Dynamic vs Rigid Seat System in Cerebral Palsy: quantitative comparison

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Dynamic Seat System Evaluation

QUANTITATIVE COMPARISON BETWEEN RIGID SEAT SYSTEM AND DYNAMIC SEAT SYSTEM USING 3D MOVEMENT ANALYSIS IN DYSTONIC PATIENTS WITH CEREBRAL PALSY

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> **Innovate means risking disappointment.**
> **But the risk must be faced because**
> **the greatest risk in life is not to risk.**
> **Only those who risk can achieve**
> **extraordinary goals.**

”

Introduction

Innovation and quality are concepts that distinguish the performance of the most dynamic companies ready to face the new challenges of the market. The scientific research carried out by the company is at the source of both these concepts, the main task of which is the correlation between the end user's needs and the features of the product itself. In Fumagalli, research, and consequently, training, are the best answer to improve the effectiveness of aids for the disabled. It is not by chance that we choose the partnership of IRCCS "E. Medea" Associazione La Nostra Famiglia in Bosisio Parini (Lc), one of the most important and prestigious centres for care and rehabilitation in child pathologies and disabilities and of the Bioengineering Laboratory "L. Divieti" of the Polytechnic in Milan, whose stature is as much renowned. The combining of different skills (clinical-rehabilitative, technical, engineering and mathematical) have led to precise research and enabled the elaboration of precious information.

The research results have been presented at the workshop of the 25° International Seating Symposium in Orlando (USA), at the workshop of the 2° European Seating Symposium in Dublin, at the workshop of Intersociety Congress of the paediatric section of SIMFER "The rehabilitation of children with multisystemic illnesses: a multidisciplinary approach", held in Bosisio Parini in 2008 and at many other conventions in Italy.

The article has also been published in the "DAAM Scientific Book 2009" and will appear in print in the international journal "Disability and Rehabilitation: Assistive Technology".

We are certain that the efforts dedicated to this activity within a company such as Fumagalli can bring about the positive feedback that is one of our main goals: the improvement in the quality of life of our users.

Abstract

High-tone extensor thrust or involuntary muscle contractions experienced by many children with Cerebral Palsy with severe dystonia, can cause a host of problems for the patients relating to the seating system. To improve postural stability the concept of a dynamic seat has been suggested as a potential solution. In this study a quantitative comparison of a dynamic seat system versus a rigid seat system in 10 dystonic patients with Cerebral Palsy, using quantitative analysis of movement (3D kinematics and pressure distribution) was conducted.

The obtained results demonstrate that the seating system in the dynamic configuration is able to reduce the forces experienced by the patients, as well as to increase the range of motion in the anterior-posterior direction, limiting the rolling down of the trunk and showing a better upper limb smoothness during the extensor thrust. This can lead to an increased occupant comfort and quality of postural stability.

Keywords

Dynamic seat system, dystonia, kinematics, pressure distribution

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Introduction

Many people spend a large portion of their day sitting, and thus a big effort has been made over the years to continuously improve seating systems.

As technology has advanced, seating systems have been modified to provide maximum safety and comfort for task-specific applications. However persons which are forced to stay on seat systems are sometimes overlooked. Disabled individuals with restricted mobility have limited seating options available to them. This deficiency has been reduced over the last few decades, yet much work remains to be done for some subjects of this population.

One subset of individuals includes those who experience high-extensor thrust. Extensor thrusts occur when the brain erroneously sends out signals to nearly every muscle group in the body, causing them to contract.

During a high-extensor thrust many muscle groups are affected by involuntary high-intensity muscle contractions. Typically, extensor muscles which straighten human joints are more powerful than the flexor muscles which bend them.

The net effect is overall straightening of the body dictated by the extensor muscles. High-extensor thrusts are exhibited by many who suffer from Cerebral Palsy, or other deteriorating neurological condition, as well as by head trauma victims. Such a neurological condition can be incapaciting, leaving one with very little volitional control over his/her muscles. Most of the time the affected muscle groups are in a relaxed state, leaving the individual in a slouched configuration, yet at times the muscles groups rapidly fire and extend the individual.

Such an extensor thrust can vary in intensity depending on the individual and on the affected muscle groups. High-tone extensor trust or involuntary muscle contractions experienced by many children with Cerebral Palsy with severe dystonia can cause a host of problems for the patients relating to the seating system and in addition increased irradiation of dystonia to upper and lower limbs.

Since most existing chairs are rigid, the occupant must be constrained in the seat, sometimes by means of seatbelts, such that he/she could not fall out of the chair during the extensor trust. Once strapped down, however, the occupant is able to exert very large forces on the seatback, on the headrest and footrest of the seating system, producing significant skin breakdown even though the seat is well padded.

In addition, from a biomechanical point of view, during these involuntary movements children have a great difficulty in postural maintenance due mainly to a destabilization of pelvic joint: and most of them have the same difficulty to replace the pelvis in the original position.

From the 80's, the concept of a dynamic seat, which allows movement with respect to the seat system frame during an extensor trust event, was suggested as a potential solution [1]. However there have been few published studies done to better understand high-tone extensor thrusts from a mechanical perspective, or to propose a means by which to design and evaluate seating systems that can better accommodate affected individuals [2; 3].

At the light of these considerations there are a lot of researches that could be done to improve the knowledge from a mechanical perspective; so the main objective of this study is to make a quantitative comparison of a dynamic seat system versus a rigid seat system in dystonic patients with Cerebral Palsy, using quantitative analysis of movement (3D kinematics and pressure distribution).

The seat system used in this study can work both in a dynamic configuration and in a rigid one thanks to a rigidizer that is engaged or not respectively in the two configurations.

In particular the objectives of our study are:

1) The development of an experimental set-up for acquisition of the movement during the extensor thrusts while sitting on a seating system effective for dystonic patients with Cerebral Palsy;
2) The application of the experimental set-up on subjects with spastic and dystonic tetraparesis in two different conditions: dynamic and rigid seat system;
3) The identification and computation of some parameters related to kinematics and pressure distribution significant for the comparison between dynamic and rigid seat system.

Materials and Methods

Subject

10 patients affected by CP (range: 6-12 years) were evaluated quantitatively during sitting on the X-PANDA seat system.

In particular the patients were affected by spastic and dystonic tetraparesis, according to Palisano classification (GMCFS: Gross Motor Classification Fuction System) of level V [4] that means that physical impairment restricts voluntary control of movement and the ability to maintain antigravity head and trunk posture; all areas of motor function are limited and children have no means of independent mobility and are transported.

All subjects were volunteers and their parents gave their written consent to the children's participation in this research, in accordance with the local ethical committee requirements.

All the patients were evaluated at Gait Analysis Laboratory of IRCCS "Eugenio Medea - La Nostra Famiglia Association" in Bosisio Parini (LC), Italy.

X-PANDA Seat system (Fig. 1)

The seat system X-PANDA (R 82, Denmark -Fumagalli srl, Italy) operates by allowing the backrest to pivot backwards when the seat is in a dynamic configuration while remaining rigid when the seatback rigidizer is engaged. When the seat is in a dynamic mode the occupant is able to dissipate some of the thrust energy and is met with less resistance than during a comparable thrust in a rigid seat, thus improving the thrust characteristics. Thanks to a piston the backward movement of seatback is possible during a solicitation of the patient's trunk during dystonic movements, involuntary or non specific movements and others. The gas piston is set with a threshold value: when the kid pushes towards the backrest (by a dystonic movement or a diskinetic movement or non-specific movement or, simply, repositioning movement, etc.) and the thrust gets past the threshold value, the gas piston gets engaged allowing the reclination backward. When the thrust ends, the gas piston loaded replaces the backrest in the original position. The pivot point position of the backrest is very important: it is really close to the anatomic hip pivot joint and works like the femur head inside the acetabulus (Hip rolling point), shifting the fulcrum of the reclination backward and downward. This mechanism increases the stability of the kid during the dynamic engagement of the backrest.

fig. 1

Data collection

All the patients were evaluated using an optoelectronic system with passive markers (ELITE, BTS, Italy, fig. 2 -2a) for kinematic acquisition, a synchronic Video system (BTS, Italy) and a system for acquisition of pressure distribution placed on the seatback (Tekscan, USA; Fig. 3).

fig. 2

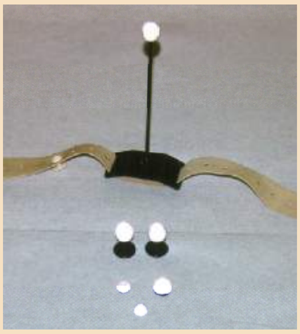
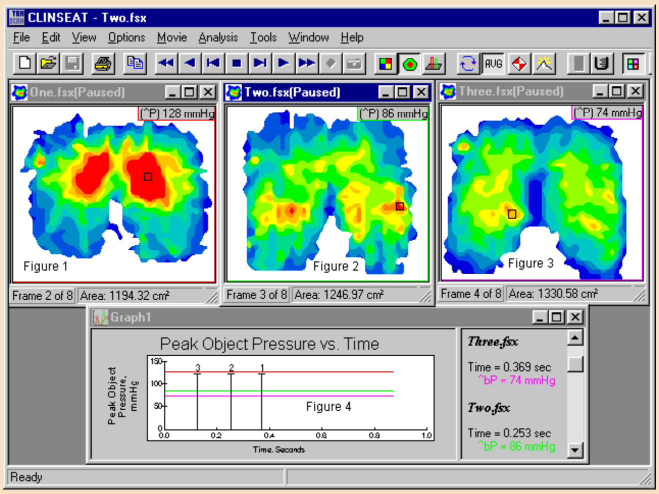


fig. 2a



(^P) 128 mmHg

Frame 2 of 8 Area: 1194.32 cm²

(^P) 86 mmHg

Frame 3 of 8 Area: 1246.97 cm²

(^P) 74 mmHg

Frame 4 of 8 Area: 1330.58 cm²

Three.fsx

Time = 0.369 sec
^bP = 74 mmHg

Two.fsx

Time = 0.253 sec
^bP = 86 mmHg

Ready

fig. 3

Passive markers were positioned at specific points of reference on the patient’s body so to represent the head, the torso, upper extremities and lower limbs during the extensor thrust dynamics; in addition 6 markers were positioned on the seat system in order to represent the movement on the seatback and on the seat.

The acquisitions were performed with the patient sitting on the seating system in a natural and comfortable manner; in particular two sessions were acquired for each patient: the first session with the seat system in the dynamic configuration and the second one in the rigid configuration, with the rigidizer engaged.

In both sessions at least 3 external perturbations were performed so to produce dystonic movements in the patient. The duration of each acquisition lasted about 60 s with a break of 10 min between each session.

Data analysis

Starting from the XYZ coordinates of each marker a 3D representation of the subject and of the seat system was done. In the next we indicate with X the anterior-posterior direction of the subject, Y the vertical direction and the Z the medio-lateral direction (Fig. 4).

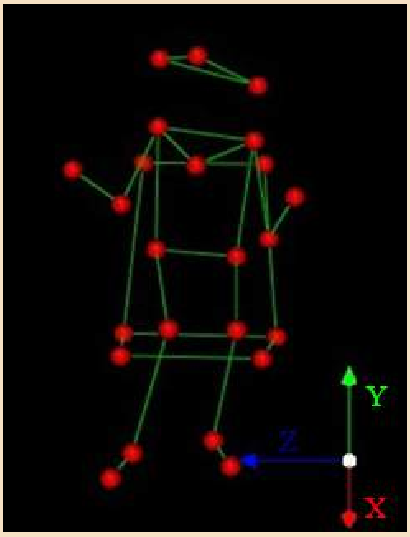


fig. 4

We focused the attention on the 3D coordinates of the markers and pressure distribution data during each extensor thrust, from the beginning of movement to its end, when the subject ends the extensor thrust and returns to quite position.

As concerns kinematic data, the following parameters were identified and computed:

HEAD MOVEMENT

The coordinates X and Y of marker positioned on forehead (expressed in mm) during the execution of each extensor thrusts are plotted as a function of time (expressed in seconds). In particular its Range of Motion on the anterior-posterior direction (ROMHx) and on the vertical direction (ROMHy), calculated as difference between end position and initial position of each coordinate, were computed.

TRUNK MOVEMENT

The coordinates X and Y of marker positioned on the sternum (expressed in mm) during the execution of extensor thrusts are plotted as a function of time (expressed in seconds). In particular the Range of Motion on the anterior-posterior direction (ROMTx) and on the vertical direction (ROMTy; Fig. 5), calculated as difference between end position and initial position of each coordinate, were computed.

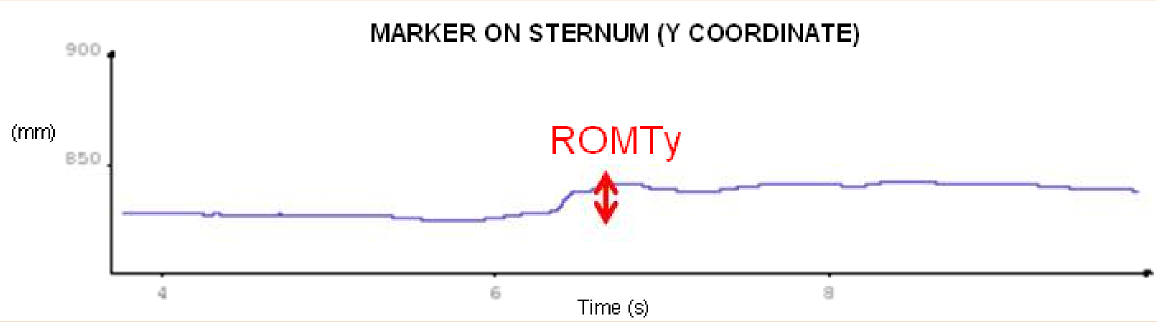


fig. 5

UPPER LIMB MOVEMENT

- The coordinates X and Y of marker positioned on the wrist (expressed in mm) during the execution of extensor thrusts are plotted as a function of time (expressed in s). In particular the Range of Motion on the anterior-posterior direction (ROMWx) and on the vertical direction (ROMWy), calculated as difference between end position and initial position of each coordinate, were computed.
- "Avarage Jerk" index (fig. 6), that represents a measure of movement smoothness of the moving segment; in this study this index is obtained from the wrist position

$$\text{Average Jerk}= \frac{1}{T}\int_0^T \left[\left(\frac{d^3x}{dt^3}\right)^2+\left(\frac{d^3y}{dt^3}\right)^2+\left(\frac{d^3z}{dt^3}\right)^2\right]^{1/2} dt$$

fig. 6

where x(t), y(t) and z(t) are the x, y and z coordinates of the wrist and T was the movement duration [5]. As concerns pressure distribution data, the peaks of force (expressed in N) on the seatback and headback during the execution of extensor thrusts were computed.

Statistical analysis

All indices were calculated for each external perturbation and for each session (in the rigid and in the dynamic configuration) and then the mean value and SD were considered in order to represent the behaviour of the subject during the different sessions. Statistical analysis was conducted applying parametric and non parametric tests in order to compare the data in the dynamic configuration vs. in the static configuration. Null hypotheses were rejected when probabilities were below 0.05 ($p < 0.05$).

Results and discussion

All patients were able to perform the assigned task without any difficulties and no interruptions during test execution. As concerns kinematic results, the range of movement in the anterior-posterior direction showed that 70% (7/10) of patients presented during the extensor trusts larger excursion of trunk (ROMTx index) and of head (ROMHx index) in this direction in the dynamic configuration than in the rigid one: this means that the rigid configuration locks the movement of the patients during the movements with high resistance (fig. 7). On the contrary, the dynamic mode enables the upper body to rotate back and then go backward in the starting position (Fig. 7a).

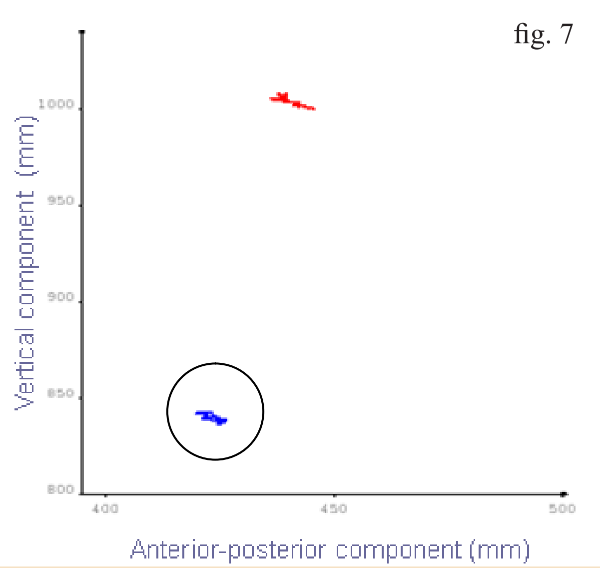


fig. 7

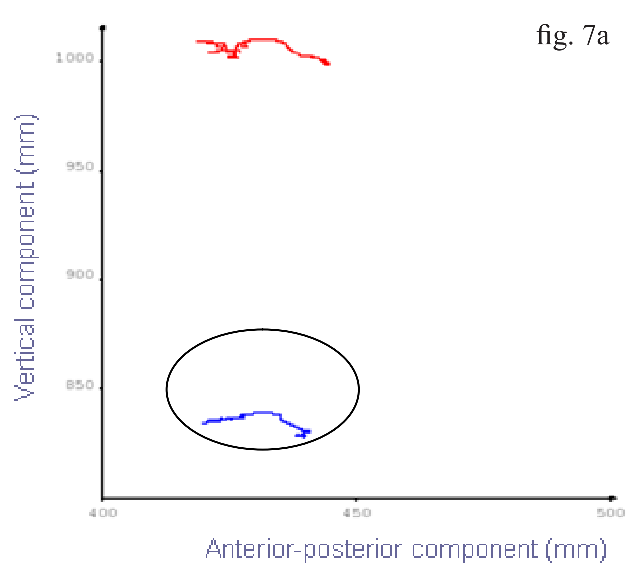


fig. 7a

The data concerning the range of motion in vertical direction displayed that 60% (6/10) of patients showed larger and negative range of motion of the trunk (ROMTy index) with the rigid configuration: this results demonstrate that in this configuration a lot of patients roll down with the trunk, showing so a low stability of trunk and pelvis. On the contrary the dynamic configuration allows the patients not to move down on the seat, leading to better stability in this arrangement. The figures 8 - 8a show the sternum marker's trajectories on the anterior-posterior component vs. vertical component during an extensor thrust for a subject in the rigid (fig. 8) and in the dynamic (fig. 8a) configuration. The larger excursion on the vertical component in the rigid configuration is evident.

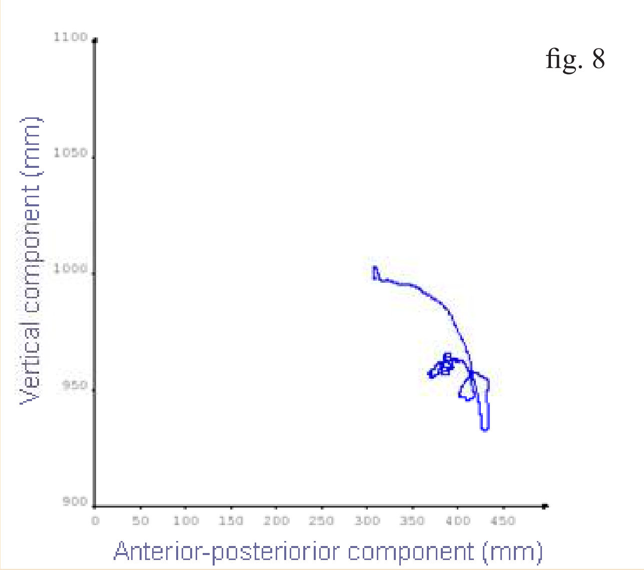


fig. 8

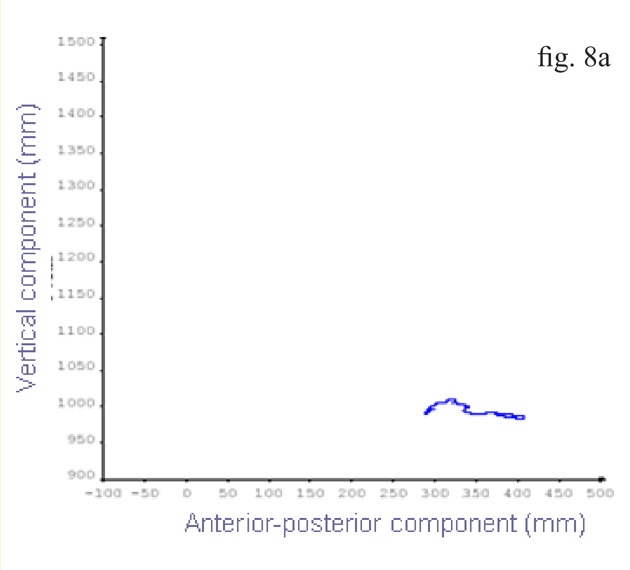


fig. 8a

As concerns the movement of upper limbs, most of patients' upper limbs evaluated (65%: 14/20) showed a larger movement excursion in all directions (ROMWx and ROMWy indexes) in the rigid configuration (fig. 9): it seemed that in dynamic configuration the "irradiation" (an inappropriate diffusion of muscles hypertone also far away from the main spastic muscles) to upper limbs decreased (fig. 9a).

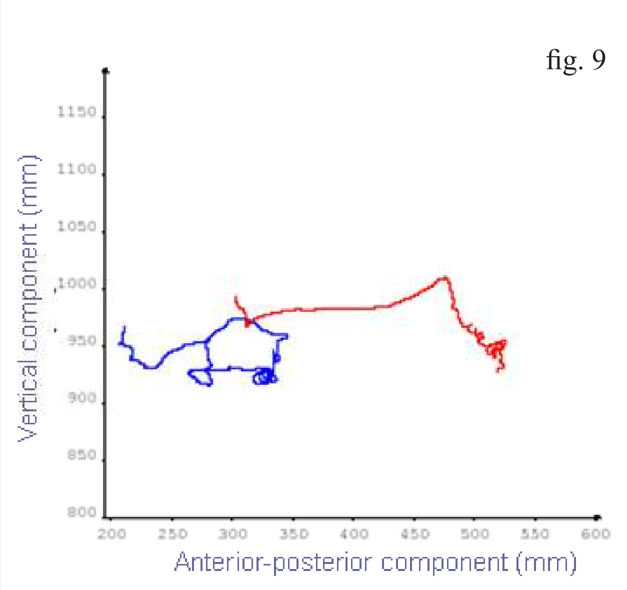


fig. 9

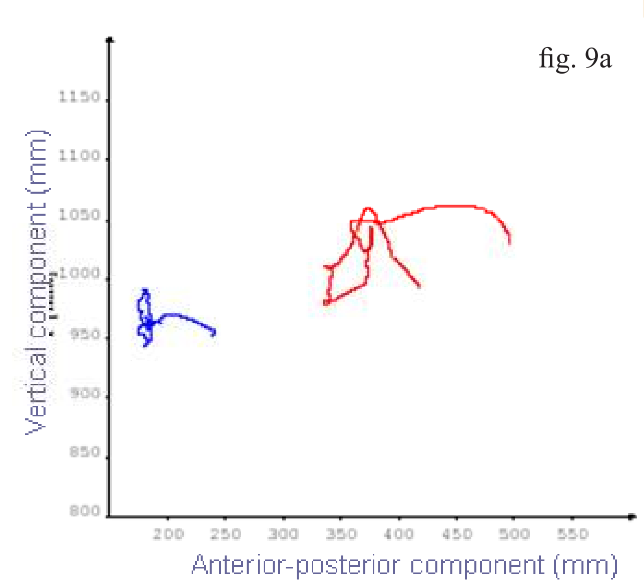


fig. 9a

In addition, in 39% of upper limbs evaluated (5/13) in the dynamic configuration the mean value of Average Jerk index was lower than in the rigid one (mean value in rigid configuration: 0.23+0.06 m/s^3; mean value in dynamic configuration: 0.18+0.02 m/s^3): the lower value of Average Jerk index of the upper limbs in the dynamic configuration revealed a better smoothness of the limb movement in comparison to the rigid configuration.

As concerns the data of distribution of pressure, we observed that patients showed generally lower peak of force in the dynamic configuration than in the rigid one, in particular on the backrest: the force reduction is an indicator that the occupant is exposed to weaker compressive loads during the thrust, which leads to improve the occupant posture(fig 10 - 10a).

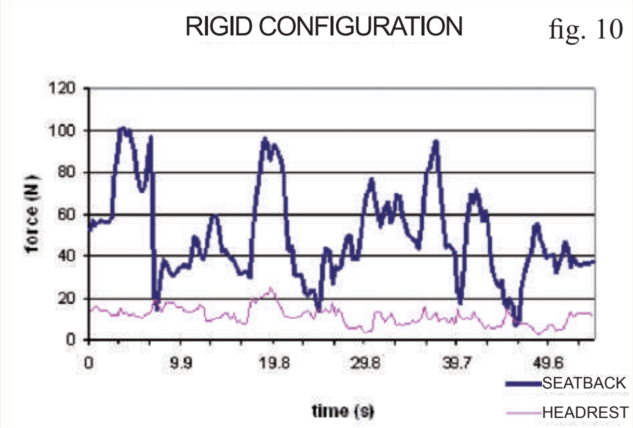

RIGID CONFIGURATION

fig. 10

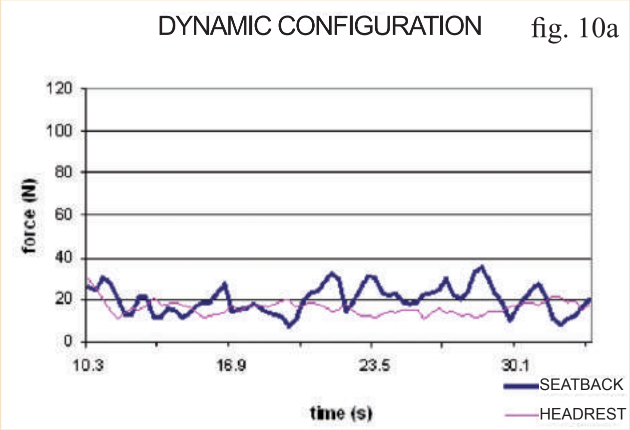

DYNAMIC CONFIGURATION

fig. 10a

The same results were obtained in terms of distribution of pressure on the backrest (Fig. 11 - 11a). The pressure map indicates in fact higher pressure on the seatback in the rigid configuration than in the dynamic one.

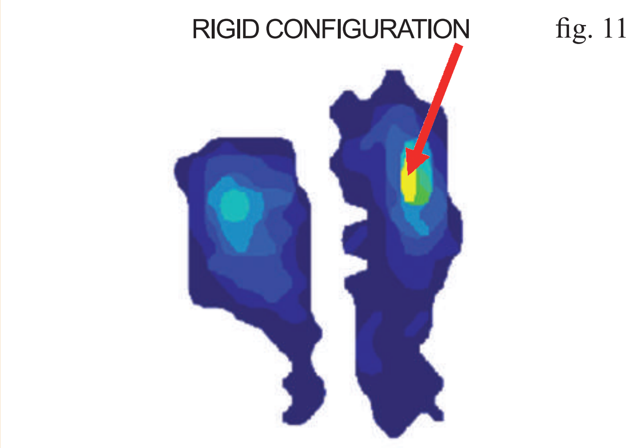

RIGID CONFIGURATION

fig. 11

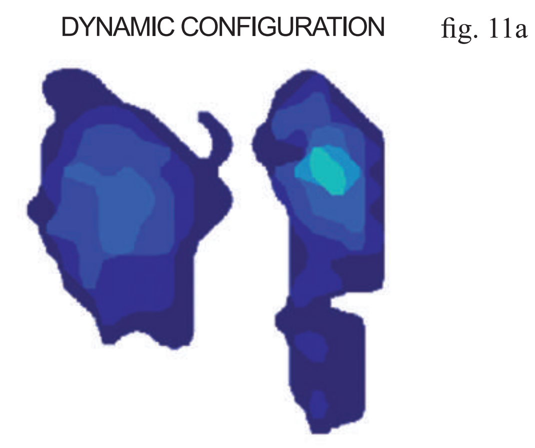

DYNAMIC CONFIGURATION

fig. 11a

Conclusions

In patients affected by Cerebral Palsy with spastic dystonia there is a strong difficulty in maintaining the postural stability. The presence of high-tone extensor trust or involuntary muscle contractions creates problems for the patients relating to the seating system and increased irradiation of dystonia to upper and lower limbs. As postural control is necessary in order to control of atypical movement patterns, prevent deformities and enable function, the concept of a dynamic back in seat system has been introduce in order to allow controlled temporary changes of the user's posture while providing support. The addition of dynamic components can address in fact some issues related to abnormal movement patterns:

- Reduction in the intensity of the non voluntary movement
- Tolerance to sitting
- Pain reduction
- Reduction in skin breakdown
- Maintained positioning over time in the seating system
- Breakdown of equipment

At the light of these considerations the aim of this study was to compare quantitatively the rigid configuration vs. the static configuration of a seat system that can work in both the configurations during extensor thrusts in dystonic patients with Cerebral Palsy. The preliminary results obtained in this study are very interesting because they demonstrate that the seating system in the dynamic configuration has some advantages if compared to the rigid mode that improve overall occupant conditions during an extensor trust. It is able in fact to reduce the forces experienced by the patients on the seatback, as well as to increase the range of motion in the anterior-posterior direction, enabling the upper body to rotate back and then go backward in the starting position and limiting the rolling down of the trunk. In addition in the dynamic configuration we observed a general reduction of "irradiation" (an inappropriate diffusion of muscles hypertone also far away from the main spastic muscles) to upper limbs and better upper limb smoothness during the extensor trust. All these elements may lead to an increased occupant comfort and postural stability. Further investigations with higher number of subjects in order to confirm these preliminary results would be necessary.

References

[1] Zeltwanger AP, Brown D, Bertocci G. Utilizing computer modelling in the development of a dynamic seating system. Proceeding of the 24th RESNA, USA, June 2001
[2] Pandyan AD et al. Biomechanical examination of a commonly used measure of spasticity. Clinical Biomechanics. 2001; 16: 859-865
[3] Hutchinson EB, Riley PO, Krebs DE. A dynamic analysis of the joint forces and torques during rising from a chair. IEEE Trans. Rehabilitation Eng. 1994; 2 (2): 49-56
[4] Palisano RJ et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev med Child Neurol. 1997; 45:113-120
[5] CJ Feng,, Mak AF. Three-dimensional motion analysis of the voluntary elbow movement in subjects with spasticity. IEEE Trans Rehab Eng 1997; 5 (3): 253-262
[6] Wook Hong, Patrangenaru et al. A method for identifying human generated forces during an extensor thrust. Int. Journ.of precision and eng. 2006; 7 (3): 66-71
[7] Cooper D., Dilabio M., Broughton G., Brown D., Dynamic seating components for the reduction of spastic activity and enhancement of function. 2001,17th International Seating Symposium, Orlando (USA)
[8] Cooper D., Antoniuk E., Dynamic Seating – A spectrum of applications. 2007, 23rd International Seating Symposium, Orlando (USA)
[9] Cooper D., Antoniuk E., Taylor S.J., Dynamic Posture Control, 20071st European Seating Symposium, Dublin (Irl).