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Motor strategies in standing up in leukomalacic spastic diplegia

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Abstract

In spastic diplegia impaired postural control jeopardizes the organization of whole-body movements. We studied segmental motor patterns involved in standing up from a supine position in ten children with spastic diplegia associated with periventricular leukomalacia and 14 unimpaired children using a visual analysis scale previously devised for developmental research. This approach examines specific movement patterns in upper limbs, axis and lower limbs. We found that children with spastic diplegia use movement patterns described in normal children but with markedly reduced intra- and interindividual variability. One previously undescribed stereotyped lower limb pattern was observed in four patients. This approach can systematically characterize the limited repertoire of movement in patients with spastic diplegia and therefore contribute to a better understanding of motor control. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Spastic diplegia is the most prevalent type of cerebral palsy (CP). It is characterized by a pyramidal motor syndrome predominating in the lower limbs commonly due to perinatal hypoxic-ischaemic insult causing lesions in the periventricular white matter. Motor functioning in spastic diplegia is not uniform, as shown for various motor tasks such as walking [1] and squatting [2]. These studies indicate that whole-body movements involving change in posture can help identify specific strategies of motor control in spastic diplegia [3]. Recently a multi-segmental approach has been proposed to systematically describe movement patterns of children standing up from a supine position [4,5]. This component analysis of movement helps in formulating a developmental sequence of patterns by considering three body regions: upper limbs (UL), lower limbs (LL) and axial region (AX) [4,5]. A validated developmental sequence of movements for each body region emerged from cross-sectional studies of unimpaired children and adults [6]. This was quantified by a segmental score (Table 1). In the present study we applied this method to analyze whether children with spastic diplegia use patterns from the repertoire described for unimpaired children and/or whether other patterns coexisted.

2. Material and methods

2.1. Patients

Ten children with spastic diplegia associated with leukomalacia (seven girls, three boys) who attend the neurology outpatient clinic of the Children's University Hospital Queen Fabiola participated in the study. They were aged between 5 and 11 years (mean 7.5 ± 2.0 years). Six were born at 28–30 weeks of gestation, two at 31–32 weeks and two at term, the latter having had acute perinatal asphyxia. The age of onset of independent walking was between 17 and 36 months (mean 22.6 ± 5.4 months). Brain magnetic resonance imaging performed between the ages of 1 and 5 years showed high-intensity areas on T2-weighted images in periventricular white matter compatible with periventricular leukomalacia in all patients. The patients were graded level 1 according to the Gross Motor Function Measure [7]. This validated test of gross motor skill was developed specifically for clinical and research use in children with CP. The items in this test include simple tasks performed while lying, rolling, sitting, creeping, kneeling, standing, walking, running and jumping. Quantification is based on the extent to which the patient can realize the tasks independently

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Table 1
Movement patterns for the task of rising from a supine position to a standing one (adapted from Marsala and VanSant [5])

UL categories
1. Push and reach to bilateral push
2. Push and reach
3. Symmetrical push
4. Symmetrical reach
5. Push and reach followed by pushing on leg
6. Push and reach to bilateral push followed by pushing on leg
AX categories
1. Full rotation with abdomen down
2. Full rotation with abdomen up
3. Partial rotation
4. Forward with rotation
5. Symmetrical
LL categories
1. Pike
2. Pike-jump to squat
3. Kneel
4. Jump to squat
5. Half-kneel
6. Asymmetrical/wide-based squat
7. Narrow-based symmetrical squat

without any reference to the quality of the performance. Scoring is adapted to age. For children aged between 6 and 12 years, level 1 corresponds to ability to run and jump with impaired co-ordination and balance.

2.2. Normal controls

The control group consisted of 14 age-matched children with normal development and no disabilities, recruited from a school population.

2.3. Movement recording

The motor task consisted of standing up rapidly from a supine position following simple verbal instructions (without prior visual demonstration). Each child was asked to perform ten consecutive trials (the minimum performed was six) at intervals of a few seconds. If at any point the child did not wish to carry on, the exercise and filming were stopped. The movement sessions were recorded using a VHS video camcorder (Sony Hi 8 camera). The camera was placed along the longitudinal axis of the child, 2 m away from the centre of the mat, on a tripod with the zoom lens adjusted to maximize the size of the child while still providing a full view of the child and the mat. A VHS videotape player with stop-play mode and a television monitor were used. For the study group the filming sessions took place before any scheduled physiotherapy sessions.

2.4. Data analysis

The videotaped performances were viewed serially, three times each by the primary investigator and one other independent observer. Observed movements of the UL, AX and LL were rated according to movement pattern categories [4–6] (Table 1). The first viewing was to observe and classify UL movement patterns exclusively. During the second viewing the AX were classified and during the third, the LL. This procedure was adopted to lessen any bias that could arise if all the trials of a particular child were reviewed consecutively (within-child rater bias). If an observed movement pattern could not be classified, it was described in detail. For each trial the score per body segment (UL, AX, LL) was defined as a 'segmental score'. The scoring system is linear, higher scores often obtained with advancing age [5,6]. The mean segmental score (MSS) according to the number of trials per child was used for statistical analyses. A total of 873 trials were analyzed. The Wilcoxon test was applied to the two independent samples to characterize the variability of strategies or movement patterns and to study differences in MSS. We used Spearman's coefficient of correlation to test if there was a correlation between age at time of recording and MSS (both samples), and between age of onset of independent walking and MSS (study sample only).

To verify interobserver reliability, a third observer classified 90 randomly selected trials from the study group according to the method described. Interobserver variation was found to be low, with a high degree of consistency between observers (Kappa values >0.6 for each body segment).

3. Results

All segmental movement patterns of both groups were identifiable according to the revised description (Table 1, Fig. 1A,B), except for one stereotyped LL pattern seen in four subjects with spastic diplegia (Fig. 2A,B). Overall, children with spastic diplegia adopted a more global flexor attitude than controls. Standard deviations for MSS show a greater dispersion for all three body segments in the control group than in the study group, with a high degree of statistical significance for UL and AX ($P > 0.001$), but failing to reach significance for LL patterns. The Wilcoxon test indicates that the two groups constitute distinct populations ($P < 0.01$ for UL and LL, $P < 0.001$ for AX).

3.1. UL patterns

A significant tendency ($P < 0.01$) for asymmetric patterns was noted in the study group (MSS 1.8, SD 0.048) while controls preferentially used symmetric patterns (MSS 2.7, SD 0.26). The children with spastic diplegia often used the pattern 'push reach to bilateral push' (>85% of trials), a pattern that did not feature among strategies used by controls, and is rarely seen beyond 4 years of age in the normal population [4]. The other pattern used by children in

Fig. 1. Sketched drawings illustrating typical patterns for standing up from the supine position. (A) 'Push and reach to bilateral push' pattern of ULs, 'full rotation with abdomen up' pattern of AX and 'pike' pattern of LLs (left drawings). (B) 'Push and reach to bilateral push' pattern of ULs, 'full rotation with abdomen down' pattern of AX and 'pike-jump to squat' (right drawings).

the study group was 'push and reach', again an asymmetric pattern.

3.2. AX patterns

At the axial level also none of the patterns observed in the study group were symmetric (MSS 3.0, SD 0.04). Patterns of full or partial rotation were present in over 70% of children with spastic diplegia but were not observed in unimpaired children, who used solely the last two strategies as defined (MSS 4.4, SD 0.27), namely symmetric patterns which require antero-posterior weight transfer.

3.3. LL patterns

Three strategies were used preferentially by children with spastic diplegia: half-kneel, asymmetrical wide-based squat and a pattern not previously described (Fig. 1) noted in four

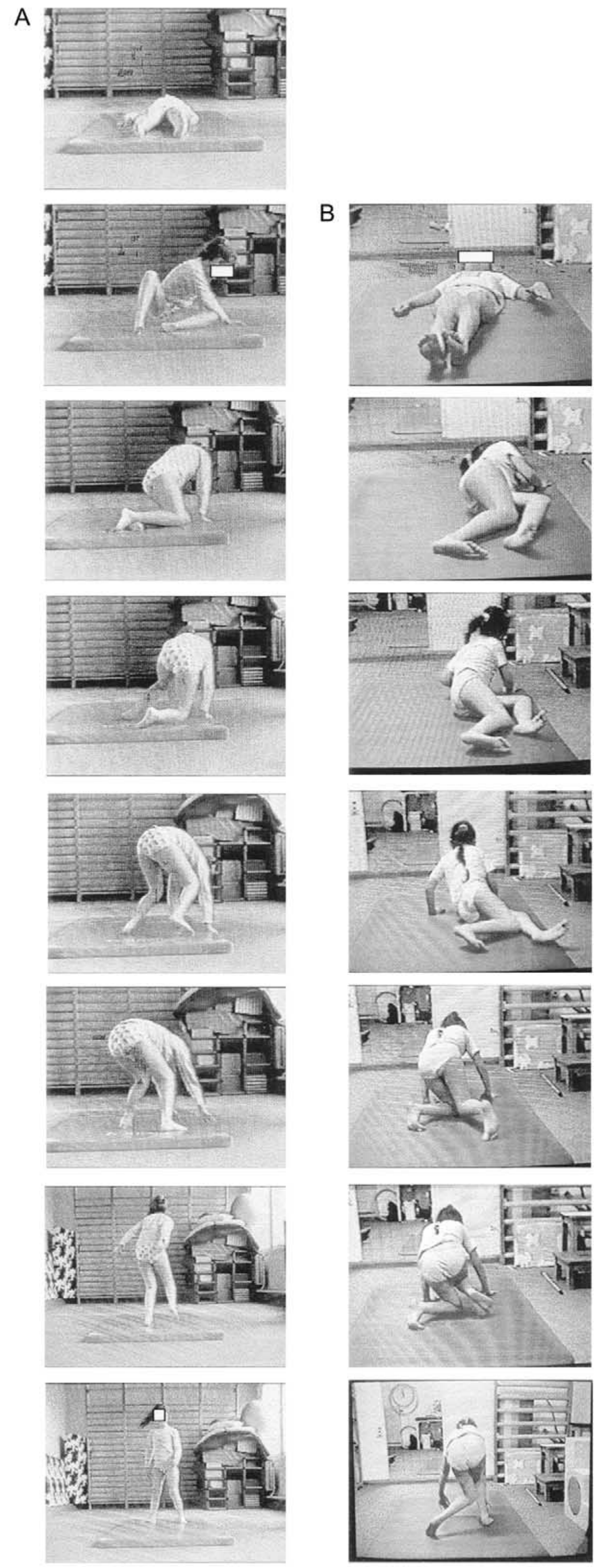

Fig. 2. Standing up from a supine position in spastic diplegia: previously undescribed LL pattern. (A) Seven-year-old girl using 'push and reach to bilateral push' and partial axial rotation. (B) Nine-year-old girl using 'push and reach to bilateral push' and full rotation with abdomen up.

subjects (MSS for the described strategies 5.5, SD 0.11). The latter pattern consisted of bilateral hip adduction and triple-flexion followed by internal rotation of one limb. Both legs were flexed towards the trunk but unlike the 'half-kneel' position neither a kneeling nor half-kneeling pattern occurred. Instead the children transferred their body weight forward antero-posteriorly while maintaining a global flexor attitude. It is to be noted that in all four cases the children had their hands on the ground until they were almost vertically upright. As for the children without motor problems they used asymmetrical/wide-based squat or symmetrical/narrow-based squat strategies only (MSS 6.5, SD 0.22). The difference between the two groups did not reach statistical significance, possibly given the unclassifiable strategy used by four of the children with spastic diplegia.

3.4. MSS and age

In the normal group a correlation was present between age at time of recording and MSS of UL ($P < 0.01$) and MSS of LL ($P < 0.05$) but not for AX patterns. In the study group a correlation was shown between age at time of recording and MSS of UL ($P < 0.05$), but not for MSS of LL or AX patterns. No correlation between age of onset of independent walking and MSS was obtained for children with spastic diplegia.

4. Discussion

This study shows that children with spastic diplegia stand up from a supine position using mostly general patterns of movement described in normal toddlers and children [4,5]. However, they show a markedly reduced intra- and inter-individual variability compared to normal age-matched controls. In addition, a previously undescribed LL movement pattern was observed in four of the ten children with spastic diplegia.

In theory any unconstrained motor act can be accomplished in an almost infinite number of ways given the excess degrees of freedom that characterize the neural and musculoskeletal system [8]. However, experimental studies show that motor control results in only a limited number of motor patterns in a given subject or population [9,10]. These preferred patterns are defined as motor strategies. They reflect motor planning taking into account central (i.e. neural) constraints.

In leukomalacic spastic diplegia the central constraints are determined by periventricular lesions that disrupt the self-tuning adaptive neural circuits involving cortico-ganglionic and cortico-cerebellar pathways [11]. As a consequence, the ability to relate motor commands and sensory information is impaired. This process is further limited since the sensorimotor experience of these children is often restricted, leading to a limited movement repertoire and more global rules of motor organization [2,9,12]. In our study the motor strategies used by children with spastic diplegia in standing up were more restricted than those of age-matched unimpaired children. This lack of variability also contrasts with motor strategies of unimpaired toddlers [4,5], arguing against an immaturity of motor patterns in CP [13]. Instead this suggests adaptability based on diversity, competition and choice in unimpaired children and a predominance of stereotyped, 'fail-safe' mechanisms in CP [14]. This is further supported by the absence of a correlation between age of independent walking and mean developmental score in the children with spastic diplegia.

Previous studies on healthy volunteers of all ages have shown a correlation between age at time of recording and MSS [4,5]. We obtained similar results in our control group. No such correlation was found in our study group for LL and AX strategies. This suggests alternative arrangement of developmental sequences compared to those proposed by VanSant et al. [5].

The motor act of standing up involves a change in posture that poses an equilibrium challenge given a necessary relocation of the centre of gravity [15]. We studied the external organization of this postural change by analyzing differentially several body segments. This approach contributes to an understanding of modular organization of postural control [15]. It has been applied to adults with Down's syndrome [16], showing the presence of movement patterns different from those described by VanSant [6]. In spite of its descriptive and qualitative aspect, this simple visual analysis system has a high interobserver reliability rate. It is a non-invasive method that only requires readily available material and incurs minimal cost. Given its reliability, it could be used as an instrument for clinical studies to evaluate change over time [17]. It could therefore be interesting to extend the present study on a larger clinical scale to gain further insight into the organization of posture and movement in defined groups of children. In this context, our results underline the necessity of an open evaluation system, given the possibility of alternative movement patterns that may characterize various populations.

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