# The central role of trunk control in the gross motor function of children with cerebral palsy: a retrospective cross-sectional study

DEREK JOHN CURTIS[1,2,3] | PENNY BUTLER[4] | SANDY SAAVEDRA[5] | JESPER BENCKE[2] | THOMAS KALLEMOSE[6] | STIG SONNE-HOLM[2] | MARJORIE WOOLLACOTT[7]

**1** Department of Physical and Occupational Therapy, Hvidovre University Hospital, Copenhagen; **2** Gait Analysis Laboratory, Department of Orthopedic Surgery, Hvidovre University Hospital, Copenhagen; **3** Department of Neuroscience and Pharmacology, University of Copenhagen, Copenhagen, Denmark. **4** The Movement Centre, Robert Jones and Agnes Hunt Hospital, Oswestry, UK. **5** Department of Rehabilitation Sciences College of Education, Nursing & Health Professions, University of Hartford, Hartford, CT, USA. **6** Clinical Research Centre, Hvidovre University Hospital, Copenhagen, Denmark. **7** Institute of Neuroscience, University of Oregon, Eugene, OR, USA.

Correspondence to Derek John Curtis at Gait Analysis Laboratory, Department of Orthopaedic Surgery, Hvidovre University Hospital, Kettegaard Alle 30, DK-2650 Hvidovre, Denmark.
E-mail: derek.john.curtis@regionh.dk

**PUBLICATION DATA**
Accepted for publication 28th September 2014.
Published online

**ABBREVIATIONS**

| | |
|---|---|
| PEDI | Pediatric Evaluation of Disability Inventory |
| SATCo | Segmental Assessment of Trunk Control |

**AIM** Improvement of gross motor function and mobility are primary goals of physical therapy in children with cerebral palsy (CP). The purpose of this study was to investigate the relationship between segmental control of the trunk and the corresponding gross motor function in children with CP.

**METHOD** This retrospective cross-sectional study was based on 92 consecutive referrals of children with CP in Gross Motor Function Classification System (GMFCS) levels I to V, 39 females, 53 males (median age 4y [range 1–14y]), and 77, 12, and 3 with spastic, dyskinetic, and ataxic CP respectively. The participants were tested using the Gross Motor Function Measure (GMFM), the Pediatric Evaluation of Disability Inventory (PEDI), and the Segmental Assessment of Trunk Control (SATCo).

**RESULTS** Linear regression analysis showed a positive relationship between the segmental level of trunk control and age, with both gross motor function and mobility. Segmental trunk control measured using the SATCo could explain between 38% and 40% of variation in GMFM and between 32% and 37% of variation in PEDI.

**INTERPRETATION** This study suggests a strong association between segmental trunk postural control and gross motor function and mobility with significant clinical implications for the treatment of children with CP.

One of the more recent and cited definitions of cerebral palsy (CP) includes the phrase 'a group of permanent disorders of the development of movement and posture'.[1] This disorder in the development of movement and posture produces a corresponding reduction in mobility, self-care, and social function[2] in children with CP. Training interventions aim at improving the child's motor function in the hope that this will improve the child's levels of activity and participation, thus enhancing the child's quality of life. There are a great variety of training interventions used by therapists to improve motor function by identifying and modifying deficits in the child's motor system. A number of studies have shown a significant relationship between motor function and various impairments such as spasticity, quality of movement, postural stability, distribution of involvement, strength, range of motion limitations, and reduced endurance.[3,4] A review of the assessment of postural control in children with CP concluded that a link between postural control and functionality was evident but that there was a lack of studies assessing postural control by means of scales and functional tests or during daily functional activities.[5] One recent study has addressed this link between trunk control in sitting and gait in children with spastic diplegia and concluded that trunk movements during gait were not solely compensatory, but could also reflect an underlying trunk control deficit.[6] Another study from the same group concluded that trunk control is impaired in children with CP, and that the impairment is dependent on the topography and severity of the motor impairment.[7]

A recent review[8] identified four clinical tools measuring trunk control: the Sitting Assessment of Children with Neuromotor Disability,[9] the Trunk Control Measurement Scale,[10] the Trunk Impairment Scale,[11] and the Segmental Assessment of Trunk Control (SATCo).[12] The Sitting Assessment of Children with Neuromotor Disability, Trunk Control Measurement Scale, and Trunk Impairment Scale are tests based on functional sitting abilities.

The SATCo test is unique among these tests in that it is much less a functional test than a specific biomechanical test. The object of the SATCo is to define the specific postural control mechanisms of the trunk which underlie the individuals's functional sitting abilities. Assessment is thus undertaken on a segmental basis to determine the static, active, and reactive balance at the discrete trunk levels. Static, active, and reactive balance are necessary in different degrees depending on the motor function and environment. Separate testing of each element of postural balance allows the tester to determine the segmental level for each of these elements of postural control discretely. In terms of clinical practice, this allows the therapist to set a more specific therapeutic goal.

This segmental approach to trunk control and its significance in relation to functional ability has been addressed in three previously published studies. The first study by Saavedra et al.[13] evaluated postural control at a simplified task level by measuring head stability during quiet sitting while systematically manipulating the level of trunk support and vision in 15 children with CP (6–16y), 26 children with typical development (4–14y), and 11 adults. A second study by Saavedra et al.[14] used a similar analytical approach using kinematics, remote eye tracking, and a trunk support device to examine the functional coupling of the eye, head, and hand, and the extent to which it was constrained by trunk postural control in 10 children with CP (6–16y). The third study by Rachwani et al.[15] investigated the effect of different levels of postural support on the success of reaching postural stability and reaching kinematics while infants reached for a toy in 17 infants with typical development between 4 months and 6 months of age. These studies demonstrated an apparently close relationship between segmental trunk control and head stability and eye–hand coordination, but did not measure the effect of segmental trunk control on a global measure of gross motor function or functional mobility. An earlier study by Butler et al.[12] reported a correlation between the SATCo test and Gross Motor Function Measure (GMFM66) Dimension *B* (sitting) ($R$=0.731–0.833) for 24 children with neuromotor disability (21 with CP). From this study it would appear that there may be a relationship between the segmental level of trunk control and gross motor function in sitting for children with neuromotor disability. The same study reported a correlation between SATCo and the Pediatric Evaluation of Disability Inventory (PEDI) Mobility Domain Child ($R$=0.695–0.803) showing an apparent relationship between functional mobility and segmental trunk control. This study was relatively small, the participants heterogeneous with the inclusion of diagnoses other than CP, and only the Sitting dimension of gross motor function included in the analyses.

The purpose of the current study was to investigate more closely the relationship between the segmental control of the trunk and the corresponding global gross motor function and functional mobility in children with CP. The hypothesis for this study was that global gross motor function and functional mobility in children with CP is dependent on their age, neuromotor abnormality, and their segmental level of trunk control.

**What this paper adds**

- Trunk control and motor function are closely related in CP.
- Trunk postural control can vary between trunk segments.
- Testing segmental trunk control gives more specific postural control information.
- Segmental trunk control is a significant predictor of motor function.

## METHOD

This study was a retrospective cross-sectional study. Data for the study were collected from a single specialized physiotherapy clinic located in the UK. The clinic has systematically collected GMFM, SATCo, and PEDI data for all children referred since August 2008. This study includes baseline measurements for all 92 referrals of children with CP in the period October 2008 to February 2014.

The children were tested in the clinical setting by experienced paediatric physiotherapists who were familiar with the tests and used them routinely. The functional skills mobility dimension of the PEDI was administered by interview between the physiotherapist and the child's parents or guardian. The GMFM test was administered using the item set approach as described by Russell et al.[16] The SATCo test was administered in accordance with the guidelines described by Butler et al.[12]

The relationship between SATCo level and GMFM, PEDI Mobility Functional Skills Scaled Score and PEDI Mobility Caregiver Assistance Scaled Score was investigated using linear modelling. Age was included in the GMFM model as age has been shown from gross motor curves to be related to GMFM and from PEDI normative data to be related to the movement subscale of the PEDI test. We also included predominant neuromotor abnormality in the regression model as we hypothesized that this also might be a significant predictor of GMFM and PEDI scores.

The model used to evaluate the predictive effect of SATCo level, age, and predominant neuromotor abnormality on GMFM was therefore:

$$\mathrm{GMFM}_i = b_0 + b_1\mathrm{SATCo}_i + b_2\mathrm{Age}_i + b_3\mathrm{Neuromotor\ abnormality}_i.$$

A similar model was used to determine the predictive effect of SATCo, age, and predominant neuromotor abnormality on the PEDI Mobility Function scaled score (PEDI Function models) and the PEDI Mobility Caregiver scaled score (PEDI Care models):

$$\mathrm{PEDI}_i = b_0 + b_1\mathrm{SATCo}_i + b_2\mathrm{Age}_i + b_3\mathrm{Neuromotor\ abnormality}_i.$$

### Statistical analysis

The data were not used to explore relations before the definition of the models, as these models were defined before data analysis to investigate the hypothesis of this study.

In both cases, SATCo and neuromotor abnormality were modelled as categorical data producing different regression coefficients for each SATCo and disability category. Each regression model was repeated three times using scores from the three discrete SATCo dimensions measuring static, active, and reactive postural control.

For each of the above models the coefficient of determination ($R^2$) was calculated. The model was then repeated without the reference category SATCo, and the difference in $R^2$ between these two models was calculated as an expression of the amount of variance SATCo explained.

The intercept of each model was based on the reference category, SATCo at Head level and the reference category Neuromotor abnormality Ataxic. The exceptions to this were the models using reactive SATCo in which the Head level was not tested. For these models the intercept was based on the reference category SATCo Upper Thoracic level and the reference category Neuromotor abnormality Ataxic.

To validate the models, QQplots were made to assess the normality of the model residuals, these showed no reason to dismiss the normality assumption. Prediction plots were also made to view the relationship between the measured and predicted outcomes. The predicted values did not deviate enough from those measured to dismiss the model structure; however, there was a tendency for slight underestimation at the larger values. Thus we proceeded with the analysis as planned.

All regression model analysis was performed using R 3.02 (R Foundation for Statistical Computing, Vienna, Austria). A $p$ value of $<0.05$ was considered statistically significant.

The capital regional committee on health research ethics did not consider that their approval was needed for this study.

## RESULTS

This retrospective cross-sectional study was based on 92 consecutive referrals of children with CP in GMFCS levels I to V (39 females, 53 females; median age 4y [range 1–14y]). Other details of predominant neuromotor abnormality (i.e. spastic, dyskinetic, ataxic),[17] Gross Motor Classification System (GMFCS) and Manual Ability Classification System[18] levels, PEDI and SATCo scores of the participants are shown in Table I.

The prediction plots for the models are shown in Figure 1. Plots were made with different symbols for the five GMFCS levels to allow the identification of patterns in the model predictions for the different GMFCS levels.

SATCo scores and age were significant predictors for the GMFM score. The $F$ test using type III SS for the SATCo scores, for whether the inclusion of the SATCo scores had a significant effect on the model, had a $p$ value of $<0.001$ for all the GMFM models, and the same test for age had a $p$ value of no more than 0.033. The $F$ test using type III SS for neuromotor abnormality did not show any significant effect in any of the GMFM models. All values for the test can be seen in Table II. We expected a monotone increasing relationship between GMFM and higher level of SATCo score, this is mostly the case for the coefficient estimates (Table II); however, there was a slight decrease in the coefficients from upper lumbar to lower lumbar in all GMFM models. There was also a large increase in the value for the full trunk control followed by a decrease at no control issues, but only in the active SATCo model. Age had a positive effect on the GMFM score in all GMFM models.

**Table I:** Descriptive statistic

| Variable | |
|---|---|
| Median age (25th–75th centile) | 4y 7mo (2y 7mo–6y 4mo) |
| Sex, Females/Males, *n* | 39/53 |
| Neuromotor abnormality, *n* (%) | |
| Ataxic | 3 (3) |
| Spastic | 77 (84) |
| Dyskinetic | 12 (13) |
| GMFCS level, *n* (%) | |
| I | 3 (3) |
| II | 13 (14) |
| III | 23 (25) |
| IV | 30 (33) |
| V | 23 (25) |
| GMFM score, mean (SD) | 40.6 (15.5) |
| MACS level, mean (SD) | |
| I | 9 (10) |
| II | 34 (37) |
| III | 20 (22) |
| IV | 13 (14) |
| V | 13 (14) |
| Missing | 3 (3) |
| Mean (SD) PEDI Mobility Function SS | 38.6 (18.1) |
| Mean (SD) PEDI Mobility Caregiver SS | 34. 3 (24.2) |
| SATCo static scores, *n* (%) | |
| Head | 10 (11) |
| Upper thoracic | 15 (16) |
| Mid thoracic | 14 (15) |
| Lower thoracic | 11 (12) |
| Upper lumbar | 11 (12) |
| Lower lumbar | 15 (16) |
| Full trunk control | 5 (5) |
| No control issues | 11 (12) |
| SATCo active scores, *n* (%) | |
| Head | 11 (12) |
| Upper thoracic | 14 (15) |
| Mid thoracic | 15 (16) |
| Lower thoracic | 12 (13) |
| Upper lumbar | 13 (14) |
| Lower lumbar | 16 (17) |
| Full trunk control | 1 (1) |
| No control issues | 10 (11) |
| SATCo reactive scores, *n* (%) | |
| Upper thoracic | 25 (27) |
| Mid thoracic | 16 (17) |
| Lower thoracic | 12 (13) |
| Upper lumbar | 15 (16) |
| Lower lumbar | 15 (16) |
| Full trunk control | 2 (2) |
| No control issues | 7 (8) |

GMFCS, Gross Motor Function Classification System; GMFM, Gross Motor Function Measure; MACS, Manual Ability Classification System; PEDI, Pediatric Evaluation of Disability Inventory; SS, Scaled Score; SATCo, Segmental Assessment of Trunk Control.

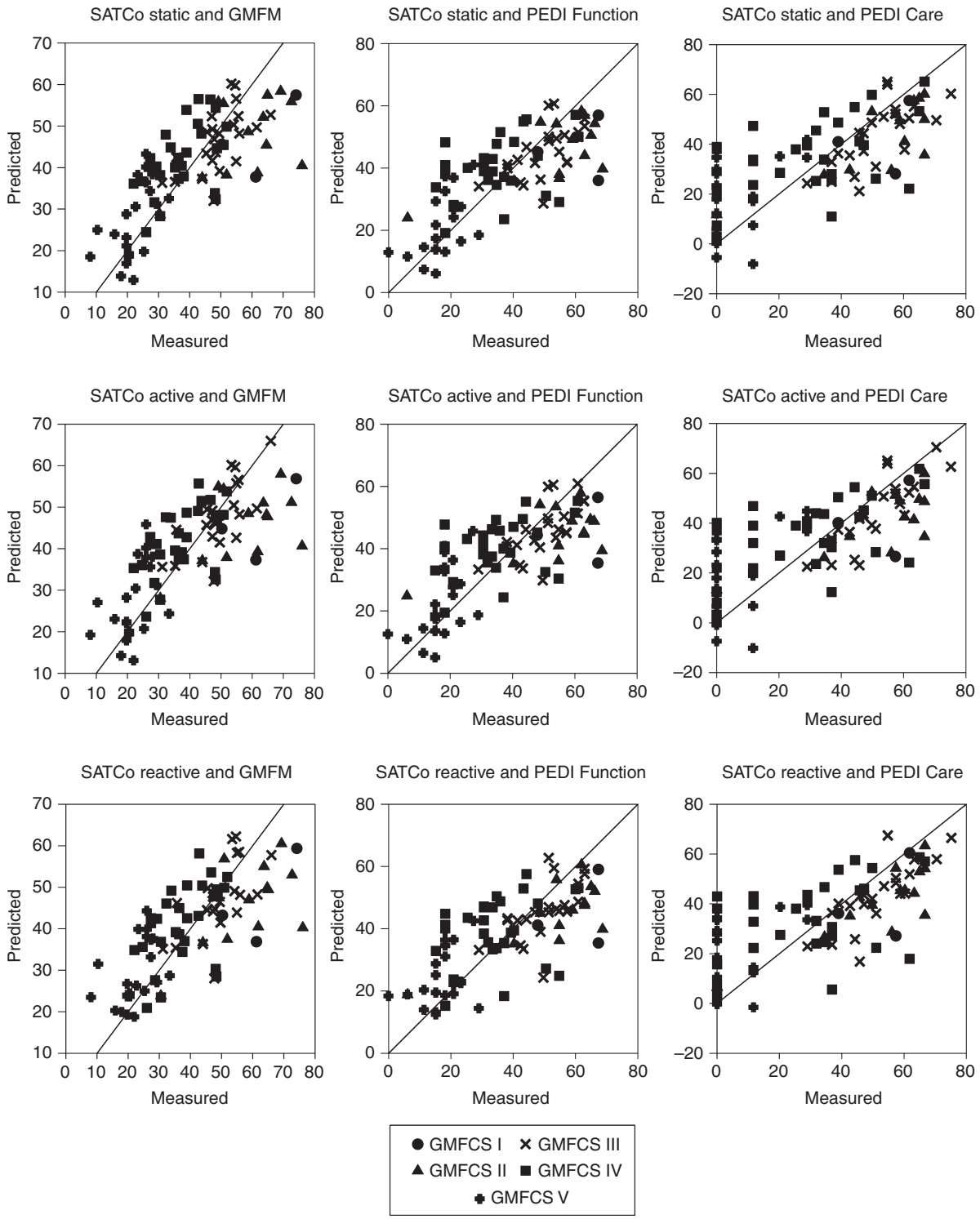


**Figure 1:** Prediction plots for the models with symbols showing the Gross Motor Function Classification System (GMFCS) levels of the participants. SATCo, Segmental Assessment of Trunk Control; PEDI, Pediatric Evaluation of Disability Inventory; GMFM, Gross Motor Function Measure.

SATCo scores and age were significant predictors for both PEDI scores. The *F* test using type III SS for the SATCo scores had a *p* value of <0.001 for all the PEDI models and a *p* value of no more than 0.015 for Age. The *F* test using type III SS for Neuromotor abnormality did not show any significant effect in any of the PEDI models. All values for the test can be seen in Tables III and IV. As with the GMFM score, we expected a monotone increasing

**Table II:** Result of the GMFM models for the three SATCo test scores

| | SATCo static | | SATCo active | | SATCo reactive | |
|---|---|---|---|---|---|---|
| Parameters | *B* (SE) | *p* | *B* (SE) | *p* | *B* (SE) | *p* |
| Intercept | 23.2 (7.7) | | 22.4 (7.7) | | 25.2 (7.4) | |
| SATCo | | | | | | |
| Upper thoracic | 9.8 (4.5) | 0.033 | 8.5 (4.5) | 0.063 | – | – |
| Mid thoracic | 17.9 (4.6) | <0.001 | 16.5 (4.5) | <0.001 | 11.7 (3.7) | 0.002 |
| Lower thoracic | 18.4 (5.1) | <0.001 | 17.8 (4.9) | <0.001 | 14.7 (4.2) | 0.001 |
| Upper lumbar | 26.7 (4.9) | <0.001 | 25.1 (4.6) | <0.001 | 19.3 (3.7) | <0.001 |
| Lower lumbar | 23.5 (4.6) | <0.001 | 24.8 (4.4) | <0.001 | 22.2 (3.7) | <0.001 |
| Full trunk control | 31.5 (6.2) | <0.001 | 43.5 (11,5) | <0.001 | 31.0 (8.2) | <0.001 |
| No control issues | 35.9 (4.8) | <0.001 | 33.9 (4.8) | <0.001 | 32.1 (4.8) | <0.001 |
| Type III SS test | | <0.001 | | <0.001 | | <0.001 |
| Age | 0.9 (0.4) | 0.033 | 1.1 (0.4) | 0.011 | 1.1 (0.4) | 0.009 |
| Neuromotor abnormality | | | | | | |
| Dyskinetic | −11.2 (7.6) | 0.143 | −10.5 (7.7) | 0.177 | −7.6 (7.6) | 0.320 |
| Spastic | −6.1 (6.8) | 0.378 | −4.8 (6.9) | 0.484 | −3.5 (6.9) | 0.619 |
| *F* test using type III SS | | 0.236 | | 0.236 | | 0.446 |
| $R^2$ | 0.51 | | 0.50 | | 0.49 | |
| $R^2$ without SATCo in model | 0.11 | | 0.11 | | 0.11 | |

GMFM, Gross Motor Function Measure; SATCo, Segmental Assessment of Trunk Control; SS, Scaled Score.

**Table III:** Results of the PEDI Function models for the three SATCo test scores

| | SATCo static | | SATCo active | | SATCo reactive | |
|---|---|---|---|---|---|---|
| Parameters | *B* (SE) | *p* | *B* (SE) | *p* | *B* (SE) | *p* |
| Intercept | 13.6 (9.2) | | 10.8 (9.1) | | 15.4 (8.8) | |
| SATCo | | | | | | |
| Upper thoracic | 10.7 (5.4) | 0.051 | 11.8 (5.3) | 0.029 | – | – |
| Mid thoracic | 21.3 (5.5) | <0.001 | 20.9 (5.3) | <0.001 | 14.9 (4.5) | 0.001 |
| Lower thoracic | 22.5 (6.0) | <0.001 | 25.6 (5.8) | <0.001 | 19.7 (5.0) | <0.001 |
| Upper lumbar | 31.7 (5.9) | <0.001 | 31.3 (5.4) | <0.001 | 22.1 (4.4) | <0.001 |
| Lower lumbar | 26.5 (5.4) | <0.001 | 27.6 (5.3) | <0.001 | 24.3 (4.5) | <0.001 |
| Full trunk control | 33.4 (7.3) | <0.001 | 44.4 (13.6) | 0.002 | 31.8 (9.9) | 0.002 |
| No control issues | 39.9 (5.7) | <0.001 | 39.4 (5.7) | <0.001 | 35.8 (5.7) | <0.001 |
| Type III SS test | | <0.001 | | <0.001 | | <0.001 |
| Age | 1.2 (0.5) | 0.015 | 1.3 (0.5) | 0.009 | 1.4 (0.5) | 0.005 |
| Neuromotor abnormality | | | | | | |
| Dyskinetic | −8.8 (9.0) | 0.332 | −7.1 (9.1) | 0.434 | −4.5 (9.1) | 0.627 |
| Spastic | −2.6 (8.1) | 0.749 | −0.3 (8.1) | 0.973 | 0.8 (8.3) | 0.925 |
| *F* test using type III SS | | 0.334 | | 0.288 | | 0.493 |
| $R^2$ | 0.48 | | 0.48 | | 0.46 | |
| $R^2$ without SATCo in model | 0.11 | | 0.12 | | 0.13 | |

PEDI, Pediatric Evaluation of Disability Inventory; SATCo, Segmental Assessment of Trunk Control; SS, Scaled Score.

relationship between PEDI and a higher level of SATCo score. As with the GMFM models, this is mostly the case (Tables III and IV), again with the same decrease for lower lumbar in the models with static and active SATCo dimensions, but not in the model with the reactive SATCo dimension measure, where the levels were increasing or equal. A non-linear increase in the values for full trunk control followed by a decrease at no control issues was also present in both active SATCo models. Age had a positive effect in all PEDI models, with slightly larger values than the GMFM models.

## DISCUSSION

Trunk control is regarded as an important element in the development of motor function, but in most previous research it has been measured functionally and biomechanically as a single segment. The development of the SATCo test allows classification of the static, active and reactive postural control of the trunk on a segmental basis. This study provides the first evidence of a predictive effect of the segmental level of trunk control on both global motor control as measured by GMFM and functional mobility performance as measured by the PEDI Mobility Functional Skills Scaled Score and PEDI Mobility Caregiver Assistance Scaled Score in children and young people with CP. This study supports the hypothesis that the segmental level of trunk control is one of the important factors determining the gross motor function and mobility skills for children with CP, predicting between 30% and 40% of the variance in GMFM and PEDI scores.

**Table IV:** Results of the PEDI Care models for the three SATCo test scores

| | SATCo static | | SATCo active | | SATCo reactive | |
|---|---|---|---|---|---|---|
| Parameters | *B* (SE) | *p* | *B* (SE) | *p* | *B* (SE) | *p* |
| Intercept | 7.9 (12.0) | | 2.9 (11.7) | | 7.9 (11.4) | |
| SATCo | | | | | | |
| Upper thoracic | 10.8 (7.0) | 0.130 | 13.2 (6.9) | 0.058 | – | – |
| Mid thoracic | 24.3 (7.2) | 0.001 | 23.6 (6.8) | <0.001 | 17.6 (5.8) | 0.003 |
| Lower thoracic | 24.2 (7.9) | 0.003 | 30.0 (7.5) | <0.001 | 23.8 (6.5) | <0.001 |
| Upper lumbar | 39.8 (7.6) | <0.001 | 40.0 (7.0) | <0.001 | 29.4 (5.7) | <0.001 |
| Lower lumbar | 31.5 (7.1) | <0.001 | 33.4 (6.8) | <0.001 | 29.5 (5.8) | <0.001 |
| Full trunk control | 42.1 (9.6) | <0.001 | 63.6 (17.6) | <0.001 | 44.2 (12.8) | <0.001 |
| No control issues | 48.9 (7.5) | <0.001 | 49.2 (7.4) | <0.001 | 45.6 (7.4) | <0.001 |
| Type III SS test | | <0.001 | | <0.001 | | <0.001 |
| Age | 2.4 (0.6) | <0.001 | 2.5 (0.6) | <0.001 | 2.6 (0.6) | <0.001 |
| Neuromotor abnormality | | | | | | |
| Dyskinetic | −18.6 (11.8) | 0.118 | −15.9 (11.7) | 0.180 | −12.4 (11.9) | 0.300 |
| Spastic | −11.5 (10.6) | 0.282 | −7.8 (10.5) | 0.837 | −6.5 (10.8) | 0.549 |
| *F* test using type III SS | | 0.240 | | 0.263 | | 0.472 |
| $R^2$ | 0.51 | | 0.52 | | 0.49 | |
| $R^2$ without SATCo in model | 0.19 | | 0.18 | | 0.19 | |

PEDI, Pediatric Evaluation of Disability Inventory; SATCo, Segmental Assessment of Trunk Control; SS, Scaled Score.

This study adds greatly to the existing body of knowledge that trunk postural control is an important determinant of motor function, by specifying more precisely the relationship between control in the individual segments of the trunk and the resultant effect on gross motor function and mobility in children with CP in all GMFCS categories. The ability to measure and quantify the segmental level of trunk control should allow the therapist or physician to be more precise in their interventions. It would appear from the study data that an increase in segmental postural control of one SATCo level can increase GMFM by between approximately 0.5 and 11 points. This analysis would also suggest that there is a trunk postural control threshold for the transition between the different GMFM dimensions, and that an increase in trunk control could be one of the principal factors separating one GMFCS level from the next. It would seem possible from this study that increasing the segmental level of trunk control through training or bracing the area of the trunk where control is weak could produce clinically significant improvements in gross motor function and mobility. This is true for all aspects of trunk postural control, static, active, and reactive, as it would appear from this study that these three aspects of segmental postural control are strongly associated with gross motor function and mobility. This study indicates that segmental trunk control should be one of the principal focus areas in the testing and intervention in this population.

The study has some limitations. One of the limitations is the small number of participants. When building regression models with categorical data, the groups in each category can become small, as can be seen in the few participants at the full trunk control SATCo level in the active and reactive trunk control tests. These few data for this SATCo level affect the generalizability of the regression model. The same is true for the reference category neuromotor abnormality. We cannot be sure that the three observations for children in the ataxic category are representative of the general population; therefore conclusions from the models with respect to this reference category should be viewed with some caution.

Another limitation of the study is the age of the participants and the severity of their motor disability. The children included in this study had a mean age of around 5 years and are more severely involved than the general population with CP, with only 16 of the 92 participants in GMFCS levels I–II. Conclusions from the regressions should therefore be used cautiously when considering older children or children with less severe CP.

The jump in the regression coefficient for full trunk control in SATCo active for all the models relates most probably to limited data available for modelling. As can be seen from Table I, the Full Trunk Control level for the SATCo active test comprised only one observation. Upon closer examination, this individual had a GMFM score above the 97th centile from the GMFM reference curves published by Hanna et al.[19] This is a probable explanation for the non-uniformity in increase between SATCo active scores and GMFM and PEDI scores at the Full Trunk level of the SATCo.

Age does not have a linear relationship with GMFM and the relationship also varies with GMFCS level, with higher GMFCS levels plateauing at an earlier age.[20] This detail of the relationship between GMFCS and age is simplified in the models used for the analysis, with age and GMFM modelled as having a linear relationship.

It can be seen from the prediction plots that the models have a tendency to over- or underestimate for some of the GMFCS groups. Larger studies would be required to give more specific clinical guidance in the importance of trunk segmental postural control on gross motor function for the different GMFCS levels. It can also be seen from the prediction plots that the models for PEDI Care have

difficulties predicting caregiver assistance at the lower levels for GMFCS IV and V.

Although this study is retrospective, data collection and recording have been rigorous. The referral clinic is small, is staffed by experienced paediatric physical therapists, and has a very systematic data collection protocol using standard outcome measures. It is unlikely that the data are biased, as the data have been collected as a normal clinical routine without any study hypothesis. The only missing data were descriptive (Manual Ability Classification System scores for three of the participants).

In conclusion, this study supports earlier studies linking trunk postural control and function and provides further evidence that trunk control, in this group of children and young people, is a fundamental determinant of gross motor function and functional mobility. With use of the SATCo test, it is possible to more closely identify the area of the trunk with reduced postural control. This information can be used to target an intervention more precisely either in the form of therapy to improve the control issues or to compensate for the lack of control with the use of trunk support either as a modification to the child's assistive devices or in the form of an orthosis. Training or compensation should be aimed at improving segmental trunk postural control to the level required to allow performance of the next functional goal.

It is hoped that this study will help to inform clinical decision-making in interventions aimed at improving gross motor function in children with trunk postural control issues by focussing more closely on segmental trunk control issues. This form of clinical reasoning may be important in targeting an intervention aimed at improving gross motor function in this group of children more precisely.

## REFERENCES


1. Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl* 2007; **109**: 8–14.
2. Phipps S, Roberts P. Predicting the effects of cerebral palsy severity on self-care, mobility, and social function. *Am J Occup Ther* 2012; **66**: 422–9.
3. Park EY, Kim WH. Structural equation modeling of motor impairment, gross motor function, and the functional outcome in children with cerebral palsy. *Res Dev Disabil* 2013; **34**: 1731–9.
4. Bartlett DJ, Chiarello LA, McCoy SW, et al. Determinants of gross motor function of young children with cerebral palsy: a prospective cohort study. *Dev Med Child Neurol* 2014; **56**: 275–82.
5. Pavao SL, Dos Santos AN, Woollacott MH, et al. Assessment of postural control in children with cerebral palsy: a review. *Res Dev Disabil* 2013; **34**: 1367–75.
6. Heyrman L, Feys H, Molenaers G, et al. Altered trunk movements during gait in children with spastic diplegia: compensatory or underlying trunk control deficit? *Res Dev Disabil* 2014; **35**: 2044–52.
7. Heyrman L, Desloovere K, Molenaers G, et al. Clinical characteristics of impaired trunk control in children with spastic cerebral palsy. *Res Dev Disabil* 2013; **34**: 327–34.
8. Saether R, Helbostad JL, Riphagen II, et al. Clinical tools to assess balance in children and adults with cerebral palsy: a systematic review. *Dev Med Child Neurol* 2013; **55**: 988–99.
9. Reid DT. Development and preliminary validation of an instrument to assess quality of sitting of children with neuromotor dysfunction. *Phys Occup Ther Pediatr* 1995; **15**: 53–82.
10. Heyrman L, Molenaers G, Desloovere K, et al. A clinical tool to measure trunk control in children with cerebral palsy: the Trunk Control Measurement Scale. *Res Dev Disabil* 2011; **32**: 2624–35.
11. Saether R, Helbostad JL, Adde L, et al. Reliability and validity of the Trunk Impairment Scale in children and adolescents with cerebral palsy. *Res Dev Disabil* 2013; **34**: 2075–84.
12. Butler PB, Saavedra S, Sofranac M, et al. Refinement, reliability, and validity of the segmental assessment of trunk control. *Pediatr Phys Ther* 2010; **22**: 246–57.
13. Saavedra S, Woollacott M, van Donkelaar P. Head stability during quiet sitting in children with cerebral palsy: effect of vision and trunk support. *Exp Brain Res* 2010; **201**: 13–23.
14. Saavedra S, Joshi A, Woollacott M, et al. Eye hand coordination in children with cerebral palsy. *Exp Brain Res* 2009; **192**: 155–65.
15. Rachwani J, Santamaria V, Saavedra SL, et al. Segmental trunk control acquisition and reaching in typically developing infants. *Exp Brain Res* 2013; **228**: 131–9.
16. Russell DJ, Avery LM, Walter SD, et al. Development and validation of item sets to improve efficiency of administration of the 66-item Gross Motor Function Measure in children with cerebral palsy. *Dev Med Child Neurol* 2010; **52**: e48–54.
17. Surveillance of Cerebral Palsy in Europe (SCPE). Surveillance of cerebral palsy in Europe: a collaboration of cerebral palsy surveys and registers. *Dev Med Child Neurol* 2000; **42**: 816–24.
18. Eliasson AC, Krumlinde-Sundholm L, Rosblad B, et al. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. *Dev Med Child Neurol* 2006; **48**: 549–54.
19. Hanna SE, Bartlett DJ, Rivard LM, et al. Reference curves for the Gross Motor Function Measure: percentiles for clinical description and tracking over time among children with cerebral palsy. *Phys Ther* 2008; **88**: 596–607.
20. 3Rosenbaum PL, Walter SD, Hanna SE, et al. Prognosis for gross motor function in cerebral palsy: creation of motor development curves. *JAMA* 2002; **288**: 1357–63.