Background
Because both the vestibulo-ocular and vestibulo-spinal pathways depend on neurological maturation during childhood, the purpose of this study was to evaluate the vestibuloocular reflexes and balance parameters of children ages six to twelve years.

Materials and methods
Visuo-vestibulo-ocular reflex (VVOR) and vestibulo-ocular reflex (VOR) were recorded in 147 healthy children during sinusoidal rotation (video-nystagmography), with calculation of the gain. The sensory organisation on postural control was studied using computerized dynamic posturography (Equitest®), with equilibrium scores (ES) and sensory organization tests (SOT).

Protocol
For the VOR, subjects sat in a rotational chair and were asked to look at the environment as the chair was rotating (0.2 Hz) symmetrically clockwise and counter-clockwise. The VOR was recorded by similar sinusoidal rotations, while subjects were in the dark, and the measure was repeated twice for reproducibility reasons (VOR1 and VOR2, respectively). Eye movements were recorded using video-nystagmography (VNG Ulmer). The ratio of eye velocity/chair velocity was measured as the gain, which is equal to 1 when the eyes perfectly follow the chair rotations.

The Equitest SOT were performed using the six standard conditions: 1- stable platform, eyes open, 2- stable platform, eyes closed, 3- stable platform, sway referenced vision, 4- sway referenced platform, eyes open, 5- sway referenced platform, eyes closed and 6- sway referenced platform and vision. The equilibrium score (ES) indicating postural stability compared the subject’s sway to the theoretical limits of stability. The subject sway was calculated from the maximum anterior and posterior center of gravity displacement occurring over the 20-s trial period. The theoretical maximum displacement without losing balance was assumed to be a range of 12.5° (6.25 anterior, 6.25 posterior). The results were expressed as percentage, 0 indicating sway exceeding the limit of stability and 100 indicating perfect stability. From the six ES obtained, the somesthesic score = condition 2/condition 1, visual score = condition 4/condition 1, vestibular score = condition 5/condition 1. A harness was used to prevent the subject from falling. Each subject’s postural sway for the six standard sensory conditions was recorded quantitatively by monitoring the forces exerted on the platform by their feet. Normalized EquiTest sensory scores based on peak to peak sway were computed. For each of the six conditions, the only first trial was considered, because of a habituation that increases the results after the first trial.

Results
1. VVOR, VOR1, and VOR2 gain: The results are given in figure 1. As there was no statistical difference between the gain of VOR1 and VOR2, the only measure given here is called “VOR”. The apparent decrease of VOR gain between the three age groups is not significant (figure 1a). In contrast, the VOR gain decreases significantly between group a and b (figure 1b), (p=0.003) and between group b and c (p=0.003). Numeric values of VVOR and VOR gain are given in table II.
2. ES on stable platform: The results are given in figure 2. Whatever the conditions, results are significantly different between groups b and c, and between groups a and c: eyes open (p<0.0001), eyes closed (p<0.0001) and with sway referenced vision (p<0.0003). No significant difference was noticed between groups a and b.
3. ES on sway referenced platform: The results are given in figure 3. Whatever the conditions, results are significantly different between groups b and c and between groups a and c, but not between groups a and b.
4. SOT: Results are given in figure 4. Somesthesic scores do not differ between the three age groups. Contrary to this, visual and vestibular scores are significantly higher in group c compared to group a and to group b. Numeric values of the six conditions of ES and SOT are given in table III.

Conclusions
Our study confirms that the nine and twelve year old children show lower VOR gains than six year old ones. In contrast, in the two higher age groups, equilibrium scores are higher compared to the young group, especially in unstable conditions that principally involve vestibular inputs in balance control. As the use of somesthesic inputs is comparable between 6 and 12 years old, the use of vestibular and visual inputs increases between eight and twelve years old. From our results it can be suggested that between six and twelve years old, children exhibit maturation of both vestibulo-ocular pathways, and of sensory organization strategy in their balance control. These results imply that the vestibular and oculomotor systems are highly functional but still under maturation throughout this age group.