INFLUENCE OF VELOCITY ON THE ANTICIPATORY POSTURAL ADJUSTMENTS IN AN ACROBATIC MOVEMENT

Philippe Nouillot, Université Paris Sud, Orsay, France,
Françoise Natta,
Institut National du Sport et de l'Education Physique, Paris, France

INTRODUCTION: When intentional movement is performed, this is generally preceded, accompanied and followed by postural adjustments. These are dynamic phenomena. These phenomena make up in part the postural kinetic capacity of the body system (Bouisset et al., 1992). Among the postural adjustments, those which are anticipatory (APA) are particularly studied. As movement is a perturbation to balance, in upper limb movements performed in upright posture (Bouisset and Zattara, 1981), the function of the anticipatory dynamic is to minimize in advance this perturbation created by the forthcoming movement. In the initiation of gait (Breniore et al., 1987) or in the sprint start (Natta et al., 1990) the function of the anticipatory dynamic is mainly to create the conditions of the progression and to obtain a suitable speed of the center of mass (CM). For these movements performed in upright and crouching postures, i.e., bipedal and quadruple stance, it has been shown that the duration and amplitude of the APA increase with the velocity of the forthcoming movement. The acrobatic movement, which consists in standing on the hands, from an initial quadruple stance, and staying in an upside-down standing posture (USP), is different. Indeed, the initial balance and posture must not be preserved, and it is not a movement of continuous progression, because the hands stay in the initial position (Nouillot, 1998). However, the body position changes, which corresponds to a partial body progression, and final balance, particularly unstable, must be controlled. Thus, the aim of this study is to examine the influence of velocity on the APA in this intermediary movement.

METHODS AND PROCEDURES: From an initial quadruple stance, the feet placed one front of the other along the antero-posterior axis, and the hands placed on the same lateral axis, the movement to be performed was to rise on the hands, after an auditory signal, by kicking up the long supporting leg, and pushing on the ground with the other leg, initially flexed. The final position must be kept for one or two seconds. Seven expert subjects had to perform the movement, with seven trials per condition. The conditions were: either a natural (NV) or a fast (FV) velocity. The subjects were placed on a force plate of large dimensions. This was an equilateral triangle of 2 meters on each side (fully described by Brenière et al., 1981). Variations of antero-posterior (Rx) and vertical ($\Delta Rz = Rz - mg$) ground reaction forces and the antero-posterior displacements of the center of foot pressure (CPx), or barycenter of stance forces, were obtained from this force plate. These forces were used to calculate the acceleration (R/m) and velocity (by integration of the acceleration) of the center of mass (CM). An electrical contact was placed under the rear foot to determined the onset of intentional movement (t0). Force plate data were digitized at a 750 Hz and recorded on a PC.

RESULTS: The variations of mechanical traces occurred systematically a long time before the onset of intentional movement (t0), at t-1 (Figure 1). Generally, the earliest variation is the antero-posterior acceleration (x"). It is directed forwards to t1. Related to this acceleration, the center of pressure (not represented in the figure) is displacing backward. As in all the forward oriented movements, the vertical acceleration is generally directed upward from t-1 to t1, but shows variations between subjects in direction and in amplitude (Nouillot, 1998). Unlike the initiation of gait, in which the onset of acceleration is directed downward, but as in sprint start. The initiation of intentional movement (t0) is, at time of the break, observed on the traces of accelerations. At t1, the forward foot is taking off from the ground, the subject is then on his hands. At this time the antero-posterior and vertical peaks of velocity correspond, and the accelerations are moving backward and downward.

The comparison of APA durations between the two conditions shows different values on the two axes (for example the acceleration on the antero-posterior axis, NV : 333 ms ± 53, FV : 257 ms ± 54, mean of subjects, t-test = 2.639, $p<.05$), but they are significantly smaller in FV than in NV for five subjects, and similar for two others. This last result is in contrast to that of the other studies.

The comparison of APA amplitude shows that the values are different between the two conditions on the antero-posterior and vertical axes, they are greater in FV than in NV (respectively 2.72 $m.s^{-2}$ ±1.4 and 1.45 $m.s^{-2}$ ± 0.99 for x" ; 0.229 m ± 0.094 and 0.11 m ± 0.011 for CPx ; 2.52 $m.s^{-2}$ ± 0.83 and 1.19 $m.s^{-2}$ ± 0.48 for *z*" ; mean of subjects). These results are agreement with the other studies.

Concerning the velocity of the CM, the amplitude of peaks, which take place after t0, is similar following the antero-posterior axis (NV : 0.74 ms^{-1} ± 0.12, FV : 0.77 $m.s^{-1}$ ± 0.14, mean of subjects) but different following the vertical axis (NV : 0.89 $m.s^{-1}$ ± 0.16, FV : 1.06 $m.s^{-1}$ ± 0.17, mean of subjects).

DISCUSSION AND CONCLUSIONS: The first results concern the APA duration and amplitude. While the amplitude of mechanical traces increases with velocity, as forward oriented movements, the duration either doesn't change or decreases. This last result must be bound to the specificity of movement. In the initiation of gait the dynamic of movement is created using gravity. The greater the CM's speed must be, the longer gravity must act (Brenière et al., 1987). In the sprint start, the increase of duration seems to be bound to rising up on the feet (Natta & Brenière, 1994). However, the feet are at the same time the final stance basis and propulsion basis contrary to our movement.

The second result concerns the velocity of movement. Subjects were was asked to perform the movement with a spontaneous velocity, and as quickly as possible. In the fast velocity condition, this is increased only on the vertical axis. We can hypothesize the perturbation of final balance is all the more important because the CM's speed is great. Consequently, this is leading the final balance more precarious on the antero-posterior axis. The dynamic strategy used was not to increase the velocity of the body on this axis, but on the vertical axis on which balance is very stable. On this axis the posturo-kinetic capacity is optimal, because, for example, the body segments are stacked.

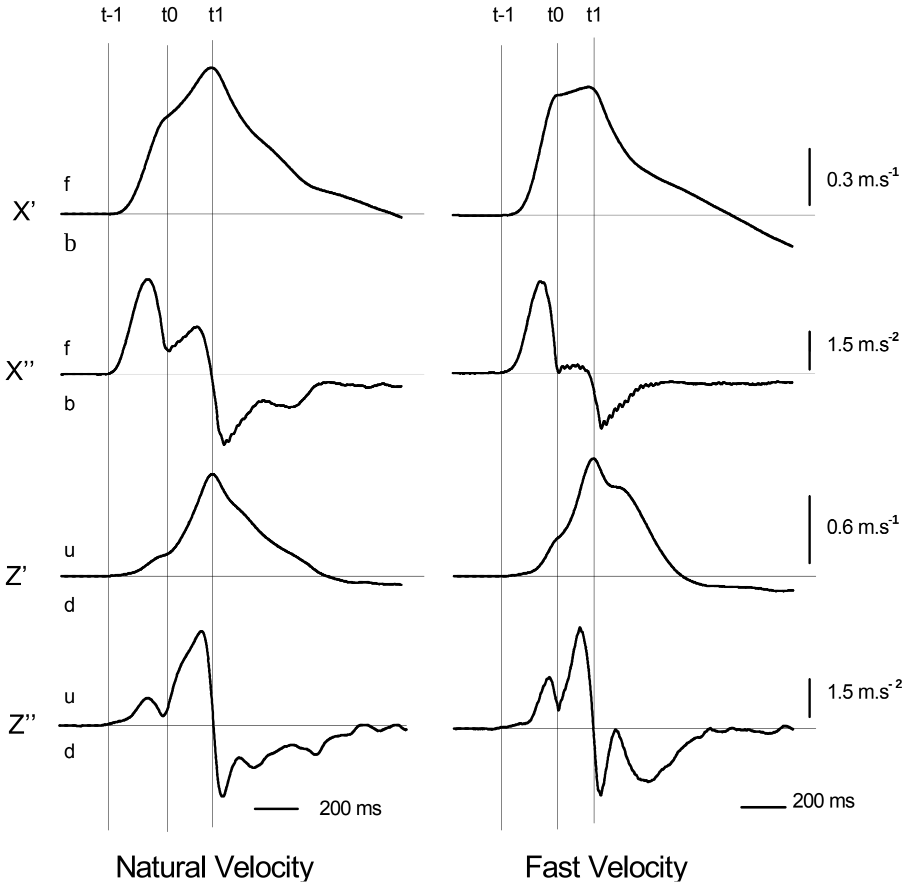

Figure 1 - Initiation of Upside-down Standing Posture (time course of mechanical traces; mean of seven trials).
x', x" : speed and acceleration of center of mass on the antero-posterior axis; *z', z*": speed and acceleration of center of mass on the vertical axis. t-1: onset of mechanical traces; t0: initiation of intentional movement (take-off of the posterior foot); t1: take-off of the anterior foot. The figure show traces of two subjects for the same experimental condition (SA and SB). T0: onset of intentional movement. f, b: forward and backward direction; u, d: upward and downward direction.

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