Trunk control in unstable sitting posture during functional activities

Running Title: Balance in sitting posture

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Abstract

Objectives: To examine trunk stability in unstable sitting posture in two different functional activities.

Design: A randomized crossover design.

Setting: Rehabilitation center.

Participants: Ten healthy subjects and ten patients suffering from MS.

Interventions: A task in which the subjects had to keep their trunk as stable as possible was compared with tasks in which they had to track an object with the head or grasp an object.

Main Outcome Measures: Mean sways and mean absolute angular speed in anteroposterior and mediolateral plane.

Results: Sways in sagittal and frontal plane showed differences between patients and healthy subjects (sagittal plane, $P<0.0001$ and frontal plane, $P<0.002$). Sway speed differentiated between the groups in both planes ($P<0.0001$). Differences between sway speed in different tasks were also detected ($P<0.0001$). Correlation coefficients between sitting balance scores and laboratory measures were low and not statistically significant. In the healthy subjects, instability in frontal plane was positively correlated with the subjects' weight and height.

Conclusion: Both patients and healthy subjects had greater difficulty in the frontal plane; the speed of the oscillations discriminated better than sways between tasks and groups. Data collected showed impairment in the quiet sitting task in MS patients. Patients were more unstable than healthy subjects during head movements in the frontal plane; conversely arm movements produced larger sways, especially in the sagittal plane.

Key Words: Sitting Posture, Balance, Trunk, Rehabilitation, Multiple Sclerosis.

Introduction

Sitting is of particular interest for several reasons: it is a common and familiar position used daily as a platform for other motor activities; it develops before standing and it is present in subjects with certain neurological impairments who cannot stand. Impairment of posture and balance in sitting affects the ability to perform the activities of daily living.[1] Stability and dynamic stability are two important aspects of the sitting position. Stability is the ability to reduce the body's motion or sway. In the sitting position the body, without trunk support, is unstable and its configuration has to be controlled through muscle activity: when weight is shifted in any plane, the trunk responds with a movement to counteract the change in the center of gravity. The CNS keeps the body center of mass within specific spatial boundaries, referred to as stability limits.[2] The stability of the trunk on an unstable surface depends upon the ability to align the projection of the center of mass with the center of rotation of the support surface; added to this there is the need to control inertial forces generated by trunk movements. Trunk stability relies on correct perception of body attitude and on the development of adequate muscular responses. Body attitude is constantly modified on the basis of information provided by the visual and vestibular systems and information deriving from somatosensory receptors,[3] and as it is modified further muscular responses are needed.

Different tasks, body configurations and environments require different muscular response patterns and modification of the role of each sensory cue. A study of adaptive postural control in the sitting position found that different seat cushions could significantly affect sitting balance during reaching tasks;[4] papers have also studied the trunk and upper limb coordination of seated subjects when the target is located at arm's length[5], and beyond arm's length.[6] [7] Trunk movements were found to be minimal if the target could be reached using just the arm; conversely, for objects located out of arm's reach, trunk motion contributed significantly to the transport phase of the hand. Other papers have investigated the influence of the lower limbs in maintaining sitting balance during forward-reaching movements. Thigh and foot support was found to permit a larger forward excursion of the center of gravity.[8 9] Since the position of the center of mass is determined by body configuration, adequate anticipatory postural reactions are needed to ensure stability. Anticipatory postural reactions are postural adjustments that begin immediately before the onset of voluntary movement;[3] despite Moore and Brunt's investigations of postural adjustments before the performance, while seated, of a reaching task, the role of trunk musculature in postural adjustments remains equivocal.[10 11]

Researchers have also studied trunk stability on unstable surfaces. Cholewicki et al.[12] used hemispheres of different diameters attached underneath a chair and found an increase in center of pressure (COP) displacement with decreasing hemisphere diameter, and a positive correlation between COP movement and the anthrompometric data of the subjects. Zedka et al.[13] investigated electromyographic responses of the trunk muscles during balance/postural perturbation in a sitting position; they found reciprocal phasic electromyographic responses in back muscles during forward and backward platform movement.

Dynamic stability, on the other hand, is the ability to transfer weight within the support base; the ability to control intentional movements of the center of mass depends on the ability to move body segments into desired positions. Trunk segment displacement without loss of balance is crucial to the performance of functional tasks[14]; Rachid et al [4] performed a stabilometric evaluation of paraplegic patients, taking increased COP displacement as a measure of improvement of dynamic balance.

Evaluation of stability, dynamic stability and other aspects of sitting posture are important for an accurate assessment of patients' impairments. Along with a basic neurological assessment clinicians should investigate a patient's impairments also in representative functional tasks. Since different tasks demand different sensory and motor strategies we chose to study stability in functional tasks often performed during daily life activities. A task in which subjects had only to keep the trunk as stable as possible was compared with tasks in which they also had to track with the head, or grasp/reach, an object. We chose these two activities because they depend on the ability to keep the trunk stable.

Movements of the head are important in environmental exploration and imply the simultaneous stimulation of eyes, vestibular system and neck proprioceptors. The importance of the independence of head movement from body movement has already been demonstrated.[15 16] During walking and grasping, the capacity to move the head freely in relation to the trunk is crucial to the ability to explore the environment without deviations of the center of mass from its desired trajectory. In this study we investigated a reaching task (see above), because it involved the coordination of multiple joints and represented a difficult but functional movement. The onset of postural anticipatory reactions during a reaching task demonstrates the importance of independence and stability of the trunk during such tasks.

In sitting, the pelvis can be regarded as a rigid body pivoting about a mediolateral axis. The axis is formed by the contact of the ischiatic bones with the support surface. Control of pelvic movements in the sagittal plane is important in order to ensure a stable support base for the trunk.

The performances of healthy subjects and of patients suffering from multiple sclerosis (MS), both groups seated on a platform rotating around a pivot, were compared. The aim of the study was to investigate trunk stability and the impact of head and arm movements on sitting posture. The subjects were also asked to tilt the platform backwards and forwards to enable us to evaluate dynamic stability too.

Methods

Ten healthy subjects and ten MS patients were enrolled in the study after giving their informed consent; to be eligible for the study, patients had to show evidence of trunk imbalance when seated. This was defined as abnormal trunk sways in steady sitting position or during head or hand movements. Patients unable to grasp an object placed within arm's reach were excluded from the study. All the patients were wheelchair-users. A series of clinical tests were administered in order better to describe the patient population. The characteristics of the sample are shown in Table 1. Muscle tone was assessed using the Ashworth scale [17 18], a 5-point scale (0 = "no increase in muscle tone" – 5="affected part rigid in extension or flexion") for the assessment of abnormal tone caused by upper motor neuron damage. We tested right and left quadriceps and calf muscles. Strength was assessed by the Motricity index[19], a clinical test of motor loss developed for use after stroke, but useful in any patient suffering from upper motor neuron disease. The score represents the sum of the strength of the hip flexor, the knee extensor, and the ankle dorsiflexor; the sum of right or left lower limbs ranged from 0 (paralysis) to 100 (normal strength). The patients were tested while sitting on a chair. Sitting posture was assessed by means of the Sitting Balance test, which has scores ranging from 1 to 4. A score of 1 means "unable to maintain sitting posture" while a score of 4 means "able to sit independently".

After clinical evaluation the patients and healthy subjects were assessed using a ProKin[a] tilting platform (Fig. 1). The system is based on the rotation of a

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surface around a pivot. The pivot allows anteroposterior (sagittal) and mediolateral (frontal) angular movements. Rotations about axes were recorded using 2 potentiometers. Because the instability of the platform prevented patients from performing all the tasks, 8 springs were placed under the support to increase its stability; the stiffness of each spring was 1mm/N. The sampling rate was 20 Hz; and the sensitivity was 0.1°. The system gave us information about the anteroposterior and mediolateral angular rotation of the support surface; instantaneous angular velocity was also computed. Both patients and healthy subjects sat on the unstable support surface with their feet apart on the floor, their shoulders aligned with their feet, and their hips and knees flexed at 90 degrees. Their hands rested on their thighs, palms up. Five different tasks were recorded. The first 3 were defined as “static tasks”, the others as “dynamic tasks”. Task 1 (STAB) assessed the stability of the body without involving a particular activity; the subjects had to keep the support surface as stable as they could for 60 seconds. Task 2 (HEAD) assessed the stability of the body during head movements. The subjects had to keep the support surface stable while turning their head 45 degrees to the right and then 45 degrees to the left tracking a moving target. In Task 3 (HAND), we evaluated body stability during arm movements; the subject had to grasp an object placed at arm’s length, pick it up and then replace it. The impact of arm movements and the role of anticipatory postural adjustments were evaluated. Tasks 4 and 5 assessed ability to move the support surface voluntarily and dynamic stability. The subjects had to look at a PC screen placed at eye level. The angular position of the surface was shown on the screen by a cursor. Task 4 (FORW) required the subjects, looking at the screen, to follow a straight line depicted on the screen by the cursor; they had to move the cursor by tilting the platform forward 10 degrees, keeping it straight. Task 5 (BACK) was the same as task 4 but this time the platform had to be tilted 10 degrees in the opposite direction. For Tasks 1-3, four variables relating to postural stability were evaluated: VL AP= the mean absolute angular speed in the sagittal plane; VL ML= the mean absolute angular speed in the frontal plane; SW AP= sway (1 standard deviation) in the sagittal plane; SW ML=sway (1 standard deviation) in the frontal plane. For tasks 4 and 5 the following variables relating to dynamic stability were evaluated: VL ML, VL AP, SW ML (the definitions of these variables are the same as those given above). The mean position with respect to the vertical axis (MP), which represented the mean distance between vertical axis displayed on the screen and the patient's actual path, was also evaluated.

After logarithmic transformation, Analysis of Variance (ANOVA) was used to verify differences between healthy subjects and patients. Spearman's Correlation Coefficient was used to look for correlations between sitting balance and laboratory variables and between laboratory data and subjects' weight and height. The level of significance was set at 0.01 to reduce the chance of a type 1 statistical error.

Results

Sways in the sagittal plane (Fig. 2) showed main effects on group (healthy subjects, patients, $P<0.0001$); statistically significant differences emerged between healthy subjects and patients in the stable (STAB) task ($P<0.001$) and in the tasks requiring head ($P<0.01$) or hand ($P<0.002$) movement. Sways in the frontal (Fig.3) plane differed significantly between the groups ($P<0.002$). A statistically significant increase in sway values was detected in the stable task ($P<0.01$) and during hand movements ($P<0.0001$).

Data regarding the speed in the sagittal plane are shown in Fig. 4. Results of ANOVA showed main effects on group ($P<0.0001$); static tasks (STAB, HEAD, HAND, P<0.0001) and group x task interaction (P<0.01). Statistically significant differences were found, within the healthy subject group, between stable and head movement tasks (P<0.01); differences between the stable and hand movement tasks (P<0.0001) were significant. Patients swayed significantly more during hand movements (P<0.0001) than during the stable task. An increase in AP speed during hand movements was observed with respect to head movements (P<0.0001). The differences between healthy subjects and patients in head, hand (P<0.0001) and stable (P<0.004) tasks were statistically significant.

ANOVA of speed in frontal plane (Fig. 5) showed statistical differences of group (P<0.002), and task (P<0.0001). Healthy subjects had a higher sway speed during hand movements than during the stable task (P<0.0001); no difference was found during head movement. Patients had higher speed both during head (P<0.009) and hand (P<0.0001) movements than during the stable task. Statistical differences between groups were found during head (P<0.0007) movements. No statistical differences were found in the stable task, or during hand movements.

Data regarding dynamic tasks are reported in Fig.s 6 and 7. Absolute mean position with respect to the anteroposterior axis is shown on the X-axis; while the speed in the mediolateral direction is shown on the Y-axis. Horizontal bars represent the sway (one standard deviation). Forward tilting of the support surface seems to have been easier than backward tilting.

During forward tilting patients had greater sways in the frontal plane (P<0.001) than healthy subjects. The difference between groups in mediolateral speed almost reached statistical significance (P<0.002).

In backward tilt, patients had greater sways in the frontal plane (P<0.0008) and higher mediolateral speeds (P<0.00002) than healthy subjects. They were also less close to the vertical axis (P<0.01), and had greater mediolateral speed (P<0.01). Forward and backward speeds were almost identical in patients and healthy subjects. During forward tilting, patients moved at 1.40 deg/s and healthy subjects at 1.35 deg/s; during backward movements patients and healthy subjects moved at 1.20 and 1.15 deg/s respectively.

Spearman Correlation Coefficients between laboratory data and sitting balance scores were low and not statistically significant: .06 and –.13 respectively for SW AP, and SW ML; the correlations for VL AP, and VL ML were .19, and .38 respectively.

A positive and almost statistically significant correlation emerged, in the healthy subjects, between weight and height and sway and sway speed in the frontal plane during the static/stable task; the correlation coefficients between weight and laboratory data were, respectively, .67 (P< .04) for sway and .71 (P< .03) for sway speed in frontal plane. Height correlated only with sway in the frontal plane (.67, P< .04).

No statistically significant correlations were found between anthropometric data of patients and laboratory measures.

Discussion

The aim of this preliminary study was to clarify some aspects of postural control during functional activities performed while seated. Upper body stability was evaluated during two activities. One involved tracking, with the eyes and with head movements, a moving object; the second grasping an object placed at arm's length.

Commento [CD1]: Da inserire in introduzione

Both the patients and the healthy subjects experienced more difficulties in the frontal plane; instability in frontal plane is likely to be due mainly to the shape of the area of stability, which can be represented as a triangle formed by the patient's feet and the pivot of the system. Speed of the oscillations was more effective than sways as a means of discriminating between tasks and groups.

The data collected indicated impairment in the quiet sitting task. Compared to healthy subjects, patients had larger sways especially in the sagittal plane. Head movements produced an overall increase in sway speed both in the frontal and in the sagittal planes; healthy subjects seemed to sway slightly more during head movement than in the stable task; however, the difference was not statistically significant, either in the frontal or in the sagittal plane. In contrast, patients showed a significantly increased sway speed with respect to the static task. Sway speed in the frontal plane was higher than sway speed in the sagittal plane.

The patients performed worse than the healthy subjects. Again, the patients' right and left head movements determined higher sways and sway speeds especially in the frontal plane. Larger sways and higher sway speeds may be due to difficulty moving the head and trunk independently or to an impairment at perceptual level. Head movements imply a shift of the retinal image and an activation of the cervical and vestibular systems; a misinterpretation of head movements as body movements may trigger inappropriate postural responses.

Hand movement was the most difficult activity. Even healthy subjects showed increased sway speed in the frontal plane, while no statistically significant increase in sway size was observed; healthy subjects were able to keep the support surface stable by means of adequate automatic postural adjustments, but with an increase in sway frequency.

The same pattern was observed in the patients' group. The patients performed worse than the healthy subjects, showing, in relation to the latter, increases in size and speed of sways. The greatest differences between the two groups were recorded in the sagittal plane.

Thus, with respect to the healthy subjects, the patients' head movements showed increased instability in the frontal plane; conversely arm movements produced larger sways especially in the sagittal plane.

Dynamic tasks, too, were impaired in the MS patients. Active forward movements seemed to be more controlled than backward movements. Forward and backward movements of the pelvis were performed with wide right and left sways and at higher speed than controls. In forward and backward tilting, the patients tilted the platform at the same speed as the healthy subjects.

Surprisingly, correlation coefficients between sitting balance scores and laboratory measures were low and not statistically significant. Differences between experimental data and clinical test data are difficult to explain. They may be due to the difference between static balance and balance on an unstable surface; patients who were/are able to sit independently on a firm surface may accomplish the task by a co-contraction of whole trunk muscles, or by the forces generated through stretching of trunk ligaments and tendons. In contrast, the ability to balance on an unstable surface depends on the correct active motion of trunk and pelvis. Patients who were able to sit independently might not have been able to use sophisticated neuromuscular synergies that counteract the movements of center of mass. In accordance with the findings of Cholewicki et al.[12] relationships emerged in the healthy subjects group between laboratory and anthropometric data.

Further investigations should be carried out in order to clarify other important aspects of trunk balance. For example, the role played by each sensory cue in different tasks should be evaluated. Further analysis of kinematic and electromyographic patterns of trunk, pelvis and head could clarify the importance of the stabilization of each body segment and the strategy used to keep the body stable. The analysis of the performances of each patient revealed great differences between subjects. These differences may be due to different neurological impairments. The inconsistent patterns shown by the patients make it impossible to reach a final conclusion about impairment in patients suffering from MS; then an individual assessment is thus necessary in order to develop tailored rehabilitative programs.

Acknowledgments

The authors thank Lucia Coita and Francesca Marazzini for their support and their assistance with this project. We also thank the people with MS who volunteered to take part in this investigation.

Table 1. Characteristics of the sample.

	No.	Male	AGE	WG	MI	AS RA	AS LA	AS RK	AS LK	SB	Onset
Patients	10	3	51.1 (6.1)	62.6 (10.9)	76 (23.8)	3.5 (2-4)	3 (2-5)	2.5 (0-5)	3 (0-5)	3 (2-4)	17.2 (4.8)
Healthy subjects	10	3	26.9 (2.9)	59.7 (14.7)							

WG: Subject's weight, mean and (SD); MI: Motricity Index Test, mean and (SD); AS RA: Ashworth scale, right ankle, median and (range); AS LA: Ashworth scale, left ankle, median and (range); AS RK: Ashworth scale, right knee, median and (range); AS LK: Ashworth scale, left knee, median and (range); SB: Sitting balance, median and (range); Onset: years since onset, mean and (SD).

Fig. 1. Tilting platform

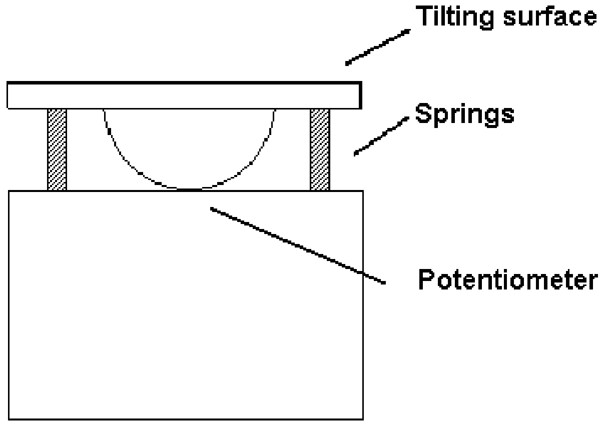


Figure 2. Sways in sagittal plane; mean values, bars represent 1 standard deviation.

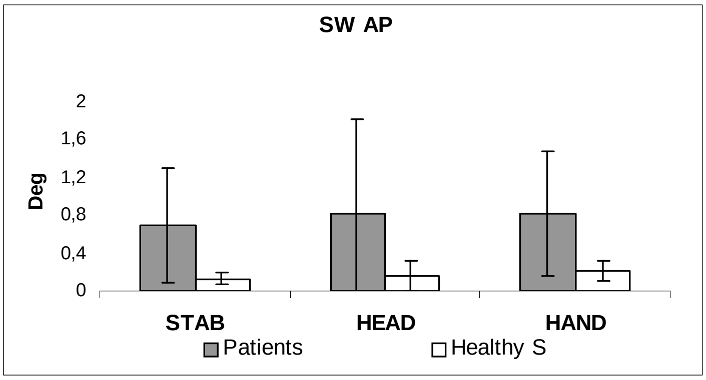


Figure 3. Sways in frontal plane; mean values, bars represent 1 standard deviation.

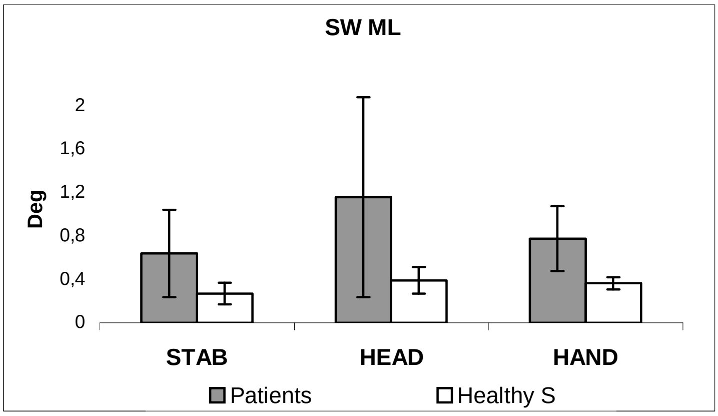


Figure 4. Speed in sagittal plane; mean values, bars represent 1 standard deviation.

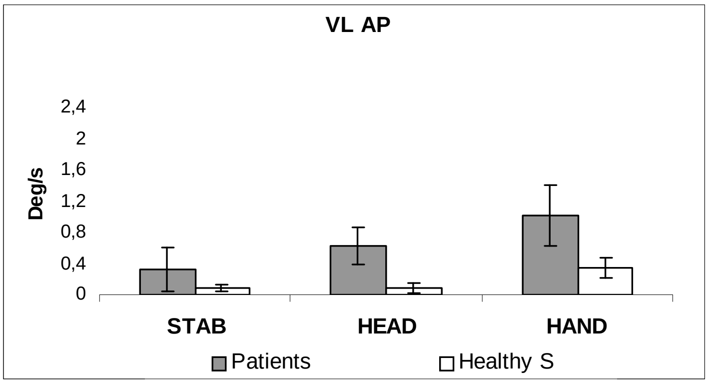


Fig 5. Speed in frontal plane; mean values, bars represent 1 standard deviation.

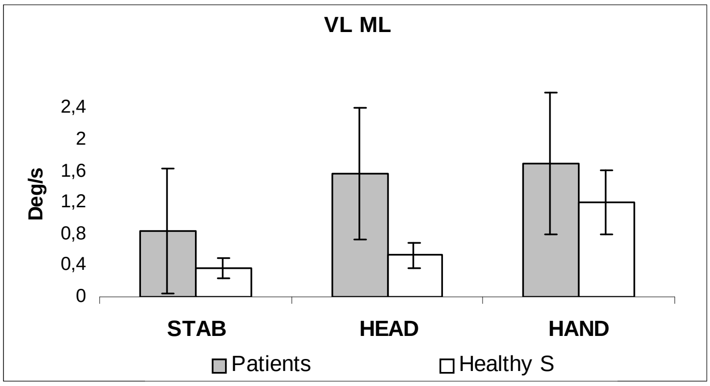
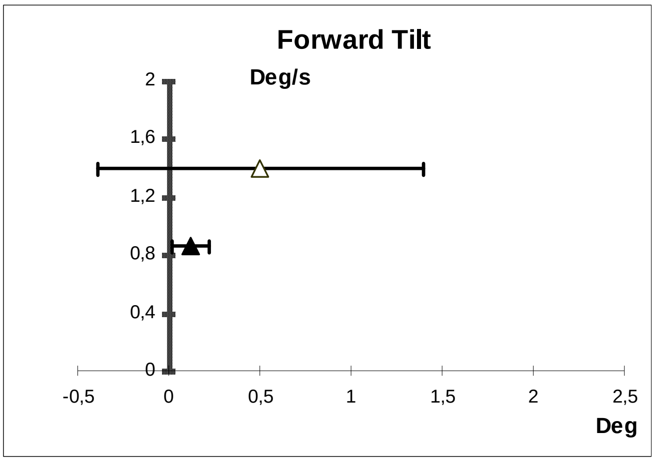
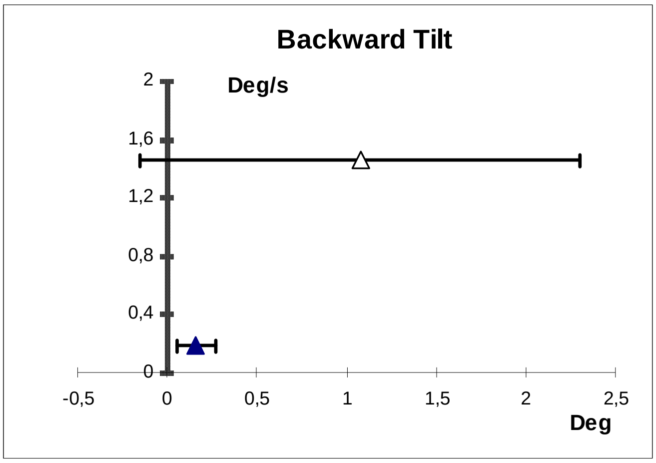


Figure. 6. Forward tilting.



X-axis: the mean distance between vertical axis displayed on the screen and the patient’s actual path.; Y-axis: speed in mediolateral direction; bars represent the sway (one standard deviation). White triangle: patients; Black triangle: healthy subjects.

Figure 7. Backward tilting.



X-axis: mean distance between vertical axis displayed on the screen and the patient’s actual path.; Y-axis: speed in mediolateral direction; bars represent the sway (one standard deviation). White triangle: patients; Black triangle: healthy subjects.

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