IS THE FEEDFOKWARD CONTROL OF IIEAD-TRUNK AXIS VERTICALITY, IN DANCERS, VISION-DEPENDENT ?

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INTRODUCTION

The performance of a leg movement raises a specific problem due to the fact that the limb to be moved is involved in supporting the hody. The motor act is therefore a posturo-kinetic sequence during which two goals have to be reached: first, displacing the center of gravity (CG) towards a new position compatible with equilibrium maintenance during the leg movement and secondly, moving the leg towards a new position. During movement performance not only equilibrium needs to be preserved but also the position of particular segments such as head or trunk which are used as egocentric reference frame for organizing the motor act. The body is a multilink structure where the pusitions of the various segments can be regulated on the basis of specific reference positions. The head axis, for example, can be stabilized either with respect to the vertical geocentric reference or with respect to the trunk axis (Assaiante and Amblard 1990; Pozzo et al. 1989). The change in CG position occurring during lateral leg raising is achieved by rotating the supporting leg externally around the antero-posterior ankle joint axis. This should incline laterally the trunk and head axes together with the leg, their initial vertical orientation in space may be lost. In a previous paper (Mouchnino et al., 1992) naive subjects and dancers wcre compared in order to explore the effects of training on the performance of body weight transfer prior to a lateral leg raising. The kinematic analysis showed that two control strategies wcre identified depending on the head-trunk orientation. An "inclination" strategy was used by the naive subjects; this consisted of an external rotation of the leg around the antero-posterior ankle joint axis. **A** counter-rocation at the neck level ensured the stability of the interorbital line in the horizontal plane. A "translation" strategy was used by the dancers; the external rotation of the supporting leg around the ankle joint was associated with a feedforward counter-rotation of the trunk around the coxofemoral joint which maintained the verticality of the whole head-trunk axis. The results showed that when naive subjects were instructed to keep the trunk vertical, they wcre unable to perform the counter-rotation of the trunk in a feedforward manner which is adopted by dancers.

It remained to he explained how the coordinated contol of equilibrium and that of 'the position of head-trunk axis was built up. The present investigation was aimed at exploring the role of vision in the feedforward counter-rotation performed at the hip joint in dancers.

METHODS

Experiments were performed on 14 healthy subjects of both sexes (mean age 26). Nine subjects were experienced in modern dance and had been trained for at least 15 years; live subjects were "naive", since they practiced nu regular sport and had no previous dance training.

The subject stood barefoot, with the heels joined at an angle of 90°, the hands behind the back, the eyes gazing horizontally at two electroluminescent diodes placed symmetrically 5 meters in front of the subject's eyes. The illumination of one of the diodes constituted the movement onset signal and indicated which leg should bc moved. At the signal onset, the subject was asked to raise one leg laterally, as fast as possible, to an angle of 45° and to maintain the final position for a few seconds. During each session, the subject had to perform 4 trials with each leg, and the order in which the legs had to be lilted was determined by a random sequence.

Three visual conditions were compared in dancers: eyes open, eyes closed and translucent goggles which provide no visual information (blurred vision). In that paradigm, the starting signal was provided by two different auditive signals, placed on each side of the subject.

The kinematic analysis was performed by means of an automatic TV-image processor (EL.I.TE. system, Ferrigno and Pedotti, 1985).

KESULTS

In order to explore the possibility that the maintenance of the head-trunk axis vertical orientation was built up on the basis of visual imput, the strategies used by the dancers in perturbed visual conditions were analysed.

The translation strategy observed in dancers under normal condition of vision allows the vertical trunk axis to be maintained and keeps both the interorbital line and the shoulders in the horizontal plane.

The results showed that in both conditions of perturbed vision, the horizontality of the interorbital line was approximately preserved and no statistical difference was present between both eyes closed (2.3X^{U} +/-2.5) and translucent gogglcs (3.2° +I-2.2) and eyes open condition (2° +/-1.4).

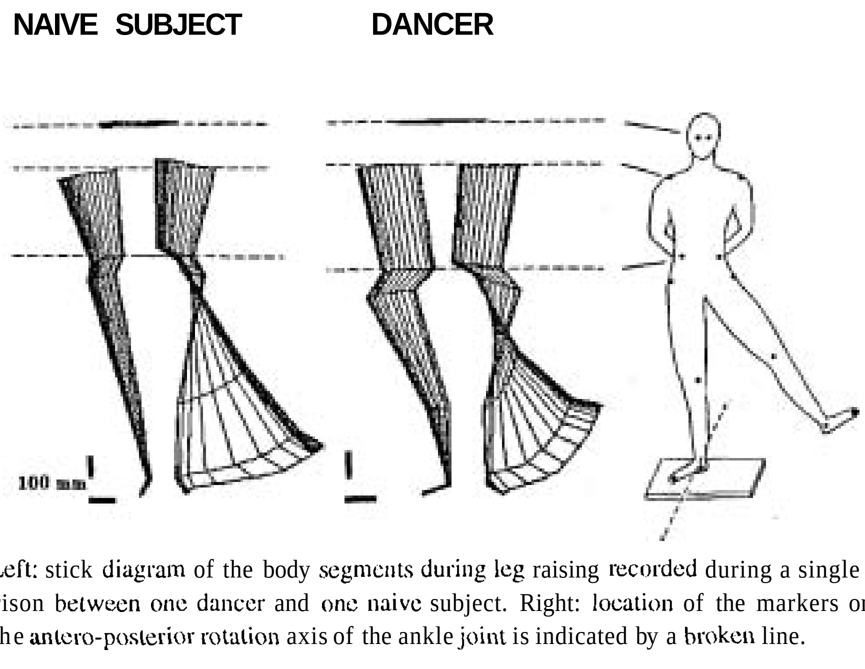

Fig.1. Left: stick diagram of the body segments during leg raising recorded during a single trial. Comparison between one dancer and one naive subject. Right: location of the markers on the body. The antero-posterior rotation axis of the ankle joint is indicated by a broken line.

In addition, the maintenance of the shoulders line in the horizontal plane was also preserved as it was in condition with eyes open (2^o +/-1.2) with both eyes closed (1.5^o +/-1.2) and translucent goggles (1.8^o +/-1.5).

To see whether the command of the counter-rotation results from a feedback or a feed-forward control, the temporal organization of the angular hip and ankle displacement was studied. The counter-rotation at the hip joint and the external rotation of the ankle joint occur simultaneously under both conditions of perturbed vision as it was under normal condition (eyes open: -28ms (+/- 119). The counter-rotation of the trunk preceded the inclination of the leg towards the supporting side by -7.3ms (+/-46) with eyes closed and by -41.5ms (+/-59) with translucent goggles. These data indicate that the control of the counter-rotation is organized in a feedforward mode. This suggest that a new motor program had been elaborated in dancers and can be programmed in absence of visual peripheral feedback.

DANCERS	α INCLINATION	β COUNTER-ROTATION	PRECESSION β / α	CORRELATION COEFFICIENT
EYES OPEN	10.6° (+/- 1.5)	7.2° (+/- 2)	-27.8ms (+/- 119)	r = 0.57
EYES CLOSED	10.4° (+/- 1.7)	7.2° (+/- 2.3)	-7.3ms (+/-45)	r = 0.95
TRANSLUCENT GOGGLES	10.2° (+/- 4.6)	6.2° (+/- 1.75)	-41.5ms (+/- 58)	r = 0.95

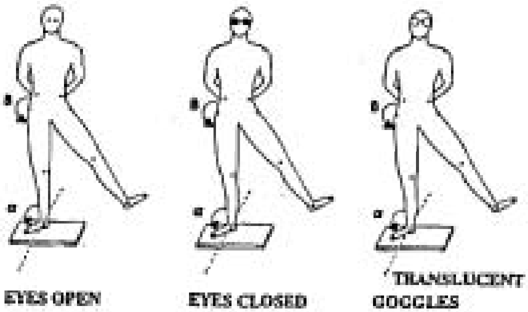

Table I. Alpha and beta angle changes between the starting signal and the end of the recording. Note first, that the counter-rotation occurs before the leg inclination towards the supporting side and second, the high correlation coefficient between onset of alpha and beta changes under both conditions of perturbed vision.

Another interesting result was that, the temporal relationships between the onset of leg inclination towards the supporting side and trunk counter-rotation were analysed. A high correlation was found to exist between the onset of the ankle rotation and the hip counter-rotation (r = 0.95) under both perturbed conditions of vision (eyes closed and translucent goggles) whereas in normal condition the correlation coefficient was much more lower (r = 0.57).

These statistical data point to the conclusion that the coordination between equilibrium control and that of head-trunk stabilisation in the vertical plane was more stable under conditions of perturbed vision than in normal condition.

DISCUSSION

The main results to emerge from the present series are first, that dancers were able to perform the external rotation of the supporting leg around the ankle joint axis and the counter-rotation of the trunk around the coxofemoral joint simultaneously in order to maintain the verticality of the whole head-trunk axis as was done in normal visual condition.

These results indicate that the maintenance of the vertical orientation of the head-trunk axis in dancers was not dependent on vision; other sensors such as otolith graviceptors in the head or possibly muscle proprioceptors of the trunk might be used to maintain the vertical orientation of the head-trunk axis. The possibility that graviceptors might be involved in the positioning of the trunk was first hypothesized by Gurfinkel et al. (1981) and more recently by Dietz et al. (1989) and Gollhofer et al. (1989).

The temporal organization between trunk stabilization and leg inclination under perturbed conditions of vision seems to be more accurate as indicated the high correlation coefficient; this coordinated control seems to be a much more stable system that it was found in normal visual condition.

The functional significance of the vertical head-trunk axis (egocentric reference frame) stabilization during the displacement of the center of gravity in dancers is that the egocentric reference frame coincides with the vertical gravity axis (geocentric reference frame); therefore the calculation of both the gravity forces on the body segments and the movement trajectory in the peripersonal space is simplified.

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