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Selective motor control correlates with gait abnormality in children with cerebral palsy

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Highlights:

- We analysed data for 194 children with bilateral cerebral palsy
- We found a significant correlation between selective motor control and gait abnormality
- The corticospinal tract may affect networks in the spinal cord responsible for walking

Abstract

Children with bilateral cerebral palsy (CP) commonly have limited selective motor control (SMC). This affects their ability to complete functional tasks. The impact of impaired SMC on walking has yet to be fully understood. Measures of SMC have been shown to correlate with specific characteristics of gait, however the impact of SMC on overall gait pattern has not been reported. This study explored SMC data collected as part of routine gait analysis in children with bilateral CP.

As part of their clinical assessment, SMC was measured with the Selective Control Assessment of the Lower Extremities (SCALE) in 194 patients with bilateral cerebral palsy attending for clinical gait analysis at a single centre. Their summed SCALE score was compared with overall gait impairment, as measured by Gait Profile Score (GPS).

Score on SCALE showed a significant negative correlation with GPS (r_s = -0.603, p< 0.001). Cerebral injuries in CP result in damage to the motor tracts responsible for SMC. Our results indicate that this damage is also associated with changes in the development of walking pattern in children with CP.

Keywords

Cerebral palsy, selective motor control, gait

Introduction

Alteration in selective motor control (SMC) forms a key impairment in people with cerebral palsy (CP). This commonly results from the inability to activate muscles without obligatory contractions of other muscles, affecting a person's ability to perform functional tasks. Measures of SMC have been shown to correlate with performance in functional tasks, disability and some parameters of gait [1,2]. Development of the Selective Control Assessment of the Lower Extremity (SCALE) [3] has allowed reliable assessment of SMC with an easily implemented tool[4].

SMC is thought to be related to integrity of the corticospinal tract (CST), which is damaged in children with CP[5]. Input from the CST is also thought to have a role in development of neural networks within the spinal cord [6], which may have a role in the automatic control of walking. SCALE correlates with ability to perform uncoupled hip and knee movement during the swing phase of gait [7], and therefore may predict outcomes of hamstring lengthening surgeries in children with CP [8]. This is supported by Rha and colleagues findings that SCALE correlates with knee flexion at initial contact in patients who walk with significant knee flexion [9].

The effect of SMC on overall gait pattern has yet to be reported to the best of the author's knowledge. This study compares SCALE with Gait Profile Score (GPS) [10], an index of how different a person's gait is to a typically developing population.

Methods

Patients under 18 years of age with a diagnosis of bilateral CP (without evidence of dystonia or ataxia), who attended our gait analysis unit between April 2013 and December 2015 were identified retrospectively. When a patient had attended for multiple analyses, data from a patients first visit only was included. Patients were excluded if a full assessment of their SMC or gait had not been performed.

Assessment of Selective Motor Control

A passive range of motion examination of each lower limb was conducted prior to assessment of SMC. SCALE was assessed according to Fowler et al [3] by one of 3 assessors. SCALE assesses 5 sets of movements on both the left and right lower limbs: hip flexion/extension, knee flexion/extension, ankle dorsiflexion/plantarflexion, inversion/eversion of the subtalar joint and toe flexion/extension. Each set of

movements is graded as 0, 1 or 2. Scores for each joint are summed giving a total score with a maximum of 20.

Assessment of gait impairment

GPS was calculated using kinematic data collected as part of routine gait analysis, captured using a VICON camera system (Vicon, Oxford, UK) with a modified Helen Hayes marker set.

Joint centres were estimated from a static trial using the PluginGait lower body model implemented in Vicon Nexus (Vicon, Oxford, UK). Dynamic trials were processed using the PluginGait lower body model, with gait cycle events manually identified and correction of thigh marker position where required [11]. Up to 5 barefoot walking trials were processed, with fewer trials used if the patient was unable to complete 5 trials, due to reasons such as fatigue or pain.

Trials were analysed using Matlab (Matlab release 2015b, The MathWorks, Massachusetts, United States). GPS was calculated according to the description by Baker et al[10], including the left and right lower limbs. GPS was calculated for each trial and the mean GPS for each patient calculated. The reference GPS has been calculated from historical data from 30 typically developing children (8 males, 22 females), with a mean age of 10 years (sd = 2.1). This data was collected at the same laboratory using the same protocols as data collected for patients used in this study.

For each patient, a contemporaneous description of general level of mobility was reported. This was used to assign each patient a GMFCS level[12].

As SCALE gives an ordinal scoring, non-parametric statistical tests were used. A Kruskal-Wallis Test was used to assess for significant difference in the distributions of total SCALE score for each GMFCS level. The SCALE scores and mean GPS for each patient were compared, using a Spearman's rank-order correlation, with significance accepted at $p < 0.05$ for all tests.

Results

Two hundred and nine patients with bilateral CP were identified. Fourteen assessments were excluded as complete sets of SCALE data had not been collected due to lack of compliance. Of the 195 remaining assessments, 194 included valid gait data, as one patient (GMFCS IV) was not able to complete walking trials. See Table 1 for group characteristics.

Distributions of total SCALE score were significantly different between GMFCS levels, $X^2(2) = 76$, $p < 0.001$, see Figure 1. Post-hoc analysis revealed significant differences in SCALE scores between GMFCS I (mean rank = 158) and II (mean rank = 113), ($p = 0.009$), GMFCS II and III (mean rank = 40), ($p < 0.001$) and GMFCS I and III ($p < 0.001$).

Preliminary analysis of the relationship between GPS and SCALE scores showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot. There was a significant negative correlation between total SCALE and GPS, $r_s = -0.603$, $p < 0.001$, see Figure 2.

Discussion

In addition to previously reported results demonstrating a relationship between SCALE and specific gait parameters [7,9], these results demonstrate a correlation between SCALE and overall gait abnormality..

SCALE is a measure of SMC, which is thought to be related to integrity of the CST [13]. The role of the CST is yet to be fully understood and is thought to be central in the modulation of afferent input to the spinal cord, the development of interneuronal networks and the lowering of thresholds of alpha motor unit modulation [6].

Damage to the CST may explain many of the impairments observed in CP such as weakness, lack of reciprocal inhibition and hyperreflexia. Consequently, a measure of SMC, such as SCALE, should be strongly associated with GMFCS and to gait abnormality. Balzer et al demonstrated a significant difference between SCALE scores for children with GMFCS levels I and II, but were unable to show a significant difference between SCALE scores for GMFCS levels II and III [4]. Data included in this study demonstrated a significant difference between each GMFCS level I-III in SCALE scores, see Figure 2, likely due to a larger sample size. When just those with

a GMFCS level of III are included, the strength of the correlation between SCALE and GPS is reduced (see Supplementary Material).

Individuals with CP demonstrate less complexity in their control strategies during gait than their typically developing peers and appear to demonstrate strategies similar to the rhythmic stepping observed in infants [14,15]. This lack of development of mature control strategies may be the underlying mechanism resulting in both impairments in SMC and impairments observed in gait. Assessing both SMC and gait abnormality may therefore provide an insight into the underlying neurological causes of both.

Limitations

This study was limited to ambulant children attending for gait analysis and therefore was unable to assess GMFCS levels IV and V. A supplementary analysis demonstrated that when SCALE and an index of key clinical examination measures are used to predict GPS, SCALE accounts for far more of the variation in GPS (see Supplementary Material).

Conflicts of Interest

Conflicts of interest: none. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest Statement

Conflicts of interest: none

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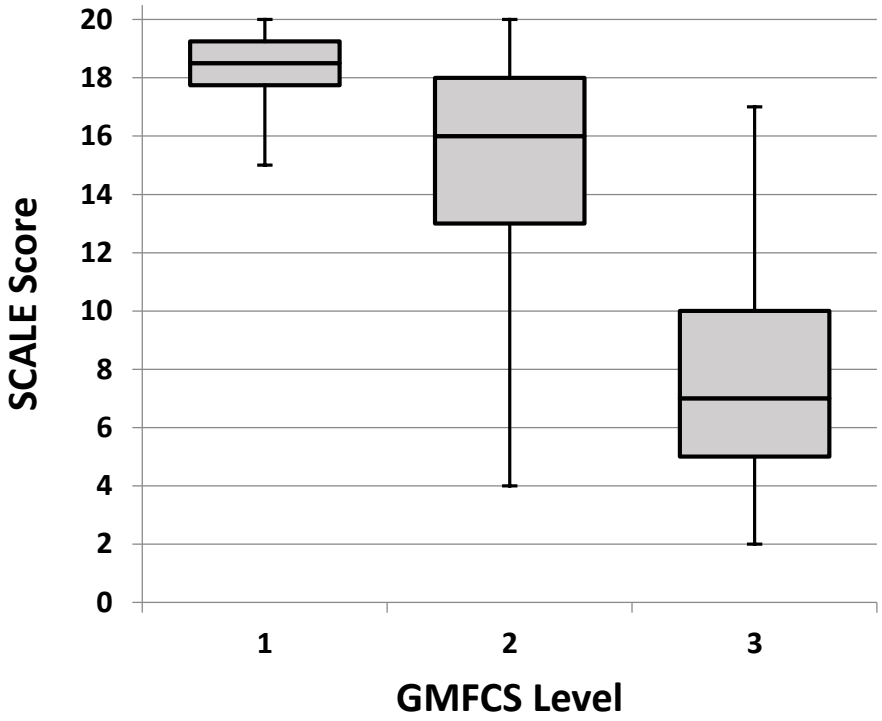

Figure 1: Boxplot of total SCALE scores for GMFCS levels I, II and III. Error bars represent range, boxes represent the interquartile range, with the median shown as a line through each box.

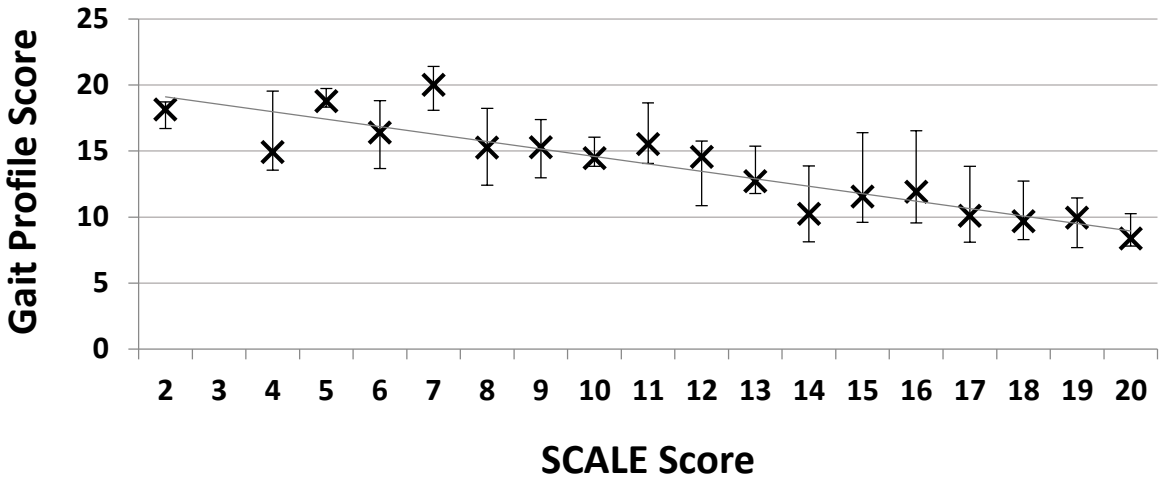

Figure 2: Median GPS for each total SCALE score. Error bars show interquartile range.

Table 1: Characteristics of patients included in analysis

Total (n)	194
Age (years)	
Mean (sd)	9.8 (3.4)
Range	3-17
Sex (n)	
Male	126
Female	68
GMFCS Level	
I	12
II	133
III	49
Conditions of Walking Trials	
Barefoot unassisted	162
Barefoot with posterior walker	22
Barefoot with walking sticks or crutches	8
Barefoot with hand held by assistant	2