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EARLY POSTURO-KINETIC ORGANIZATION IN RELATION TO VOLUNTARY UPPER LIMB MOVEMENT.

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ABSTRACT

Voluntary movement of the upper limb is preceded by postural movements occuring in the lower limbs, the pelvis and the trunk, which are shown by recording accelerations at a general level as well as at a local one.

The anticipatory accelerometric and EMG patterns are specific to the forthcoming voluntary movement and therefore can be considered as preprogrammed.

The sequence of the anticipatory activities may represent part of a central motor program and tends to reduce the early perturbations of the body's center of gravity.

INTRODUCTION

The existence of postural activity prior to and during a movement was established in Man by BELENKII et al. (1). Since these pioneering studies, it has been confirmed in some experimental conditions where standing subjects performed voluntary movement of the upper limb (2, 4, 6).

The aim of the present research program is to give a complete description of the anticipatory postural adjustments and an interpretation of their biomechanical organization.

METHODS

Subject stood on a force platform which made it possible to measure the acceleration of the body's center of gravity, according to the antero-posterior, lateral and vertical axes (3). Accelerometers fixed on splints were bound to the wrist of the moving upper limb and to various body segments. This made it possible to measure the tangential acceleration of the arm (Aw_i) and to determine the onset and the sign of the anticipatory antero-posterior local accelerations. The activity of the Anterior Deltoideus (AD) and of the main muscles of the lower limb, pelvis, trunk and scapular girdle, on the ipsi- (i) and contra- (c) lateral sides, were recorded by surface electromyography (EMG). The instruction given to the subject was to point as quickly as possible, with his upper limb stretched out, at a light located in front of him at shoulder level. The lighting up of the target was the signal that the instruction should be carried out.

Movements of antepulsion-flexion of the upper limbs have been investigated according to three conditions : unilateral flexions with no additional inertia (OUF), with an additional

inertia (IUF) and bilateral flexions (BF), i.e., movements for which dynamic asymetry increased from BF to OUF and from OUF to IUF conditions.

Fifteen healthy adult subjects were tested during experimental sessions of 40-70 movements carried out in series of 3-5 movements of each type. During each trial, EMG activity of the AD_i and/or Aw_i were recorded. The other muscles and accelerations were recorded by rotation in order to make all the relevant comparisons possible. The onset of the activity of AD_i and the onset of Aw_i were used respectively as time origins for the EMG and biomechanical activities.

RESULTS

Before the activation of the AD_i, a sequence of inhibitions (-) and excitations (+) concerned muscles of lower limbs, pelvis (fig. 1) and trunk (fig. 2). These anticipatory EMG activities were arganized according to a pattern reproducible for one subject and consistent from one subject to another. Moreover, this pattern was specific to the forthcoming voluntary movement : 1) for the UF condition, the chronology of anticipatory EMG activities was $Soleus_i$ (-), $Tensor\ Fosciae\ Latae_c$ (+)/$Rectus\ Femoris_c$ (+), $Semi\text{-}tendinosus_i$ (+)/$Gluteus\ Maximus_i$ (+), $Erectores\ Spinae_c$ (+) ;

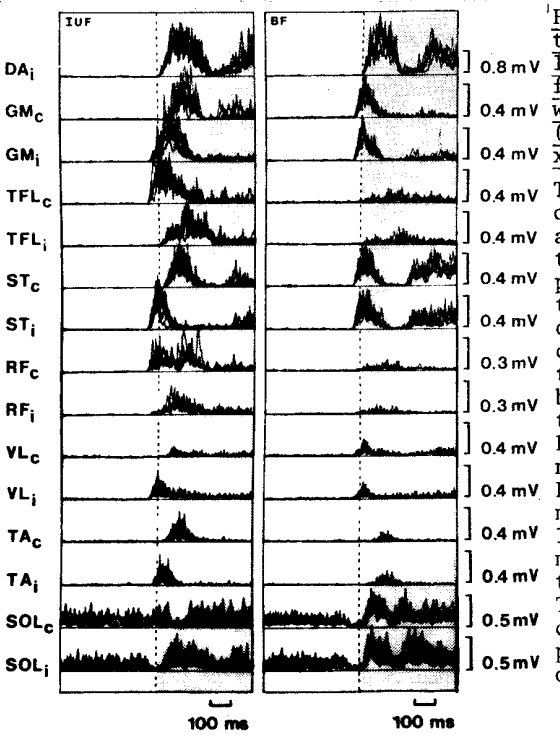

Fig 1- EMG activities of the main muscles of the lower limbs and pelvis for unilateral flexions with an additional inertia (IUF) and bilateral flexions (BF). The figure represents, for one subject, the rectified and smoothed EMG activities of five trials, superposed by synchronizing the records on the onset of the Anterior Deltoideus (DA_i). From bottom to top : Soleus (SOL), Tibialis Anterior (TA), Vastus Lateralis (VL), Rectus Femoris (RF), Semitendinosus (ST), Tensor Fasciae Latae (TFL), Gluteus Maximus (GM) i and c : ispilateral and contralateral muscles with respect to the moving upper limb. The shaded portion of the curves corresponds to the period posterior to the onset of DA_i activity.

2) for the BF condition, anticipatory EMG only concerned the pairs of Soleus, Semitendinosus, Gluteus Maximus and Erectores Spinae ; 3) for both types of conditions, the anteposition of the EMG activities of the lower limb and pelvis increased with the dynamic asymmetry of the forth-coming movement.

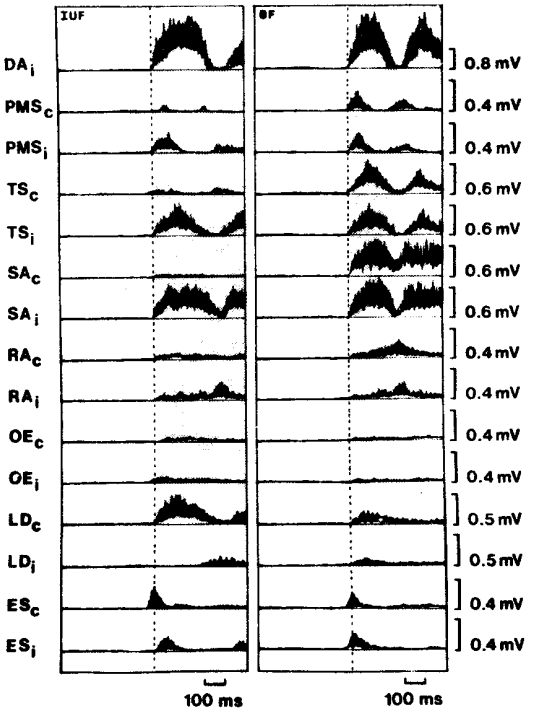

Fig 2- EMG activities of the main muscles of the trunk and the scapular girdle for unilateral flexions with additional inertia (IUF) and for bilateral flexions (BF).

As for figure 1, this figure represents, for one subject, the rectified and smoothed EMG activities of five trials, superposed by synchronising the records on the onset of the Anterior Deltoideus (DA$_i$). From bottom to top: Erectores spinae (ES), Latissimus Dorsi (LD), Obliqus Externus (OE), Rectus Abdominis (RA), Serratus Anterior (SA), Trapezoidus Superior (TS) Pectoralis Major, sternal portion, (PMS). i and c, : ipsilateral and contralateral muscles with respect to the moving upper limb. The shaded portion of the curves corresponds to the period posterior to the onset of DA$_i$ activity.

The onset of Aw$_i$ was preceded by anticipatory accelerations at the general level as well as at the local one. The shape of these anticipatory accelerations was reproducible for one subject and consistent from one subject to another. The body's center of gravity was always subjected to a foward and upward anticipatory acceleration (Fig 3). The duration of this general anticipatory acceleration increased with the asymmetry of the forthcoming movement. The local anticipatory accelerations were organized according to a pattern which is specific to the forthcoming movement (see Fig 4): 1) for the UF condition, the local anticipatory accelerations of the ipsilateral side were different from the contralateral side. Indeed, on the contralateral side, shank and thigh showed forward anticipatory accelerations while hip and shoulder showed forward ones, but on the ispilateral side, shank and thigh showed backward anticipatory accelerations while hip and shoulder showed forward ones ; 2) for the BF condition, identity was the rule. Indeed, both shanks, thighs and hips showed

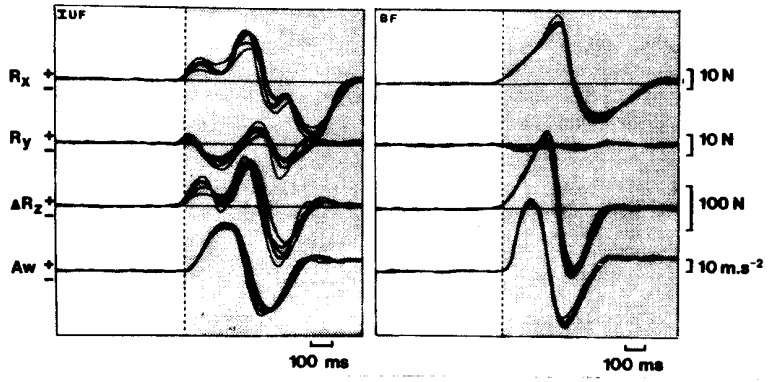

Fig 3- General accelerations for unilateral flexion with an additional inertia (IUF) and for bilateral flexions (BF). The figure represents, for one subject, five trials superposed by synchronizing the records on the onset of the tangential acceleration of the arm recorded at wrist level (Aw_i). R_x, R_y and ΔR_z are respectively the antero-posterior, lateral and vertical accelerations of the center of gravity ; positive accelerations correspond to forward, right -to- left, and upward accelerations. The shaded portion of the curves corresponds to the period posterior to the onset of voluntary movement.

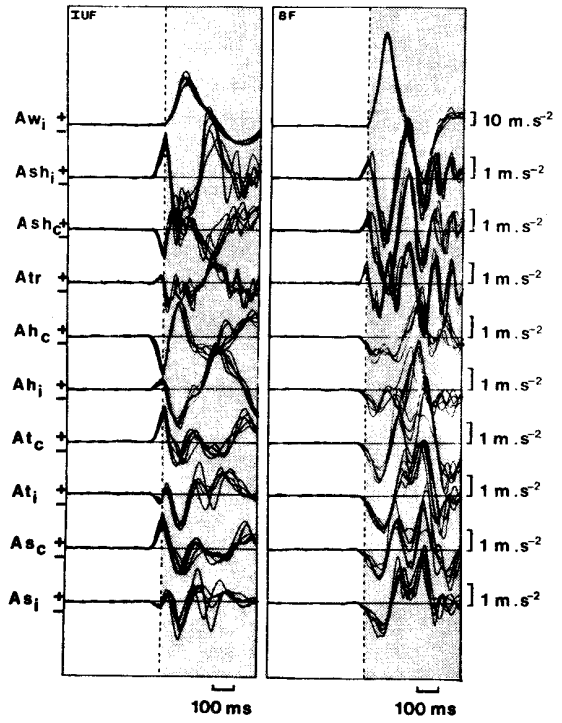

Fig 4- Local accelerations for unilateral flexion with an additional inertia (IUF) and for bilateral flexions (BF).
As for figure 2, the figure represents, for one subject, five trials superposed by synchronizing the records on the onset of Aw_i. Measurement axes are initially parallel to the postero-anterior direction.
As and At are recorded on both sides of the knee, Ah at the superior iliac crest level, Atr at xiphoïd point, and Ash at shoulder level. Positive accelerations correspond to forward accelerations. i and c: ipsilateral and contralateral accelerations with respect to the moving upper limb. The shaded portion of the curves corresponds to the period posterior to the onset of voluntary movement.

backward anticipatory accelerations while both shoulders showed forward ones ; 3) the anteposition of these local anticipatory accelerations increased with the asymmetry of the forthcoming movement.

Thus, the anticipatory local accelerations pattern showed the same modifications with respect to the type of the forthcoming movement as the anticipatory EMG activities pattern.

DISCUSSION

The present results establish that voluntary elevation of the upper limb is preceded by movements of the body's center of gravity which are related to postural anticipatory movements of the lower limbs, pelvis, trunk and shoulders. These postural adjustments are organized according to a consistent pattern which is specific to the forthcoming movement.

Therefore, they can be considered as preprogrammed, a result which is in accordance with BELENKII et al. (1). Moreover, it is likely that voluntary movement and postural adjustments are parts of a same motor program, as suggested by GAHERY and MASSION (5). This concept implies that the postural adjustments may depend on the nature of the task (unilateral or bilateral movements,...) as well as initial conditions (additional inertia load, initial posture,...), which is shown in the present paper and reported recently by CORDO and NASHNER (4) who studied the influence of various initial balance conditions in the case of a given voluntary movement.

The purpose of these anticipatory movements should be studied from the point of view of biomecanical necessities. In view of this, it is necessary to consider the system of forces acting on the body at the very beginning of the movement (see fig 5).

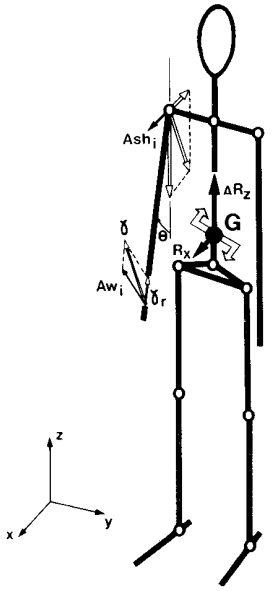

Fig 5- Schematic representation of the system of forces corresponding to the subject at the onset of the voluntary movement.

The empty arrows correspond to theoretical biomechanical parameters.
The filled arrows correspond to recorded biomechanical parameters.

In the movement studied, the forces of reaction applied at the shoulder level have a resultant acting backwards and downwards, including a backward and downward acceleration of the body's center of gravity. Moreover, for UF conditions, the resultant moment about a vertical axis induces a contralateral to ipsilateral rotation.

Now, before the onset of arm deviation, a forward and upward acceleration is applied to the body's center of gravity (as shown in fig. 3) ; moreover for UF confitions, anticipatory local accelerations (as shown in fig. 4), indicate an ipsilateral to contralateral rotation about a vertical axis. Thus the anticipatory postural changes are directly opposed in effect to the forthcoming movement.

These results support the attrative explanatory hypothesis according to which the anticipatory postural adjustments serve to create in the body a movement whose forces of inertia would, when the time comes, balance the inertia forces due to the movement of the mobile limb which tend to disequilibrate the rest of the body.

In conclusion, a consistent sequence of anticipatory movements concerning all the body limbs precede the onset of voluntary movement of the upper limb. These postural changes are specific to the forthcoming movement and therefore can only be preprogrammed. They contribute to the general organization of balance and serve to reduce postural disturbance due to a forthcoming movement.

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