POSTURAL STABILITY IN PERSONS WITH CEREBRAL PALSY AND ITS RELATIONSHIP WITH THE PERFORMANCE IN VERTICAL JUMPING

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The main purpose of this study was to evaluate the quality of postural stability of persons affected by different symptoms of cerebral palsy, and, on the other hand, to determine its relationship with the level of the neuromuscular potential of the subjects, evaluated on the base of their performance in the two-legged countermovement jump. The obtained results confirmed, first, significant differences between the subjects affected by hemiplegia and those affected by tetraparesis concerning the quality of postural stability, and, second, that the higher capacity for neuromuscular activity of the lower extremities is correlated with more stable posture (-.729; p<.000). In this way, muscle strength seems to be a limiting factor in standing posture.

KEY WORDS: postural control, stabilometry, countermovement jump, cerebral palsy.

INTRODUCTION: One of the main characteristics of the human nature is the adoption and maintenance of the upright posture in standing. Posture is the outcome of fine, steady and coordinated actions of many physiological organs and systems such as those of the biokinematic chain of the lower extremities. Postural stability depends on the external and internal forces developed by the antigravity muscles of the lower extremities (Fig. 1). Knee extensors, for instance, are necessary to counteract gravity in standing posture where the knees are kept nearly straight and motionless limiting the vertical acceleration of the center of mass. Stabilometry, or Posturography, is the field of biomechanics that deals with the mechanical description and evaluation of human capacity to control posture. Small changes of the pressure center's position (CoP) on the support surface can be measured and evaluated in the time and frequency domain using electronic devices such as force plates.

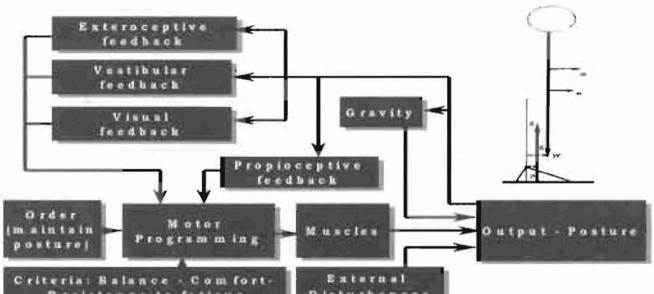

Figure 1. Flow–chart of the "information" concerning the mechanisms that influence on the posture.

If the CoP is defined as the point of application of the resultant of the external forces applied to the support area, its variability with respect to the time, expresses the neuromuscular answer to the instantaneous position of the Body's Centre of Gravity. This is possible thanks to built-in coordinated sequences of motor commands to a number of joints leading to the desired goal synergy. Data concerning CoP displacements have been considered as reliable metrics for the assessment of postural stability and many researchers have used a variety of algorithms to analyse stabilometric data (Duarte and Zatsiorsky, 1999). Cerebral palsy (CP) as neurological disorder is characterized by lose of the selective control of muscles, and the emergence of spasticity and primitive patterns of contraction, which affect the postural control process. In this way many stabilometric studies were realized to evaluate postural stability for persons affected by cerebral palsy. On the other hand, Kuo and Zajac (1993) used musculoskeletal modeling and optimization techniques to deal with the biomechanics of the posture studying coordination of posture and its sensitivity to muscle strength. However, there is a lack of information concerning the relationship of the level of the neuromuscular potential of the lower extremities of persons affected by cerebral palsy with their capacity to control their posture. Bobbert et al. (1988) defined coordination as "the concerted action of the muscles in producing movement. As such it is ultimately determined by timing sequencing and amplitude of muscle activation". Gianikellis et al. (2001) obtained relevant information concerning the coordination of the stretch shortening cycle and the appearance of a positive initial force at the very beginning of the stretching in the two - legged countermovement vertical jump performed by persons affected by cerebral palsy. The main purpose of this study is, on the one hand, to evaluate the capacity of persons affected by cerebral palsy to limit the displacements of the centre of pressure (CoP), and, on the other hand, to determine the relationship between the level of neuromuscular potential, measured in the two-legged countermovement jump test, and the capacity to maintain posture stable.

METHODS: Twenty three subjects (21.3±8.9 years) affected by different symptoms of cerebral palsy like tetraparesis with ataxia, tetraparesis with athetosis, tetraparesis with spasticity, diplegia with spasticity, right and left hemiplegia, right and left hemiparesis, participated in this study. They were requested by their instructors to realize Romberg's test with eyes open maintaining their posture as stable as possible for 40 seconds. CoP displacements were recorded by an origin-calibrated strain-gauge force plate (DINASCAN 600M) at a sampling rate of 100 Hz. The estimated error of the anterior/posterior (Y) and medial/lateral (X) coordinates of the CoP was 1mm. Position–time data concerning CoP were treated using the package "Generalized Cross-Validatory Spline" (Woltring, 1986) according to the true predicted mean-squared error developed in MATLAB 5.3. Postural stability was parameterized in terms of the RMS of CoP coordinates, the range of CoP displacements, CoP path length, sway area, the trend of CoP displacements and finally the range and RMS of the CoP velocity and acceleration in anterior/posterior and medial/lateral direction. In other experimental session subjects were requested by their instructors to perform two – legged countermovement vertical jump, jumping as high as possible, keeping their hands on the hips and performed with no other constraints than the anatomical and them of their disability. Ground reaction forces were registered by the mentioned force plate at a sampling rate of 500 Hz. The calculated errors with respect to the measurement of the components of the ground reaction force are below 2%. The processing of the information referred to the vertical component of the ground reaction force evolution during the two-legged countermovement jump yielded the following study parameters: total take-off time, time intervals of the linear force impulses, the instant of maximum force, the maximum force, the slope of the best fit line to the positive force– time trend, the take off velocity, the mean value of the normalized to the weight force in the interval of the acceleration impulse, the value of the three parts of the linear force impulse (negative impulse, breaking impulse, acceleration impulse) and finally the ratio (m) between the breaking and acceleration impulses.

RESULTS AND DISCUSSION: The conducted study yielded information concerning the quality of postural stability of all subjects affected by cerebral paralysis (Table 1) and their neuromuscular potential evaluated on the basis of the results concerning the trend of the vertical component of the reaction force (Table 2). The obtained results confirmed the expected lack of homogeneity of the sample because of the variety of motor disorders and symptoms of the subjects. However, it is worth to mention that results confirm the accomplishment of the biomechanical principle of initial force where the mean value of the ratio between the breaking and acceleration impulse is very close to its optimum value (.35 ± .067). Once a two-tailed t-test ($p<.05$) has been performed concerning stability parameters significant differences between the subjects affected by hemiplegia and those affected by tetraparesis have been determined (Table 3).

Table 1. Descriptive statistics concerning selected postural stability parameters.

	Minimum	Maximum	Mean	Standard Deviation	Variation Coefficient
RMS (X)	2.68	12.00	6.33	2.21	.35
RMS (Y)	2.73	14.30	6.42	2.95	.46
Sway Area (mm^2)	28.91	587.98	171.08	135.65	.79
Path Length (mm)	2598.95	12087.88	4395.66	2045.88	.46
RMS CoP Velocity (mm/s)	0.065	0.302	0.11	0.051	.46

Table 2. Descriptive statistics of the selected parameters related to the vertical force-time trend.

	Minimum	Maximum	Mean	Standard Deviation	Variation Coefficient
Negative Impulse	-62.88	-6.29	-35.09	17.18	.49
Breaking Impulse	6.29	62.88	35.09	17.18	.49
Acceleration Impulse	40.85	172.83	110.68	42.07	.38
Acceleration Impulse/Weight	.11	.28	.20	4.05E-02	.20

Table 3. Two-tailed t-test for subjects affected by hemiplegia and those affected by tetraparesis.

	t	df	Sig. (2-tailed) p<.05	Mean Difference	Std. Error Difference	95% Confidence Interval of the Mean	
						Lower	Upper
Sway Area	2.152	15	**.048***	111.436	51.777	1.250	221.621
Length CoP Path	2.307	12	**.040***	1785.354	773.969	96.482	3474.225
Mean CoP Velocity	2.307	12	**.040***	4.46E-02	1.94E-02	2.41E-03	8.69E-02

Table 4. Linear correlations between postural stability parameters and performance in the two-legged counter-movement jumping.

Sample Correlations

		SWAY AREA	COP PATH LENGTH	BREAKING IMPULSE	ACCELER. IMPULSE	NOR-LISED IMPULSE
SWAY AREA	Pearson's Coefficient	1,000	,530**	-,380	-,507*	-,580**
	Sig. (bilateral)	.	,009	,074	,014	,004
	N	23	23	23	23	23
COP PATH LENGTH	Pearson's Coefficient	,530**	1,000	-,459*	-,729**	-,484*
	Sig. (bilateral)	,009	.	,027	,000	,019
	N	23	23	23	23	23
BREAKING IMPULSE	Pearson's Coefficient	-,380	-,459*	1,000	,646**	,479*
	Sig. (bilateral)	,074	,027	.	,001	,021
	N	23	23	23	23	23
ACCELER. IMPULSE	Pearson's Coefficient	-,507*	-,729**	,646**	1,000	,814**
	Sig. (bilateral)	,014	,000	,001	.	,000
	N	23	23	23	23	23
NOR-LISED IMPULSE	Pearson's Coefficient	-,580**	-,484*	,479*	,479**	1,000
	Sig. (bilateral)	,004	,019	,021	,000	.
	N	23	23	23	23	23

**. p< 0.01.

*. p<.05.

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48896372	1	48896372	23.77601 068311	.000[a]
	Residual	43187389	21	2056542.3 2807		
	Total	92083761	22			

a. Predictors: (Constant), ACCEL_IMPL

b. Dependent Variable: DISTANCE

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8317.883	858.165		9.693	.000
	ACCEL_IMPL	-35.438	7.268	-0.729	-4.876	.000

a. Dependent Variable: DISTANCE

The tetraparesis group exemplified better scores with respect to the quality of postural stability for the here mentioned experimental conditions. For instance its postural stability parameters are lower concerning the sway area (106.34 mm^2 vs. 217.77) ($p<.048$), the length of CoP path (5187.05 mm vs. 3401.69 mm) ($p<.40$) and the mean CoP velocity (.03 mm/s vs. 0.13 mm) ($p<.40$). Finally, the results confirmed statistically significant correlations ($p<.000$ – $p<.02$) between the postural stability parameters (area and CoP path length) and those expressing the neuromuscular potential of the lower extremities (acceleration impulse and normalized acceleration impulse with respect to the subjects weight). Negative Pearson's coefficients (Table 4) justify the initial hypothesis that subjects who develop more impulse quantity in the two-legged countermovement vertical jump have better control on their upright posture. In this way, muscle strength seems to be a limiting factor in standing posture.

CONCLUSION: This study provides relevant information concerning the relationship of the level of the neuromuscular potential of the lower extremities of persons affected by cerebral palsy, with the capacity to control their posture. The obtained results could suggest wider investigation projects for the study of muscular coordination and strength level in multi-joint movements applied to standing posture.

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