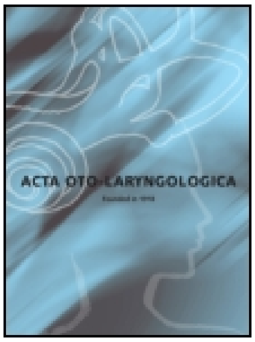

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Dizziness in Discus Throwers is Related to Motion Sickness Generated While Spinning

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While both discus and hammer throwing involve rotating movements resulting in the throw of an object, discus throwers sometimes report dizziness, a condition never experienced by hammer throwers. We investigated whether this susceptibility was related to the sensitivity of the thrower or to the type of throwing achieved. For the latter, we compared the determining features of gesture, gaze stabilization and projectile trajectory in both sports. A total of 22 high-level sportsmen in these 2 disciplines, half of them practising both sports, were interviewed. Slow motion video recordings of discus and hammer throwing were examined to determine the visual referential, head movements and plantar surface support area involved at each stage of the motions. Discomfort was reported by 59% of the sportsmen while throwing discus, but by none while throwing hammer. Because several individuals practised both sports, these results exclude the hypothesis of individual susceptibility to dizziness. Video analysis evidenced that during hammer throwing, visual bearings can be used more easily than during discus throwing. Moreover, there is a loss of plantar afferents and generation of head movements liable to induce motion sickness, such as Coriolis acceleration. In conclusion, although hammer and discus throwing present numerous similarities, we demonstrate here that crucial differences in the specific execution of each sport are responsible for the dizziness experienced by discus throwers. *Key words*: *dizziness*, *motion sickness*, *throw*, *vestibulo-ocular reflex*, *visual input*.

INTRODUCTION

During voluntary movements, motor organization takes place at least on three different levels: evaluation and integration of sensory information; decision-making; and motor response. The vestibular function contributes to balance control, gaze stabilization and spatial orientation in static and dynamic situations. Congruous vestibular, visual and proprioceptive inputs are necessary to regulate efficiently the upright stance (1, 2), which also depends on and serves to motor control involved in voluntary and automatic corrections of the position of the limbs, trunk and head (3, 4). Vestibular, visual and podal afferents contribute to spatial orientation, while articular and muscular receptors inform the central nervous system (CNS) on the relative positions of the various body segments (5). Visual inputs ensure an analysis of the structural and spatio-temporal characteristics of the surroundings (6–8). Proprioception and specially plantar sensitivity contribute to the central programming of precision movements, the former being mediated by sensorial cues relative to position, joints orientation and movement and deformation of cutaneous and muscular tissues (9–11). In experiments involving stance and sensorial perturbations, postural stabilization can be performed normally as long as at least two of the three afferent systems provide congruent information. It has also been suggested that the determination of subjective verticality, involved in balance and in the control of body movements depends on proper vestibular and visual afferences (1, 6). Moreover, these two sensory modalities are essential for gaze stabilization (12). In fact, the CNS makes use of several different mechanisms to achieve head and gaze stability, including the vestibulo-ocular, the vestibulo-collic and the cervico-collic reflexes (3, 13–15). During orientation and self-generated motor tasks, unusual variations in the stimulus (for example an unexpected increase of movement velocity, intensity or repetition) could affect the functionality of the mechanisms mentioned above, and generate subjective sensorial conflicting situations, such as vestibulo-ocular conflict or Coriolis forces (16, 17).

In sports such as discus or hammer throwing, the performance partly depends on the velocity acquired by the ballistic object during the subject's revolution(s) (18). Several repetitions of body rotation, triggering considerable vestibular stimulation, might generate dizziness and nausea during training, head movements being classically identified as the dominant sickness-inducing stimuli (19, 20). In fact, during the acceleration phase of discus or hammer throwing, both the discrepancies in the information provided by different sensory modalities (i.e. due to the variation of pressor input from the feet and to visual vection) and the stimulation of vestibular and neck proprioceptive systems, could be aetiological factors liable to induce subjective motion sickness symptoms, such as stomach discomfort, nausea, yawning or belching (21). This could also depend on individual susceptibility to motion sickness.

Here we investigated the incidence of motion sickness experienced by trained discus and hammer throwers, in an attempt to elucidate whether this susceptibility is related to the subject's sensitivity (thrower) or to the nature of the situation (throwing). We also investigated precisely the motions specific for each of these sports, which could be involved in sensory conflict during discus throwing. Better knowledge of the different effects of these sports on dizziness could be beneficial to help dizzy discus throwers to change their behaviour and avoid this discomfort.

MATERIALS AND METHODS

Subjects

A total of 22 throwers, aged between 20 and 32 years (mean age $\pm$ SE $= 28.3 \pm 1.2$), mostly members of the Athletics Federation, participated in this survey. Their mean duration of practice was 11 ± 3 years. Five 3-h training sessions per week were performed, in addition to competitions according to the specificities of the athletic season. At this high level of expertise, these athletes did not engage in other sports. Moreover, physical training is specific for both sport disciplines. None of the subjects had any history of inner ear, CNS or neck disorders. Sedative and alcoholic beverages were proscribed 48 h before the evaluation.

Methods

Interviews were conducted to determine which sport the subjects practised: hammer and/or discus throwing, whether they practised both, what their main discipline was and whether they had been experiencing dizziness while practising. For individuals involved in both discus and hammer throwing, the precise conditions of when discomfort was experienced were investigated.

In order to understand the aetiology of dizziness in discus throwing, 120 slow motion videos of 56 discus- and 64 hammer-throwings, respectively, were examined by taking into account the opinions of 3 neurophysiologists, 1 of them an ENT surgeon, and an elite athlete practising both sports studied here. A first examination of the videorecordings was made in order to deconstruct each throwing movement into different phases and steps, to determine their duration and list balance control patterns. The latter were: (i) gaze fixation on the throwing area or on the horizon; (ii) gaze fixation on the implement; (iii) head movements; (iv) head-trunk deviation; and (v) plantar surface support area. A second examination was performed by the same jury in order to characterize the different phases according to the presence or absence of these five patterns.

Procedure, technical aspects and description of the movement

The aim of athletic throwing is to throw a projectile as far as possible following strict rules.

Discus throwing

The procedure of discus throwing (Fig. 1), which involves rotation and translation, comprises three successive parts. (i) First, the athlete, standing upright, sets the discus backwards as far as possible by rotating his trunk while keeping his head facing the throwing area and his eyes staring straight ahead at a point on the horizon. At that time, the axes of the sportsman's hips and shoulders are orthogonal, as well as those of his shoulders and head. (ii) Next, the discus acceleration phase begins. There is a simultaneous rotation and forward translation of the thrower within the circle. At the end of this part, the thrower's feet leave the ground (turning jump) and landing is accompanied by head and trunk flexions, liable to generate Coriolis acceleration. (iii) Finally, as he releases the discus, the thrower aligns his head, shoulders and hips, standing upright on the ground,

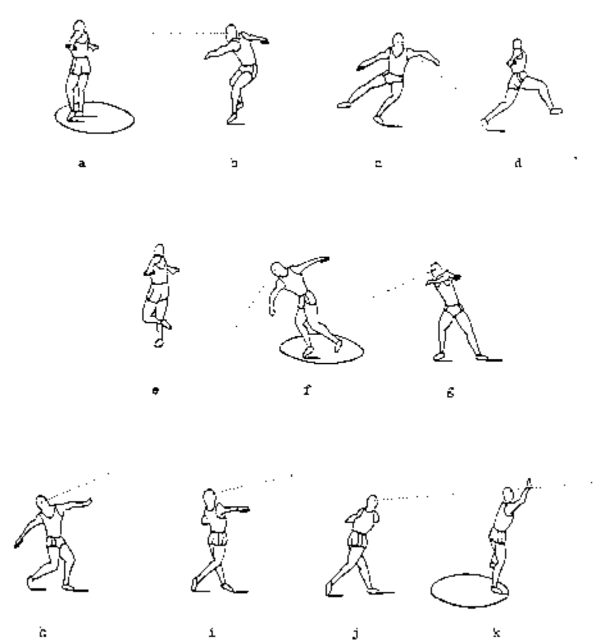

Fig. 1. Discus throwing. The three phases of the movement (see text) can be broken down into 11 steps: (*a*) phase 1; (*b*–*f*) phase 2; and (*g*–*k*) phase 3.

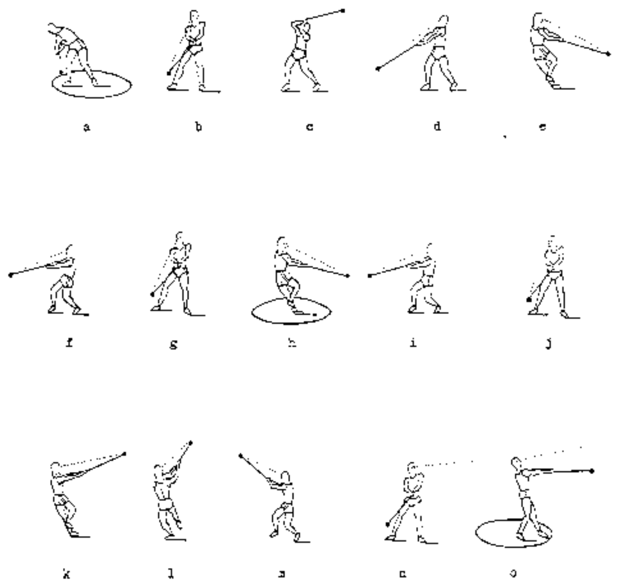

Fig. 2. Hammer throwing. The four phases of the movement (see text) can be broken down into 15 steps: (*a*) phase 1; (*b*–*d*) phase 2; (*e*–*n*) phase 3; and (*o*) phase 4.

facing the throwing area. His head is tilted backwards in order to assess the discus trajectory in space.

Hammer throwing

Hammer throwing can be split into four successive parts (Fig. 2), essentially involving rotation. (i) First, the athlete stands in a semi-sitting position, with his back to the throwing area and stares straight ahead at a point on the horizon. The implement is placed on the ground on the right side of the thrower (if the thrower is right-handed). (ii) Then, the athlete swings the hammer up above his left shoulder in a right-to-left motion, and whirls his arms round as rapidly as possible in order to accelerate the ballistic object. During this phase, his feet are still firmly set on the ground, and his head is tilted backward to avoid contacts with upper limbs. The athlete whirls the hammer twice above his head on his right, allowing an acceleration of the implement's motion, while the lower limbs and head of the thrower remain almost immobile. This is a phase of acceleration of the implement, and not of the subject. (iii) Thirdly, the second hammer acceleration phase begins; during three or four consecutive revolutions of the thrower on himself within the circle, his head is straight and his gaze fixed on the hammer. The shoulders and hands (or head of the hammer) form an isosceles triangle. The subject in rotation alternatively stands on one foot (the implement induces the athlete to turn, which means it is not a phase of acceleration of the hammer) or on two feet (the athlete makes the implement turn, which means it is a phase of acceleration of the hammer). (iv) Finally, as the forward translation of the thrower in rotation stops, the athlete stretches his body while releasing the hammer. The sportsman's head is slightly tilted backward and his gaze is stable in order to assess the hammer's trajectory in space.

Statistical analysis

All comparisons were performed using χ^2 and McNemar tests with the Statview software.

RESULTS

Interviews

Eleven athletes were recruited for each of the two disciplines. Among the 11 discus throwers, 5 were also hammer throwers. Among the 11 hammer throwers, 6 were also discus throwers.

None of the 11 hammer throwing specialists experienced imbalance when throwing their projectile. Among the 11 discus throwing specialists, 7 experienced imbalance while throwing their projectile ($\chi^2 = 10.27$, degree of freedom = 1, $p < 0.001$) (Table I). Imbalance symptoms, when they occurred, were described as gait deviation to the opposite side of handedness, dizziness, loss of bearings, impression of being on a roundabout, need to stop because of discomfort. These symptoms were reported even by trained athletes and were exacerbated by cold. They also seemed to be worse during training than in competition. Nausea sometimes occurred, especially during indoor training, but no athlete reported vomiting.

When assessing the occurrence of symptoms in the 11 throwers practising both sports, we observed that out of the 6 hammer throwers also throwing discus, none of them showed symptoms of dizziness when they threw the hammer, while 3 of them did when they threw the discus. Similarly all five discus throwers also throwing the hammer reported symptoms of dizziness when they threw the discus, while none of them did when they threw the hammer (McNemar-$\chi^2 = 6.12$—degree of freedom = 1, $p < 0.02$).

The discus throwers who showed symptoms during competitions saw their symptoms worsen when doing multiple rotations during training.

Table I. *Partition of the 22 throwers according to their discipline (hammer or discus throwing) and to their dizziness symptoms*

Dizziness	Yes	No	
Discus throwers	7	4	11
Hammer throwers	0	11	11

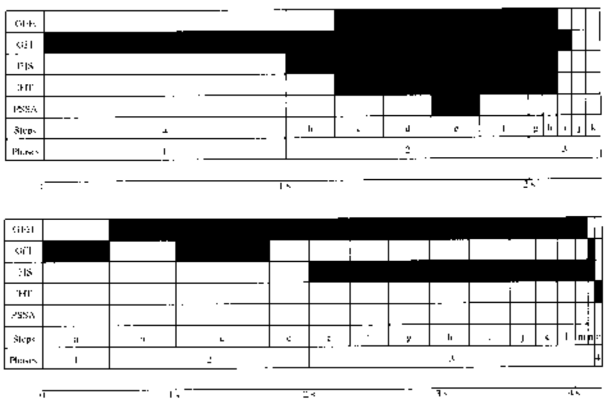

Fig. 3. Chronograms (presence: white slots; absence: black slots) of each of the 5 postural patterns during each step of the discus (*top*) or hammer (*bottom*) throwing movements, which lasted 2.3 ± 0.2 s and 4.2 ± 0.3 s, respectively. Abbreviations are as follows: GFH: gaze fixation on the horizon or on the throwing area, GFI: gaze fixation on the implement, IHS: immobility of the head in space, IHT: immobility of the head vs the trunk, PSSA: plantar surface support area. Phases: see Figs 1 and 2.

Hammer throwers showed no symptoms whether in competition or training.

Video analysis

As indicated in materials and methods, the presence or absence of 5 types of patterns was examined for each of the 11 steps of discus throwing and of the 15 steps of hammer throwing. All sportsmen had remarkably similar behaviours in each sport and although there were small individual variations in the time allotted to each phase, positions were highly reproducible. Fig. 3 summarizes these observations, indicating the phases during which stabilizing criteria were present or not. The qualitative comparison of these chronograms showed striking differences between discus and hammer throwing. The most relevant difference was noted for gaze fixation on implement, which concerned 2/11 steps (j,k; 0,10s – 5% duration of the throwing) for discus throwing vs 12/15 (b, d to m, o; 3,17s – 70% duration of the throwing) for hammer throwing, and immobility of head vs trunk, which concerned 5/11 steps (a, b, i, j, k; 1,20s – 59% duration of the throwing) for discus throwing and 14/15 (a to n; 4,47s – 99% duration of the throwing) for hammer throwing. In discus throwing, 4 patterns were simultaneously absent during 6 of 11 steps (c to h; 0,92s – 46% duration of the throwing). This situation was never observed in hammer throwing, in which a maximum of two patterns were simultaneously absent. Absence of plantar surface support area was observed only for discus throwers, during step e characterized by the absence of all stability parameters.

DISCUSSION

Discus throwers experienced dizziness significantly more frequently than did hammer throwers, who do not report such discomfort while practising their sport. Here we also demonstrated that sportsmen performing both sports only experience dizziness symptoms when throwing the discus, indicating that susceptibility to dizziness is not related to the subject but to the discipline. This suggests that specificities of the gesture and movements involved in discus throwing must be implicated. Indeed, we were able to demonstrate significant differences between major parameters of control balance in both sports explaining the disorientation of discus throwers.

In sports requiring precise movement coordination during the execution of complex body rotations, the contribution of the various sensory systems to the maintenance and/or restoration of postural control depends on precise stimulus conditions in terms of velocity, acceleration and amplitude of the movement.

Spatial orientation plays a key role during fast rotatory accelerations combined with constant angular velocities as occurs in both discus and hammer throwing. During the rotations performed by both kind of throwers, visual orientation relative to the surroundings becomes impossible because of the high velocity at which the inhomogeneous visual scene impacts on the central retina, although the implement remains stable for hammer thrower. Thus, visual fixation, which is involved in the regulation of the balance as well as in the orientation of the subject, cannot be achieved using the surroundings.

While throwing discus, the lack of visual fixation prevents the suppression of the vestibular input during rotations. As a consequence, a strong post-rotatory vertigo, or in case of prolonged stimulation also a considerable per-rotatory vertigo may occur. Neither the smooth pursuit system, nor the vestibulo-ocular reflex, nor the opto-kinetic reflex can be used sufficiently to reduce these effects.

While throwing the hammer, target fixation allows visual suppression of the vestibular stimulation (22) and enables a fast spatial reorientation after the rotatory movement, therefore compensating balance and avoiding dizziness. In dance and ice-skating, turns can be even faster than those of throwers. During high-speed rotations, whereas body rotations are regular, those of the head occur in fits and starts, with short periods of fixation on an environmental target at each turn. In addition to the stabilization effect, visual fixation also contributes to the aesthetics of the exhibition. More especially in ice-skating, visual stabilization during rotation can be made by fixating a point on the ceiling. Moreover, gaze fixation permits post rotatory nystagmus inhibition (8, 23).

Mittelsteadt has reported that graviceptors located in the trunk, or motion detection perhaps associated with movements of the viscera, may have an even stronger influence on perceived self-orientation than the otolith receptors during rotation (24). In addition, proprioceptive information from the lower limbs, hip and trunk allows the CNS to assess the displacements of the sportsman in space, relative to the positions and axes of shoulders and feet (5). This is the case for hammer throwers who always have at least one foot in contact with the ground. Trunk and head motion in space can therefore be reconstructed by further adding low threshold proprioceptive signals of the trunk on foot (5). This vestibular-proprioceptive interaction contributes in maintaining and regulating the subject's balance during throwing events because plantar information, associated with vestibular cues, allows humans to assess their verticality, and to correct it efficiently if needed, e.g. to counterbalance the centrifugal force developed by the throwing object.

Conversely, loss of contact with the ground during the turning jump while throwing discus, which do not occur in hammer throwing or in dance, contributes to significantly hamper spatial orientation, resulting in the induction of dizziness.

During head tilting in discus throwing, a pins-and-needles sensation is sometimes experienced, described as similar to electric shocks, and testifying to the intensity of the neck movement even in trained and warmed-up athletes. In contrast to discus throwing, hammer throwing does not imply a tilting of the head of the subject during the turning phase, and predominantly the lateral semicircular canals are stimulated during this movement. Moreover, the constantly upright position of the head and its immobility in relation to the trunk during throwing, inhibit the vestibulo-collic and cervico-ocular reflexes, while proprioceptive signals of the neck do not detect any head movement. Head and trunk are therefore interdependent. Head to trunk stabilization is well preserved in hammer throwers, while it is clearly absent in discus throwers, who display considerable head movement relative to the trunk. During rotations, this induces the occurrence of Coriolis forces, which are known to prompt motion sickness (25), and an extra degree of freedom for the brain to detect spatial orientation, which requires the input of cervical propriocepsis.

That discus thrower's symptoms were worse during training may be explained by the fact that competition allows a single rotation (volte), while coaches often rely on multiple-rotation (multivolte) exercises for training purposes (usually three rotations). In hammer throwing, there are usually three rotations (multitours) in competitions, and usually 9–10 during training, yet no vertigo is induced.

During training sessions, the repetition of multivolte induces dizziness in trained discus throwers and neither habituation nor adaptation could have taken place. In fact, since two of the three sensory systems were suppressed during the turning jump while the third one (i.e. the vestibular system) was submitted to an excessive stimulation, all impairment of spatial orientation and erroneous sensorimotor regulation are usually accompanied with moderate to severe vertigo as well as motion sickness and discomfort syndromes (25). As suggested by these authors, proprioceptive cues project a three-dimensional somatotopical map in the brain, in daily life situation. Similarly, visual cues project a three-dimensional map of the outside world. Then, in order to perform voluntary actions in space, each kind of map must be translated into the other by the vestibular system and projected to the cerebellum. The most likely candidate for the control of motor commands may be the internal framework of the outside world, which represents the ego-spatial relationship. As far as the latter is correctly represented and/or reproduced in the brain, voluntary actions are automatically adjusted to suit the surroundings. Once the ego-spatial relationship is impaired, consecutively to the loss of visual cues during rotation, nausea always acts as a safety device to brake improper "ataxic" actions (25). This is indeed the case in discus throwing events, the fast rotation of the thrower being moreover performed with lack of proprioceptive cues. The severity of sickness in discus throwers does not depend on the subject's susceptibility but on impairment of spatial orientation provoked by multiple rotations.

In conclusion, this study demonstrates the reality of dizziness experienced by discus throwers as unrelated to individual susceptibility, but relying on precise physiological grounds and associated with specific phases of the motion involved in this sport.

REFERENCES

1. Nashner LM, Mc Collum G. The organization of human postural movements: a formal basis and experimental synthesis. Behav Brain Sci 1985; 8: 135–72.
2. Odkvist LM, Gripmark MA, Larsby B, Ledin T. The subjective horizontal in eccentric rotation influenced by peripheral vestibular lesion. Acta Otolaryngol (Stockh) 1996; 116: 181–4.
3. Allum JHJ, Gresty M, Keshner E, Shupert C. The control of head movements during human balance corrections. J Vest Res 1997; 7: 189–218.
4. Perrin Ph, Schneider D, Deviterne D, Perrot C, Constantinescu L. Training improves the adaptation to

changing visual conditions in maintaining human posture control in a test of sinusoidal oscillation of the support. Neurosci Lett 1998; 245: 155–8.
5. Mergner T, Hlavacka F, Schweigart G. Interaction of vestibular and proprioceptive inputs. J Vest Res 1993; 3: 41–57.
6. Soechting JF, Berthoz A. Dynamic role of vision in the control of posture in man. Exp Brain Res 1979; 36: 551–61.
7. Paulus W, Straube A, Brandt Th. Visual postural performance after loss of somatosensory and vestibular function. J Neurol Neurosurg Psychiatry 1987; 50: 1542–5.
8. Hugel F, Cadopi M, Kohler F, Perrin Ph. Postural control of ballet dancers: a specific use of visual input for artistic purposes. Int J Sports Med 1999; 20: 86–92.
9. Horak FB, Nashner LM, Diener HC. Postural strategies associated with somatosensory and vestibular loss. Exp Brain Res 1990; 82: 167–77.
10. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. Am J Sports Med 1997; 25: 130–7.
11. Perrin Ph, Gauchard G, Perrot C, Jeandel C. Effects of physical and sporting activities on balance control in elderly people. Br J Sports Med 1999; 33: 121–6.
12. Demer JL, Crane BT. Vision and vestibular adaptation. Otolaryngol Head Neck Surg 1998; 119: 78–88.
13. Keshner EA, Woollacott MH, Debu B. Neck, trunk and limb muscle responses during postural perturbations in humans. Exp Brain Res 1988; 71: 455–66.
14. Ron S, Berthoz A, Gur S. Model of coupled or dissociated eye-head coordination. J Vest Res 1994; 4: 383–90.
15. Padoan S, Karlberg M, Fransson PA, Magnusson M. Passive sustained turning of the head induces asymmetric gain of the vestibulo-ocular reflex in healthy subjects. Acta Otolaryngol (Stockh) 1998; 118: 778–82.
16. Guedry FE Jr. Habituation to complex vestibular stimulation in man: transfer and retention of effects from twelve days of rotation at 10 rpm. Percept Mot Skills 1965; 21: 459–81.
17. Eyeson-Annan M, Peterken C, Brown B, Atchison D. Visual and vestibular components of motion sickness. Aviat Space Environ Med 1996; 67: 955–62.
18. Maronski R. Optimal distance from the implement to the axis of rotation in hammer and discus throws. J Biomech 1991; 24: 999–1005.
19. Oman CM, Lichtenberg BK, Money KE, McCoy RK. M.I.T./Canadian vestibular experiments on the Spacelab-1 mission: 4. Space motion sickness: symptoms, stimuli, and predictability. Exp Brain Res 1986; 64: 316–34.
20. Isu N, Yanagihara M, Mikuni T, Koo J. The severity of nauseogenic effect of cross-coupled rotation is proportional to gyroscopic angular acceleration. Aviat Space Environ Med 1996; 67: 325–32.
21. Oman CM. Sensory conflict theory and space sickness: our changing perspective. J Vestib Res 1998; 8: 51–6.
22. Gresty MA, Bronstein AM. Visually controlled spatial stabilisation of the human head: compensation for the eye's limited ability to roll. Neurosci Lett 1992; 140: 63–6.
23. Teramoto K, Sakata E, Ohtsu K. Use of the visual suppression test using post-rotatory nystagmus to determine skill in ballet dancers. Eur Arch Otorhinolaryngol 1994; 251: 218–23.
24. Mittelstaedt H. Somatic versus vestibular gravity reception in man. Ann N Y Acad Sci 1992; 22: 124–39.
25. Takahashi M, Ogata M, Miura M. The significance of motion sickness in the vestibular system. J Vestib Res 1997; 7: 179–87.

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