THE EFFECT OF A CONCURRENT COGNITIVE TASK ON POSTURAL CONTROL IN CHILDREN

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Abstract: the effect of different cognitive loads on the control of balance on a scholastic population was investigated. 135 children, divided into three age groups ranging from 7 to 11 years were asked to stand quietly on a force platform under four different conditions implying vision and concurrent cognitive tasks. Selected postural parameters were extracted from Centre of Pressure data, and underwent statistical analysis. Data proved a decline on the influence of both cognitive load and vision on postural performance, and confirm the reliability of instrumented postural tests to monitor the development and maturation of balance competencies.

Introduction

Postural balance is one of the most important achievements to attain gross and fine motor control. Poor motor coordination has been implied in motor clumsiness [1], and even learning disabilities. Learning disabilities (LD) affect 3-5% of children, independently of culture, language or other variables. The term LD is generally referred to as a condition in which a child without mental retardation, sensory impairment, primary psychiatric disorder or inadequate learning opportunities falls behind his expected level of academic achievement. Among problems referred to as LD, developmental dyslexia, characterized by a deficit in the automatization of reading ability, accounts for about 80%.

Various hypotheses are currently under investigation to explore the biological basis of dyslexia and more generally LD. All theories lead to basically three principal lines of thought: deficit in auditory perception [2, 3], deficit in visual perception [4, 5], and deficit in the cerebellar mechanisms [6].

The assessment of cerebellar functions is generally obtained by observer-dependent judgments of particular sets of movements [7]. Although a trained clinical observer can give reliable test-retest results, generally he/she is not blinded to the clinical condition of the patients, and more importantly, to the authors' knowledge, the results are neither precisely predictive of the extent of a particular deficit nor sensitive enough to developmental changes over time. Even if still affected by a strong observer-dependence, one of the best attempts to a quantitative assessment for LD is represented by the Physical and Neurological Examination of Subtle Signs, PANESS as reviewed by Denckla, [8].

An approach to objective quantification has been recently proposed by Moe-Nilssen [9] where the ratings were obtained by instrumented balance and gait tests, although with a population of about 11.9 yrs of age. The cerebellum controls postural stability by processing and interpreting inputs from multimodality sensory systems, thus quantitative posturography can be used to characterize its functioning.

Platform posturography has been extensively proposed to assess postural control and its modifications with age [10]. The extraction of parameters from the trajectory of the Centre of Pressure (CoP) makes it possible to provide information on the presence of pathology information. From a longitudinal study, the control strategy to maintain balance does not vary linearly with age, but presents a step-like transition in the age range 6÷8 years [11] and a clear rise toward adults stability limits at age 7 [12]. On the other side, little has been said on the effect of cognitive assignments as perturbations of balance mechanisms.
Following this rationale, the present study investigates balance control mechanisms in orthostatic posture, and their variations with the presence of a concurrent cognitive task in a school population ranging from 1st grade (7 years), to 5th (11 years).

Materials and Methods

A sample population of 135 children divided into three groups (1st grade n= 54, age: 7±0.3 years; 3rd grade, n=44, age: 9±0.3 years; 5th grade, n=44, age: 9±0.3 years) was recruited from the same primary school, after obtaining informed consent from parents and teachers to participate in the study.

A force plate examination was administered, consisting of 4 tests (60 s each) on a 2x2 basis: standing with parallel feet (10 cm apart) with either eyes open or closed (V-NV), and while either performing or not a concurrent cognitive task (NT-T). The cognitive task consisted of mental (i.e. no articulation) counting backwards in steps of 1, 2, and 3 for 1st, 3rd and 5th grade, respectively. The overall number of administered tests was thus 540.

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During the administration of tests, signals coming from a force platform (sampling rate 100 samples/s, corner frequency 25 Hz) allowed to extract the instantaneous position of the ground reaction force vector application point, i.e. the Center of Pressure (CoP), in both its anteroposterior (ap) and mediolateral (ml) directions.

For each trial, a set of 28 posturographic parameters, including time domain, frequency domain measures, and diffusion coefficients according to [13], was extracted from CoP data, thus obtaining a 2D matrix of size (540x28). The time and frequency domain measures are defined in Table 1.

Table 1: Definition of Parameters

Parameter	Definition
SP	$\int_0^T \sqrt{\left(\frac{\partial COP_{AP}(t)}{\partial t}\right)^2 + \left(\frac{\partial COP_{ML}(t)}{\partial t}\right)^2}\, dt$
MA	$\frac{1}{T}\int_0^T COP_R(t)dt$
SA	$\int_0^T \left[\left(\frac{\partial COP_{AP}(t)}{\partial t} \cdot COP_{ML}(t) - \frac{\partial COP_{ML}(t)}{\partial t} \cdot COP_{AP}(t)\right) \Big/ 2\right] dt$
MPF	$\frac{\int_0^{Fc/2} f \cdot P_{COP_{AP}}(f)df}{\int_0^{Fc/2} P_{COP_{AP}}(f)df}$
CF	$\sqrt{\frac{\int_0^{Fc/2} f^2 \cdot P_{COP_{AP}}(f)df}{\int_0^{Fc/2} P_{COP_{AP}}(f)df}}$

After normalization of parameters, to retain the most significant ones, the dimensionality of postural data was reduced, by using Principal Component Analysis (PCA) on the 28 columns, with threshold at 70% of the entire variance.

Four PCs resulted sufficient to explain the threshold on variance, and for each of the first four PCs the parameter with the highest correlation coefficient with the corresponding PC was retained.

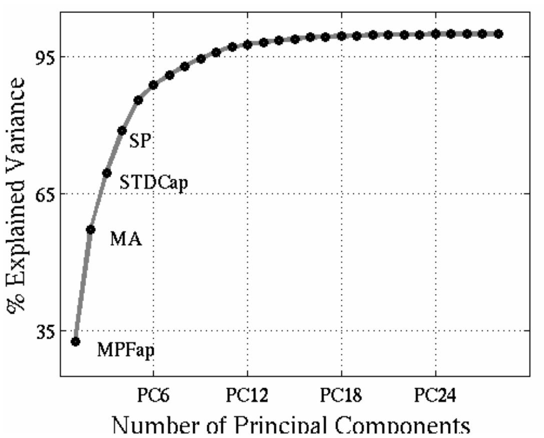

Figure 1: results on PCA. Beneath the first four PC sorted by percentage of explained variance, the parameter with the corresponding highest coefficient is displayed.

Those were Mean Power Frequency (MPF) in anterior-posterior direction (MPFap) for PC1, mean Amplitude (MA) for PC2, Short Time Diffusion Coefficient in anterior-posterior direction (STDCap) for PC3, and Sway Path (SP) for PC4. Results obtained on PCA are depicted in Figure 1.

Remarkably, the four extracted parameters are representative of almost complementary information: MPF provides information on the frequency features of CoP data, MA and SP are respectively evocative of how far and how fast does the CoP travel, and STDC is proposed as indicator for the level of stochastic activity in postural control [13].

The extracted parameters underwent a statistical analysis aiming at characterising items value for each class. Moreover, to detect if and how cognitive and vision load could affect balance control, new items were calculated in different conditions by considering the ratios between the parameters following the rationale of Romberg sign. A complete panel of the ratios is reported in Table 2.

Table 2: Ratio definitions

Item	Composition
SPv	SP Ratio between NVNT and VNT
MAv	MA Ratio between NVNT and VNT
MPFv	MPF Ratio between NVNT and VNT
STDCv	STDC Ratio between NVNT and VNT
SPt	SP Ratio between VT and VNT
MAt	MA Ratio between VT and VNT
MPFt	MPF Ratio between VT and VNT
STDCt	STDC Ratio between VT and VNT

Results

A remarkable decrease in VNT condition was evident from 1st to 5th grade of both amplitude oscillations (MA 8.0 ± 3.2 mm for 1st, 7.6 ± 2.5 mm for 3rd, and 6.8 ± 2.2 mm in 5th) and sway length (SP 1.13 ± 0.31 m for 1st, 1.12 ± 0.46 m for 3rd, and 1.03 ± 0.27 m in 5th). The concurrent cognitive task affected MPF in all the three grades (VNT 0.26 ± 0.10 Hz, VT 0.32 ± 0.15 Hz in 1st, VNT 0.25 ± 0.09 Hz, VT 0.35 ± 0.14 Hz in 3rd, VNT 0.27 ± 0.11 Hz, VT 0.29 ± 0.13 Hz in 5th).

Moreover, the influence of cognitive task on postural performance declined with age, as displayed by the quantitative increase of scores approaching to one. The same analysis on vision ratios revealed that the scores improved (i.e. approached to 1) over age.

Discussion

The obtained results are in favour of a non monotonic development of postural strategies in children, whose dependence with respect to anthropometrical factors could be verified: the role of vision clearly varies within the studied age range, and probably the maturation of balance control is not yet complete, even at the age of 11.

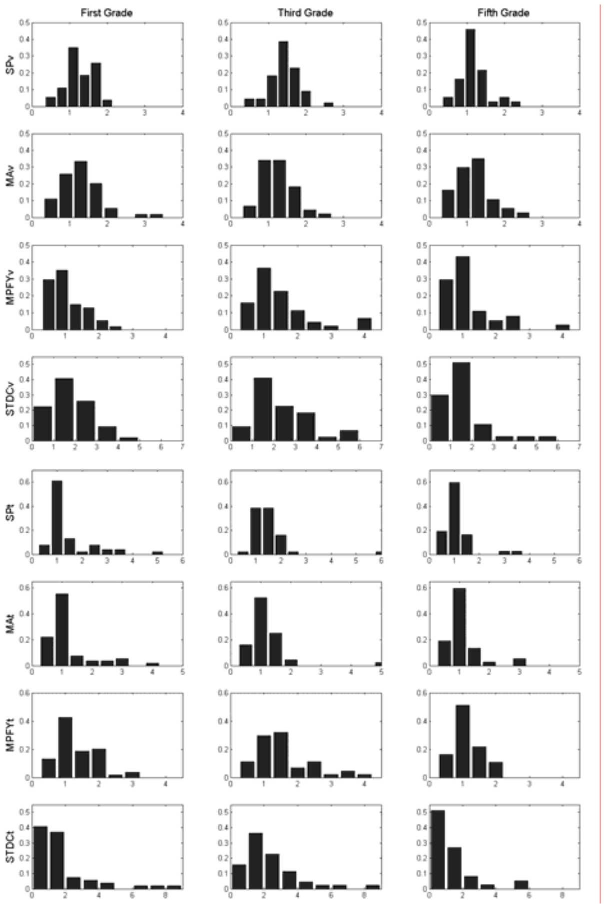

Figure 2: Ratios for vision and cognitive task on selected parameters, for the three groups

As far as the cognitive load is concerned, the obtained results confirm the hypothesis of a decline of the postural performance in presence of a concurrent cognitive task. The presence of cognitive tasks with increasing difficulty among age groups makes it possible to speculate on the ability to handle concurrent cognitive tasks: the cognitive load is a destabilizing factor with decreasing intensity with respect to age, even if this factor could be affected by the difference in the kind of task.

An interesting question remains to be unveiled: is the development of postural ability paralleled by a corresponding change in cognitive process? The combination of instrumented posturography with clinical and educational judgements such as PANESS or ratings by teaching staff could represent a useful tool to monitor development of motor coordination and possibly learning competencies.

Conclusions

The present study was performed to test the reliability of quantitative posturography as a tool to monitor the developmental stages of scholar children. The observer-independence of this approach grants the absence of ceiling or floor effects. The posturographic data were actually sensitive in discriminating developmental changes and could be efficiently used in evaluating also the effects of cognitive or sensory loads on postural control.

These data indicate that the combination of instrumented tests with clinical and educational judgements can serve as diagnostic tool to monitor development of motor coordination and possibly learning competencies.

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