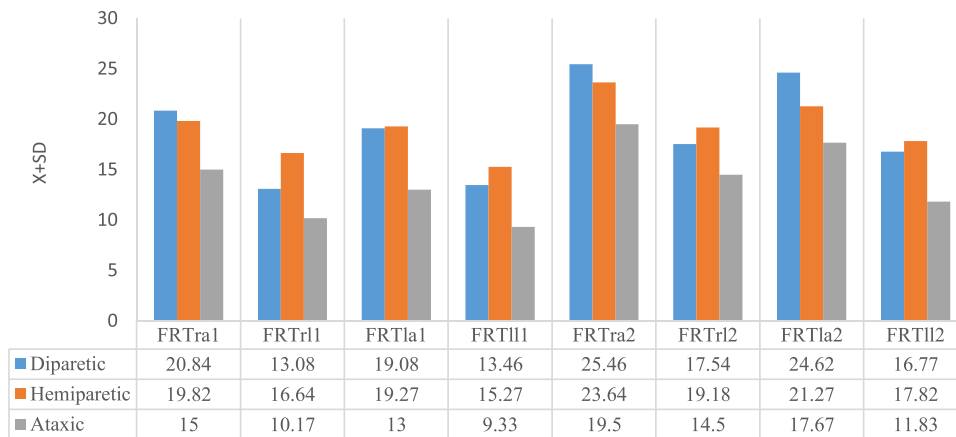


Figure 5. Functional Reach Test of cerebral palsy types.

our study, an attempt was made to increase trunk control using a trunk brace. After the examinations and tests, it was seen that the brace was significantly beneficial in body control. After the results of the tests were positive, custom-made braces were given to the younger children with CP who were not included in the study for use at home to contribute to the formation of the sitting balance and to correct their impaired posture. They were asked to use them for 3–4 hours a day, and their families responded positively. After the tests performed on a child with ataxic CP, who was also included in the study, the results were very good, and the brace was given to the child to use at home, and serious improvements were observed in trunk sways after 2 weeks. This shows us that it is beneficial to use the brace in daily life. This study only measures the immediate effects of brace use, but we are planning new studies to measure the long-term effects in the future.

LIMITATIONS

Our study is a comparison research in which the measurement results before and after are compared. In our study, tests for trunk control and balance were performed without using any device, therefore subjectively. If trunk control tests were performed via kinematic analyses and balance tests with a pressure center device, the tests would be more objective and more detailed. The other limitations of our study were that only four sizes of braces were used during the study and no custom-made braces for each individual were used.

CONCLUSIONS

This study was designed to show the immediate effect of the brace. It was observed that the trunk brace, which supports physiological lordosis in children with CP, increases trunk control and improves postural control skills of children, and this helps children to better use their limbs and fine motor movements. Postural control and upper-limb functionality in children with CP vary depending on the clinical type. Postural control and upper-limb functionality are more difficult to achieve in dyskinetic children than in spastic children. It was observed that dyskinetic children gained more in trunk control than spastic children. A decrease in trunk sways was observed, especially in children with ataxic CP. An

increase in limb functionality was observed as a result of increased proximal stabilization. It was observed that trunk control increased, and a straighter sitting posture was gained by supporting physiological lordosis in children with CP. It is thought that the brace provides these gains by providing core stabilization in the trunk as well as supporting the lordosis angle.

In line with the results, this study revealed that lower trunk support, which supports lumbar lordosis, increases trunk control and upper-limb functions, and improves sitting posture in children with CP. This made us think that this brace can be used in studies to increase trunk control during upper-limb use and at home to provide correct sitting posture.

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