# POSTURAL CONTROL AT DIFFERENT ANATOMICAL LEVELS : DEPENDENCE UPON SPORT PRACTICE.

Serge MESURE and Jacques CREMIEUX

CNRS, UPR NBM, BP 71, 13402 Marseille Cedex 9, France.

## INTRODUCTION

Control of equilibrium in human upright posture is a multifactorial phenomenon influenced by the sensory modalities involved or by the characteristics of the environment (darkness, instability of the support...) or of the subjects (age, sex, weight and height...), especially their training or their performance level in sports. We have to specify how the practice of sports, especially judo or dance, could influence the role of the sensory information and the postural strategies used. Differences in height and weight due to sexual differences can partially explain the discrepancy of postural performances between men and women, but not those occurring between subjects of the same sex as a result of training in sports. Several hypotheses can be formulated to explain these differences between experts and beginners (Mesure et al., 1992), such as the possibility that experts select postural strategies, as described by Nashner et McCollum (1985), which are better adapted to the required task.

Practicers of Judo, the "art of throwing", and dancers, need to train their static and dynamic equilibrium control, in order for the judokas to maintain their own standing position while attempting to throw their opponents to the ground, and for the dancers to make the movements of the desired shape. Is this experience and skill generalized to the control of static equilibrium (Crémieux, Mesure, 1990), which sensory aspects are trained the most (Crémieux, Mesure, 1992), and does it change the postural strategies of the subjects?

To answer these questions, an experiment was carried out with 60 young healthy adults of both sex, in five groups homogeneous for sex and age (21 to 24 years in average), but differing for their level in sport : 2 groups of 15 men and 15 women novice in Judo or in dance, one group of 15 men and one group of 8 women expert in Judo (black belt: first Dan or more) and one group of 7 women expert in dance (more than 5 years of practice, principally in classic dance).

## METHODS

The lateral postural equilibrium of the subjects was tested in a sharpened Romberg position (heel to toe), on either a hard or a soft surface within a vertical cylinder (Amblard et al., 1985, Crémieux, Mesure, 1990). The task was to maintain equilibrium without moving the feet, in a situation of static postural equilibrium, without deformation or change of the base of support, maintaining the projection of the gravity center of the body in this base.

The visual pattern consisted of vertical black and white stripes with a broad central bar. Three types of illumination were used : normal or 2 Hz stroboscopic light, and darkness. The task in these conditions was novel for the novices as well as for the experts. Each subject did 8 trials per condition, 10 seconds each, for each of the 6 conditions (2 supports by 3 types of illumination) in a pseudo random order, in 2 sessions separated by at least one day. Accelerometers placed at three anatomical levels : head (about eye level), hips (about the iliac crest) and ankles (slightly above the malleolus), were used to measure the subject's lateral (head and hips) or antero-posterior (ankles) body sways (see the papers of Lekhel et al., 1990, and Amblard et al., 1992b, for the study on normal subjects of the lateral body sways at the 3 levels).

For each trial and each anatomical level, a frequency power spectrum of the acceleration signals was calculated by means of a standard Fast Fourier Transform (FFT). The area of average power spectrum up to 20 Hz was then calculated and used to evaluate the performances in each situation, and to study the effect of the support and of the visual deprivations. The number of falls was also recorded. We calculated also a classical visual

Romberg Quotient (Van Parys, Njiokiktjien, 1976) : (performance in darkness (or in strobe) / performance with normal vision) * 100, for each support (example : (MO/MN)*100). Calculation of the mean and standard deviation, of t-test and sign test were done with the program Statgraphics. Results with a confidence level higher or equal to 10% were noted as nonsignificant (NS), between 10% and 5% as a tendency (T) and significant (S) for a value equal or less than 5%.

A classical study of the correlations between postural performances (reduction of the body sways) at the different anatomical levels was performed. But, to better study this relative body movements, we try to applied a new statistical method (Amblard et al., 1992a, b). To compare the effect of sex and level of sport practice of the subjects on the use of postural strategies, we did a statistical determination of postural strategies between two anatomical levels, in the frontal plane, or between frontal and sagital planes, by mean of a method based on the cross-correlation functions (CCFs) between two simultaneous time series of accelerometric measurements.

When two body segments (levels of measurement) are statistically coordinated in their movements, but with a consistent delay between them, their CCF displays a peak at the corresponding time abscissa. This can be a positive peak (same sense of variation of both accelerations) as well as a negative peak (opposite sense). Usually, several significant peaks can be observed on a CCF. These peaks can be located at either a positive or a negative time lag abscissa. In the case of head-hips CCF, for example, a positive value of a time lag of x ms means that the head tends to move x ms before the hips. Each significant peak of these CCFs corresponds to a 2-level mode of statistically coordinated movements, each of them being defined by a given sign and a given time lag between coordinated segments. In this experiment we have not study the possible 3-level modes of coordinated movements, as the body sways were recorded in different planes (sagittal or frontal).

## RESULTS

The results of the frequency power spectrum analysis (example fig. 1) showed a global effect of sport practice. There was a better static postural control in the men and women expert in Judo (mainly for men, only for the number of falls for the expert women in judo), and expert dancers than in the beginners.

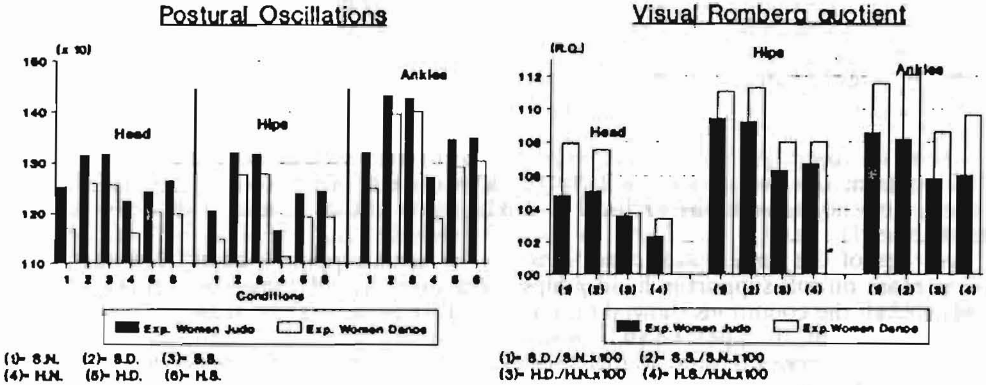


*Figure 1*

*For the expert women in judo (in black) and in dance, left : Mean postural performances (higher values meant more oscillations, and so worst equilibrium), at the 3 anatomical levels, on soft support, (1) normal light, (2) darkness and (3) strobe 2 Hz; on hard support, (4) normal light, (5) darkness and (6) strobe. Right : Visual Romberg quotients, at the 3 anatomical levels, for soft support (1, darkness/normal vision and 2, strobe/normal vision) and hard support (3 and 4). Higher values indicated a greater effect of the visual deprivation.*

The results showed that on average all the subjects depended significantly more on visual information when they were in difficult situations on soft support than on a hard surface. They showed also that with homogeneous groups with respect to age and level of practice, women had on average better postural performances than men. Differences were found concerning the postural performances between expert women in dance and in judo, but no difference was found between the number of falls of the two groups, numbers which are significatively smaller than those of the novices.

Novices depended significantly more on visual information than experts of the same sex, for both men and women. However, training in sports had no effect on the use of static visual cues, as there was no difference on average between situations without vision and in strobe 2 Hz. At least, the comparison between Romberg Quotients showed that women were significantly more dependent on vision than men, and women of dance more than those of judo.

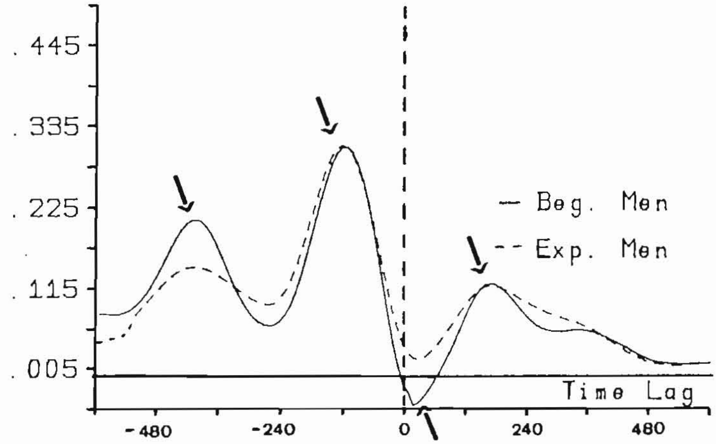


*Figure 2*

*Averaged cross-correlation functions (CCFs), after z transforms, between pairs of accelerometric measurements at the head-hip anatomical levels, in subjects of the two groups of men, standing heel to toe situation, in all conditions mixed (on a soft or hard support, under various lighting). Each curve is the average of 720 trials (15 subjects with 8 trials per subject for 6 conditions). The significant peaks of CCFs are indicated by arrows.*

Three or four significant peaks were found for the correlations between head / hips lateral motion; one peak between hips / ankles correlations (lateral and antero-posterior motion), and no peak between head / ankles correlations (lateral and antero-posterior motion).

Average of the three visual conditions, on the same support, showed that one negative peak, present on soft support in head / hips correlations, could disappeared on hard support. Average of all the conditions showed that one negative peak, present in beginner men in head / hips correlations, disappeared in expert men in judo (figure 2). The place and number of significant peaks were the same in the three groups of women, but the significance level of the correlations change, with higher correlations in expert women in dance. Shape of the curves was very similar between beginner men and women, and between expert men and women in judo, but the level of the curve of the expert women in dance was always higher.

## DISCUSSION

Does the kinematic of postural control depend on sex and level of practice in sport of the subjects, and does this postural control differ at various anatomical levels?

The results of the experiment clearly showed a global effect of practice, sport training resulting in better static equilibrium, but training in dance does not produce the same effect than in judo. In addition, this improvement is not due to a non specific increase in the use of visual, vestibular or proprioceptive cues for the three expert groups; rather it depends on the sport and sex of the subjects. They did not choose the same information for their own control, and this may have different effects on the anatomical level analyzed.

However, it is not so easy to explain the differences found. Between the several hypotheses that have been formulated to explain the differences between experts and beginners, the possibility that experts select postural strategies, which are better adapted to the required task (as they have better postural performances), for example with shorter latencies, have to be demonstrated.

The classical study of the correlations between body sways at the different anatomical levels show that the relation between motion of the different body levels were not the same for the five groups, as the percent of significant correlations was not the same. But this result indicates only that there was or not a relation between the oscillations at two anatomical levels.

Postural strategies have been mainly described in terms of the movements and the patterns of electromyographic activity in response to imposed transient perturbations of the supporting surface (Nashner and McCollum, 1985). This approach requires the exact knowledge and monitoring of the muscles involved, and the use of a time origin, e.g. the onset of the imposed perturbation. This new method does not require any monitoring of, or any particular information about, the muscles and does not involve the use of a time origin, so that it is especially appropriate to the study of stationary postural control (Amblard et al., 1992b).

The highly reproducible position of the peaks on the two supports, or in the five groups, usually reflects biomechanical or physiological constraints. Several significant peaks can be observed in a CCF, and some of the peaks disappeared when comparing mean results obtained on hard support to those on soft support, or when comparing groups differing by sex or by sport practice. But other developments of this new method of statistical analysis of the postural strategies need to be elaborated in order to compare the significance level of the correlations found; in order to better understand the results obtained, as for example the higher values of the correlations of the expert women in dance.

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