Influence of Trunk Control on Gait Characteristics and Capacity in Children with Spastic Diplegic Cerebral Palsy

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Abstract

Aim: This study was conducted with the aim of to determine the relationship between trunk control and walking with time-distance characteristics and walking capacity in children with spastic diplegic cerebral palsy.

Method: The study included 14 children with spastic diplegic cerebral palsy, aged between 7-13 years, who were Level I-II according to Gross Motor Function Classification System. Trunk control was assessed with the Trunk Control Measurement Scale (TCMS; static, dynamic, reach, and total score). Temporo-spatial characteristics of gait were evaluated with a posturography device NeuroCom Inc. by means of a force-plate, and step length (cm), step width (cm), walking speed (cm/s) and right-left symmetry in walking (%) were evaluated. Walking capacity was evaluated with the modified timed get up and go test (mTUG). Relationships between variables were evaluated with Spearman's Correlation and linear regression analysis.

Results: According to the correlation analysis, there was a significantly negative good relationship between the static subscale of TCMS and mTUG (r: -0.754; $p<0.01$), and a significantly negative excellent relationship between dynamic and reaching subscales and total TCMS scores (respectively r=-0.837; -0.861; -0.872 $p<0.01$). Additionally, there were significantly good positive correlations between the static subscale of TCMS and step length, step wide and symmetry (respectively 0.624; 0.690; 0.720 $p<0.01$); a good positive correlation between the dynamic subscale of TCMS and step length, good positive correlation between reaching subscale of TCMS and step length; moderate to good positive correlations between total score of TCMS and step length, step wide and gait symmetry (respectively r:-0.872; 0.677; 0.585; 0.626 $p<0.01$). According to the regression analysis, the total TCMS score was a predictor of all gait characteristics except gait velocity; and mTUG (R2 = 0.796; 0.394; 0.303; 0.027; 0.320).

Conclusion: The results of this study show the importance of trunk control on gait characteristics and capacity in children with spastic diplegic CP.

Keywords: Cerebral palsy, postural control, gait.

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Spastik Diplejik Serebral Palsili Çocuklarda, Gövde Kontrolünün Yürüme Özellikleri ve Kapasitesine Etkisi

Öz

Amaç: Bu çalışma, spastik diplejik serebral palsili (SP) çocuklarda, gövde kontrolüyle yürümenin zaman mesafe özellikleri ve yürüme kapasitesiyle ilişkisinin belirlenmesi amacıyla yürütüldü.

Yöntem: Çalışmaya yaşları 7-13 arasında değişen, Kaba Motor Fonksiyon Sınıflandırma Sistemi'ne göre Seviye I-II olan 14 spastik diplejik serebral palsili çocuk dahil edilmiştir. Gövde kontrolü, Gövde Kontrolü Ölçüm Skalasıyla (TCMS; statik, dinamik, uzanma ve toplam puan) değerlendirildi. Yürüme zaman-mesafe özellikleri NeuroCom Inc. postürografi cihazı ile force-plate aracılığı ile değerlendirildi ve adım uzunluğu (cm), adım genişliği (cm), yürüme hızı (cm/s) ve yürümede sağ – sol simetrisi (%) değerlendirildi. Yürüme kapasitesi, modifiye zamanlı kalk ve yürü testi (mTUG) ile değerlendirildi. Değişkenler arasındaki ilişkiler Spearman Korelasyon ve doğrusal regresyon analizleri ile değerlendirildi.

Bulgular: Korelasyon analizlerine göre, TCMS'nin statik alt ölçeği ile mTUG arasında anlamlı derecede negatif iyi düzey bir ilişki (r: -0,754; $p<0,01$), dinamik ve uzanma alt ölçekleri ile toplam TCMS puanları arasında ise anlamlı derecede negatif mükemmel (sırasıyla r=-0,837; -0,861; -0,872 $p<0,01$) bir ilişki vardı. Ek olarak, TCMS'nin statik alt ölçeği ile adım uzunluğu, adım genişliği ve simetri arasında anlamlı derecede iyi pozitif korelasyonlar vardı (sırasıyla 0,624; 0,690; 0,720 $p<0,01$); TCMS'nin dinamik alt ölçeği ile adım uzunluğu arasında iyi pozitif korelasyon (r: 0,636 $p<0,01$), TCMS'nin uzanma alt boyutu ile adım uzunluğu arasında iyi pozitif korelasyon (r: 0,724; $p<0,01$); TCMS toplam puanı ile adım uzunluğu, adım genişliği ve yürüyüş simetrisi arasında orta ila iyi pozitif korelasyon vardı (sırasıyla r:-0,872; 0,677; 0,585; 0,626 $p<0,01$). Regresyon analizine göre, toplam TCMS puanı, yürüme hızı dışındaki tüm yürüyüş özelliklerinin ve mTUG'un prediktörüdür (sırasıyla R^2 = 0,796; 0,394; 0,303; 0,027; 0,320).

Sonuç: Bu çalışmanın sonuçları, spastik diplejik SP'li çocuklarda gövde kontrolünün yürüme özellikleri ve kapasitesi üzerindeki önemini göstermektedir.

Anahtar Sözcükler: Serebral palsi, postüral kontrol, yürüme.

Introduction

Cerebral palsy (CP) is a group of non-progressive permanent disorders resulting in activity limitation that affects both posture and movement and is caused by brain injury at the early stages of life[1]. Inefficient postural and selective control, weakness of muscles and muscle tone problems are impairments seen primarily, and these impairments may cause secondary problems such as contractures and bony deformities[2]. Both primary and secondary impairments present in various degrees of severity, coming together they negatively affect the performance of functional activities such as gait[3,4].

Postural control, which is defined as control of the body for both stabilization and orientation in the space during activities, is base of all movements and inefficient postural control is an important problem in the development of children with CP[5,6]

Trunk control is one part of postural control and it is pro-necessity for adequate movement; because of its role in maintaining posture, shifting weight during activities, moving against to gravity, controlling and changing body position for equilibrium and achieving functional activities as walking[7,8].

Trunk control includes selective trunk movements, and trunk stabilization is basic for active and selective movements of different parts of the body such as limbs[4] and especially important for equilibrium during walking[7]. Moreover, the trunk works for a several control functions during walking. It has an important function in equilibrium control proactively; and in controlling sways related with gait to maintain head stability. Moreover, trunk control plays an important role in achieving efficient locomotion with the interaction of the lower limb movements[9] as well as upper limb[10], and have important role in functionality[11]. According to the International Classification of Functioning, Disability and Health (ICF) trunk control is a bodily function, and impairment in trunk control, may influence activity and participation limitations affected by mobility. Additionally, poor trunk control affects stability of the head in space thus affecting visual skills, eye-hand coordination, upper limb functions, and may cause restrictions on major life areas such as educational settings and social interaction of children with CP[5].

Improving or maintaining the gait is one of the primary goals of rehabilitation, and functional gait is important for children with CP for mobility in daily life, and benefits for health as well. To develop optimal gait rehabilitation strategies, investigating the role of the trunk during walking and understanding the trunk-gait combination is important[3].

The trunk is an important part of the body during gait, because of its role in locomotion control. Additionally, the trunk stabilizes the head during walking and this stabilization is essential to integrate visual and vestibular inputs that have basic functions in maintaining postural control[12].

Although trunk kinematic abnormalities during gait were described as compensation for gait disorders, to have a better gross motor function, according to studies it is recommended to add training of trunk control, on the other hand studies focused on either trunk control or gait and researches evaluate the role of trunk control on gait function objectively are limited[13]. Therefore, it was aimed in this study to evaluate the effects of trunk control deficiency on temporal-spatial characteristics of gait and give direction to new studies.

Material and Method

This study was conducted at Hacettepe University, Faculty of Physical Therapy and Rehabilitation between September 2017 - September 2018. Ethical approval for the study was gathered from Hacettepe University, Non-invasive Clinical Researches Ethical Committee (Number: GO 16/368-41; Date: 31.05.2016). All parents of children with CP were informed and written consent was gathered.

The minimum sample size required to reach 80% power when tested at the 95% confidence level is a total of 12 individuals. Considering the possibility of 25% missing data, we decided to recruit 14 children. Fourteen children with spastic diplegic CP, age between included to the study. Inclusion criteria were *i.* being level I or II according to Gross Motor Function Classification System (GMFCS), *ii.* not having cognitive problems, *iii.* being able to walk without any orthosis; exclusion criteria were *i.* having Botulinum Toxin injection in past 6 months; *ii.* undergone orthopedic or neurosurgery in the past one year.

Evaluations:

Gross Motor Function Classification System (GMFCS)

The GMFCS is widely used to classify motor impairment in individuals with CP in a standard manner. Levels are divided according to functional condition, the necessity for mobility aids such as hand-held wheeled mobility devices[14]. The Turkish version of the GMFCS, whose validity and reliability of has been demonstrated by El et al, was used in this study. Test-retest reliability of the Turkish GMFCS was found high (ICC: 0.94; 95% CI: 0.94–0.98)[15].

The Trunk Control Measurement Scale (TCMS)

The TCMS was used to assess trunk control. The TCMS consists of 15 items in total within three subscales as static sitting balance, selective movement control and dynamic reaching. All these three subscales evaluate trunk control in movements related to daily tasks. The total score of the TCMS ranges from 0 to 58 and higher score indicates a better trunk control performance. Psychometric properties of the TCMS established before[16]. Test was translated into Turkish and found to be valid and reliable (ICC: 95% CI (0.823-886), and the intra-rater reliability: 95% CI (0.986-0.992). The Spearman rank correlation coefficient between the Gross Motor Function Measure total score and Turkish TCMS rs: 0.827; $p < 0.05$ Part B was rs: 0.863; $p < 0.05$)[5].

The Turkish version of the TCMS was used and during the test, children were seated on a bench without any support. The evaluation had done without any orthoses or shoes. The test was repeated three times and the best performance was scored.

Evaluation of Gait Characteristics:

Gait characteristics were investigated with NeuroCom SMART Balance Master (NeuroCom International Inc. Clackhamas, USA) static posturography device as step length (centimeters – cm), step wide (cm) gait velocity (cm/second) and right/left side symmetry during gait (%). This system measures gait characteristics objectively and digitally via force-plate located on a flat surface. Each child walked on the force-plate three times without any orthosis or shoe. Each characteristic was calculated by computer software integrated into the system.

Modified Timed-Up and Go Test

The pediatric version of the Timed Up and Go (mTUG) test was used for assessing the gait capacity. The test records the duration that a child needs to stand up from a chair, walk three meters to a set target, turn around and come back to the chair and sit down, and the passed time during this performance was recorded. All children performed the mTUG three times and calculated the mean time. Psychometric properties of the mTUG were shown in children with CP[17].

Statistical Analysis:

All data were analyzed by using SPSS for Windows version 24.0 package program (SPSS Inc. Chicago, IL, USA). Normality distribution was evaluated using the Shapiro-Kolmogorov test and found to be non-parametric. The Spearman correlation test was used to evaluate the relationships between non-parametric data. The correlation score and its meaning are as follows: no correlation between 0 and 0.25, fair correlation between 0.25 and 0.50, moderate to good correlation between 0.50 - 0.75, and excellent correlation over 0.75[18]. Simple linear regression analysis was carried out to determine the most important predictor(s) for explaining gait characteristics. A model was analyzed using step length, step wide, gait velocity and right/left side symmetry during gait, and TCMS total scores were determined as independent variables. For descriptive statistics mean and standard deviation were used.

Results

The mean age of 14 children included in the study were 10.57±3.24 (minimum 7, maximum 13) years; 8 of them were boys and 6 of them were girls. Distribution according to the GMFCS levels was; Level I: 6 and Level II: 8.

The TCMS, mTUG scores and gait characteristics showed in Table 1.

Table 1. Trunk control measurement scale, modified timed up and go test and gait characteristics scores (n=14)

	Mean±Standard Deviation	**Minimum - Maximum**
Trunk Control Measurement Scale		
Static	12.2353±1.75105	9-14
Dynamic	10.5882±3.75930	7-17
Reaching	6.2353±0.97014	5-8
Total	29.0588±5.88930	24-39
Gait Characteristics		
Step length (cm)	17.3706±4.99209	9.10 – 24.00

Step wide (cm)	34.8941±10.39829	22.40 – 53.10
Velocity (cm/s)	49.2647±9.13653	27.30 – 61.00
Symmetry (%)	21.8824±10.86210	5.00 – 37.00
mTUG	10.9100±1.58296	8.03 – 12.92

cm: centimeter; s: second; %: per cent; mTUG: modified Timed Up and Go Test

According to the correlation analyses, there was a significantly negative good relationship between the static subscale of TCMS and mTUG, and a significantly negative excellent relationship between dynamic and reaching subscales and total TCMS scores. Additionally, there were significantly good positive correlations between the static subscale of TCMS and step length, step wide and symmetry; a good positive correlation between the dynamic subscale of TCMS and step length, good positive correlation between reaching subscale of TCMS and step length; moderate to good positive correlations between total score of TCMS and step length, step wide and gait symmetry. All correlations between parameters showed in Table 2.

Table 2. Relationships between trunk control and gait characteristics (n=14)

Trunk Control Measurement Scale (TCMS)		**mTUG**	**Step length**	**Step wide**	**Velocity**	**Symmetry**
Static	**r**	-0.754**	0.624**	0.690**	0.168	0.720**
	p	0.0001	0.007	0.002	0.519	0.001
Dynamic	**r**	-0.837**	0.636**	0.477	0.153	0.284
	p	0.000	0.006	0.053	0.559	0.269
Reaching	**r**	-0.861**	0.724**	0.399	0.357	0.201
	p	0.0001	0.001	0.112	0.160	0.440
Total	**r**	-0.872**	0.677**	0.585*	0.265	0.626**
	p	0.0001	0.003	0.014	0.304	0.007

Spearman Correlation Test; mTUG: Modified Timed Up and Go Test; r: Spearman's rho; *: $p<0.05$; ** $p<0.01$

According to the regression analysis, the total TCMS score was predictor of all gait characteristics except gait velocity; and mTUG (Table 3).

Table 3. Regression analysis of variables

Dependent variable	Independent variable	B	Standard error B	Beta	R^2
TCMS Total Score	**mTUG**	-0.240	0.031	-0.892 **(p<0.01)**	0.796
	Step length	-0.557	0.165	-0.657 **(p=0.004)**	0.394
	Step wide	0.791	0.381	0.550 **(p=0.022)**	0.303
	Velocity	0.254	0.395	0.163 (p=0.531)	0.027
	Symmetry	-1.043	0.393	-0.566 **(p<0.018)**	0.320

mTUG: Modified Timed Up and Go Test, TCMS: Trunk Control Measurement Scale, bold characters indicate p<0.05

Discussion

The current study showed that trunk control is closely related with both gait characteristics and capacity; in addition, trunk control is an important predictor for gait capacity and characteristics in children with diplegic CP.

In general, motor control inefficiency and impairments in lower limbs were seen as the cause of both primary and secondary gait deviations, respectively and as described trunk postural control, trunk control and its evaluation in children with CP were becoming more important in researches and clinic rehabilitation settings[9]. This current study is one of the few studies that show interaction between trunk control and gait characteristics directly.

Studies on gait in children with CP to define gait pathologies based on three-dimensional analysis, were mainly evaluated on the impact of impairments in lower extremities during walking, on the other hand trunk movements were not evaluated. Van de Walle et al., in their study suggested that the decreased gait efficiency found in children with diplegic CP was mainly attributed to increased mechanical work of the head, trunk and arms[19]. Therefore, as Van de Walle et al., the current study underlines the importance of trunk active movements and its static control to gain further insights into the pathological gait patterns in children with CP.

In general, different studies tended to explain the role of the trunk in children with CP as compensatory due to lower limb impairments[4,6,19]. However, these studies failed to investigate the occurrence of an underlying trunk control deficit in their study population. As such, the reported compensatory role of the trunk appears mainly based on assumptions rather than on objective evidence[20]. Therefore, a valid clinical measurement for trunk control in children with CP such as TCMS that evaluates static and dynamic aspects of trunk control in seated position, with reducing the influence of lower limb impairments on trunk performance is important[13]. Although the TCMS remains unclear if and how this deficit is manifested during the performance during gait, the results of the current study may help to explain the relationship and importance of trunk on gait characteristics.

Heyrman et al., in their study investigated the functional relation between the altered trunk and lower limb movements during gait in children with spastic diplegia to explain an underlying trunk control deficit in this group, or if they should be solely considered as compensatory movements for lower limb impairments[7]. Their results showed that increased altered trunk movements during gait were related to the presence of an underlying trunk control deficit, and they found significant correlations with the subscales selective movement control and dynamic reaching, pointing to the dynamic character of trunk control requirements during gait. Putting together our results provide an evidence for the presence of underlying impaired trunk control in children with spastic diplegia exhibiting difficulties with sustainment of trunk stability during gait. The results of both our and Heyrman et al[7]. indicates the importance of including trunk control deficits in the treatment plan, since compensatory trunk movements do not require direct specific treatment, while impairment in the trunk requires for gait[7]. With this hypothesis, Numanoğlu Akbaş and Kerem Günel, in their study, investigated the effects of trunk based therapy on gross motor functions evaluated with Gross Motor Functions Measurements – GMFM, in which E part directly related with gait; and after the therapy found improvements in motor functions[21]. All these findings support the results of the current study that impaired trunk control is related to gait performance.

In their study, Balzer et al. showed a correlation between trunk control measured by TCMS and gait capacity using the mTUG test, in their study the strongest predictor of gait capacity was trunk control[13]. In our study we found a correlation between static, dynamic and reaching subscales and the total score of TCMS, and both with gait capacity and step length. This finding may reflect to improve step length and gait capability, enhancing overall trunk control is important in clinical gait rehabilitation in children with CP.

Although the findings of this study are important, this study has some limitations. The main limitation of the study is the lack of three dimensional movement analysis with kinetic and kinematic values. Therefore, in future research, it is recommended to use dimensional movement analysis to explain the role of the trunk during gait.

Conclusion

In conclusion, the results of this study show the importance of trunk control on gait characteristics and capacity in children with spastic diplegic CP. Therefore, it is strongly recommended to clinicians evaluate the trunk in children with CP before deciding on therapy goals, especially to improve gait and mobility as well as gait capacity, and it is important to add into the physiotherapy and rehabilitation program trunk targeting interventions. Therefore, the results of this study indicate consideration of a case for combined strength and postural control training of the trunk for gait rehabilitation in children with spastic diplegic CP.

Ethical approval for the study was gathered from Hacettepe University, Non-invasive Clinical Researches Ethical Committee (Number: GO 16/368-41).

All parents of children informed about the study and written consent gathered.

Authors declared that no conflict of interest.

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