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The effect of expertise in gymnastics on postural control

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Abstract

The goal of this paper was (1) to investigate if gymnasts have a more stable standing posture than experts in other sports, and (2) to determine how much gymnasts are affected by the removal of vision in different postural tasks. Six expert gymnasts and six experts in other non-gymnastic sports were asked to maintain balance in three standing postures of increasing difficulty: bipedal, unipedal, and unipedal + unstable support (i.e. 7 cm thick foam surface). Each posture was tested successively with and without vision. Based on the displacement of the center of pressure (range and mean average speed), the results showed that when visual cues were available, postural sway increased with the difficulty of the task, but both groups had comparable performance in all the tasks. When vision was removed, although both groups demonstrated larger postural sway in the unipedal tasks, this effect was less accentuated for the gymnasts. We concluded that gymnasts are able to use the remaining sensory modalities to compensate for the lack of vision in unstable postures.

Keywords: Posture; Gymnastics; Vision; Expertise

Performing complex motor skills, such as those performed by gymnasts or dancers, requires a great sense of balance. Consistent with this view, Robertson et al. [17] showed that experts in gymnastics are faster than novices when they are required to walk across a balance beam as quickly as possible, suggesting that gymnasts can control their balance better than inexperienced athletes. It still remains unclear, however, if gymnasts can demonstrate a better sense of balance than sedentaries or other sportsmen in non-acrobatic tasks, like standing as immobile as possible. This issue can be debated in the context of the two leading theories proposed for the transfer of motor abilities (i.e. the capability for performance in one task as a result of practice or experience on some other task). On one hand, based on the general motor ability hypothesis [1], any human skill (like a better sense of balance) should remain observable among various tests. This opinion is supported by several studies. Using several tasks, Kioumourtzoglou et al. [13] showed that elite gymnasts have better dynamic and static balance than novices. In addition, during unilateral leg movements performed while standing, Mouchnino et al. [16] reported that the lateral sway of the center of pressure was smaller in dancers than in untrained subjects. On the other hand, there are also reports showing that the transfer of motor abilities is not such a simplistic mechanism. In fact, Henry's hypothesis [11] predicts that transfer among skills should be quite low because motor abilities are specific to a particular task (see also Ref. [19]). A recent study conducted on ballet dancers suggests that these athletes develop specific modalities of balance that are not transferable to posture control in daily life situations [12]. More confounding, Bachman [2] found that individual performances in a ladder climbing test and in an unstable balancing board test (stabilometer) were poorly correlated. This means that there might not be a general balancing ability, but that this aptitude is likely to vary depending on the nature of the task. Bearing these two camps of research in mind, a question arises; is gymnasts' aptitude for maintaining balance in complex moves transferable to more simple tasks? In an attempt to

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Table 1
Age, weight, height and foot length of non-gymnasts and gymnasts groups[a]

	Non-gymnasts ($n = 6$)	Gymnasts ($n = 6$)	t-test ($P < 0.05$)
Age (years)	23.3 ± 1.5	20.6 ± 1.4	Ns
Weight (kg)	69.5 ± 7.9	65.3 ± 8.6	Ns
Height (cm)	173.0 ± 7.4	172.3 ± 7.5	Ns
Foot length (cm)	26.5 ± 1.5	26.2 ± 2.0	Ns

[a] Values are means and standard deviations (±); Ns = non-significant difference between the two groups.

answer this question, we have compared the postural sway of expert and non-expert gymnasts during bipedal standing, given the instruction of being as immobile as possible. In order to test if task difficulty would possibly help to differentiate the performance of both groups, the subjects were also tested in two more challenging postures (unipedal stance, and unipedal stance on an unstable surface).

Postural control is known to result from the integration of visual, somesthesic and vestibular information [15]. The suppression of one type of sensory information can be used to estimate the importance of that information to postural control and indicate how the central nervous system adapts and reorganizes information provided by the remaining sensory information [20]. Although the role of vision in postural control has been widely demonstrated (for a review see Ref. [14]), the role of visual cues for gymnasts is still under debate. First, there are contradictory reports about whether or not gymnasts' performance is affected by the removal of vision. Roberston and Elliot [18] found that expert gymnasts performed equally well in the full vision and no vision situation when asked to cross a balance beam as quickly as possible. But Bardy and Laurent [3] showed that gymnasts were clearly affected by the removal of vision for the execution of a backward somersault. Golomer et al. [10] studied the postural sway of professional dancers maintaining balance on a seesaw or a platform, and like Bardy and Laurent [3], found that these athletes' performance was affected by the removal of vision. Second, it is unclear if the effects of vision suppression are similar in gymnasts and non-gymnasts. For walking in a straight direction [7], standing on a stabilometer [9], or crossing a balance beam [17], gymnasts were found to be less dependent on visual cues than untrained subjects. However, Bardy and Laurent [3] found opposite results for the execution of a backward somersault. The second goal of the present experiment was to compare the visual dependency of gymnasts and non-gymnasts in postural tasks. In an attempt to clarify some of the discrepancies between all these experiments which used a wide variety of tasks, we propose to manipulate the role of task difficulty in a set postural tasks that are very similar (i.e. bipedal, unipedal, and unipedal + foam). This investigation was motivated by reports showing that the role of vision increases when sedentary subjects perform postural tasks of increasing difficulty [6,8]. We hypothesized that if gymnasts are really less dependent on vision than others, this characteristic should be emphasized by the difficulty of the posture.

Two groups of athletes from the Faculty of Sports Sciences at the University of Grenoble voluntarily participated as unpaid subjects in the experiment. The group of expert gymnasts consisted of six males having an experience in gymnastics ranging from 10 to 13 years. Because our findings may originate simply from the practice of sports in general, gymnasts' performance was compared to the performance of a control group composed of non-gymnasts who were also experts in sport where control of balance is required in order to excel (soccer, handball, or tennis). We also adjusted the composition of the two groups such that there was no significant difference either in age, weight, height, and foot length (see Table 1), because body

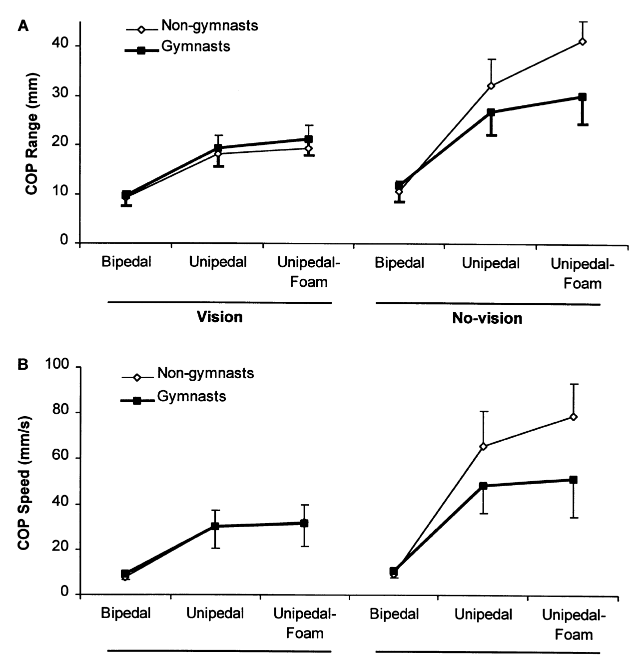

Fig. 1. Mean and standard deviation for the range (A) and the speed of the COP displacement (B) for the two groups of gymnasts and non-gymnasts across the three postural conditions (Bipedal, Unipedal and Unipedal-Foam) and the two conditions of vision and no-vision. The two experimental groups are presented with different symbols: gymnasts (square) and non-gymnasts (diamond).

properties have been demonstrated to be determinant for postural tasks [4].

In each trial, the subjects were asked to stand barefoot on a force platform as immobile as possible for 10 s. Three postures of increasing difficulty were tested. In the first posture (Bipedal), subjects stood with their feet forming a 20° angle relative to each other, with their heels 4 cm apart. In the second posture (Unipedal), they stood on their preferred foot, the other foot was lifted so that subject's big toe touched the medial malleolus of the supporting leg. In the last posture (Unipedal-Foam), the subjects also stood on their preferred leg but the force platform was covered by a 7 cm thick foam support. Given that the sagging of the foam impedes a full stabilization of the foot, and that the somatosensory information from the plantar sole is altered, we thought that the maintenance of balance would be more challenging than on stable support. For each posture, the subjects were tested with and without vision. In the no-vision conditions, subjects were asked to close their eyes and to keep their gaze in a straight-ahead direction (e.g. Ref. [5]). In the sighted vision conditions, they were asked to fixate a white cross (20 × 25 cm) located 1.20 m away from the force platform, at eye level. In all trials, subjects were instructed to keep their body straight, and their arms loosely hanging by their sides. For each experimental condition, subjects performed three trials, representing a total of 18 trials per subject. The order of presentation of the six experimental conditions across these 18 trials was randomized over subjects. The signals from the force platform (AMTI model OR6–5–1) were sampled at 100 Hz (12-bit A/D conversion) and low pass filtered with a second-order Butterworth (10 Hz). Then the displacement of the center of pressure (COP) was assessed by computation of the three orthogonal components of the ground reaction forces and their associated torque.

Two dependent variables were used to describe the subjects' postural behavior. The range of COP displacements indicates the maximal deviation of the COP in any direction. The mean speed of COP displacements is the sum of the displacement scalars (i.e. the cumulated distance over the sampling period) divided by the sampling time. Note that the range and speed of the COP are a priori independent measurements (e.g. a fast displacement can be contained within in small surface), but as revealed by Fig. 1A,B, very similar results were provided by these two parameters. Therefore each statistical analysis presented in the following paragraph will account for both parameters.

For the sake of simplicity, the data related to the vision (Fig. 1A,B, left side) and no-vision conditions (Fig. 1A,B, right side) were first analyzed separately. For each condition of vision, two groups × three postures analyses of variances (ANOVAs) with repeated measures on the last factor were applied to the data. In the presence of vision, we found no significant effect of group ($F(1,10) < 0.55$, $P > 0.05$). Both dependent variables showed a strong dependency with respect to posture ($F(2,20) > 63.82$, $P < 0.001$). In the vision condition, we did not find any significant interaction between group and posture ($F(1,10) < 0.23$, $P > 0.05$). The same statistical analyses led to different results in the non-vision condition. Indeed, although a similar effect of posture ($F(2,20) > 130.92$, $P < 0.001$) was observed, we also found a significant effect of group ($F(1,10) > 6.68$, $P < 0.05$) and a significant interaction between posture and group ($F(1,10) > 8.06$, $P < 0.01$). In fact, in the lack of vision, all subjects increased their postural sway (range and speed of COP displacement) when the difficulty of the posture increased, but this effect was weaker in the gymnasts.

The effect of vision (vision/no-vision) was investigated by applying two groups (three postures × two visions ANOVAs with repeated measures on the last two factors to the data. The results showed an effect of vision ($F(1,10) > 70.77$, $P < 0.001$), such that in general vision helps minimize the postural sway. However, the magnitude of this effect was largely related to posture and group as demonstrated by a significant triple interaction ($F(2,20) > 8.96$, $P < 0.01$). In the bipedal task, the performance of both groups was not altered by the suppression of vision, whereas in the unipedal tasks, the suppression of vision induced larger postural sway, especially for the non-gymnasts.

The first goal of this paper was to investigate if gymnasts have a more stable standing posture than other sport experts do. In the visual conditions, gymnasts were not more stable than other sport experts. Manipulating the difficulty of the task did not help to discriminate the performance of both groups. Thus, the present results do not support the general motor ability hypothesis [1], but rather argue in favor of Henry's hypothesis [11] under which the transfer of motor skills is not an automatic phenomenon. Based on our results, the eloquent sense of balance demonstrated by the gymnasts during their acrobatic moves does not provide any benefit to the achievement of more simple tasks, like balance control in bipedal or unipedal stance. As pointed out by Bachman's study [2], there might not be such general ability as balance, but rather the ability to maintain balance would depend on the task.

The second goal of this paper was to investigate whether the visual dependency of gymnasts versus non-gymnasts changed as task difficulty increased. The results showed that the performance of both groups became progressively altered by the absence of vision as the difficulty of the posture increased. In accordance with previous studies [6,8], this suggests that the role of vision increased when the difficulty of the stance increased. Interestingly, this effect was less pronounced for the gymnasts. Indeed, with respect to the controls, gymnasts demonstrated the particularity of being less affected by the removal of vision during unipedal tasks. Previous studies [7,9,17] have shown that gymnasts could be less affected than others by this sensory manipulation, but our study emphasizes that this observation is strongly related to the difficulty of the task. In fact, in situations where vision played a crucial role, gymnasts knew better than others how to cope with the lack of vision. Together, these results indicate that gymnasts cannot always fully compensate for the lack of vision, but their capability to use the remaining sensory modalities in unstable postures is improved with respect to non-gymnasts. Because gymnasts often have to perform complex moves with poor visual environments, we suggest that having or developing this capability is a requirement to become an expert.

In conclusion, these results showed no direct evidence that sighted gymnasts would possess a better sense of balance than any other sighted sportsmen during bi- and unipedal standing. Nevertheless, gymnasts present the particularity of being less dependant on visual cues than other sportsmen for maintaining balance in challenging postures. We would like to offer two possibilities for this: (1) gymnasts can switch between visual and other sensory systems more efficiently; (2) gymnasts have a more sensitive sensory system as compared to other sports experts.

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[1] Adams, J.A., Historical review and appraisal of research on the learning, retention, and transfer of human motor skills, Psychol. Bull., 101 (1987) 41–74.
[2] Bachman, J.C., Specificity versus generality in learning and performing two large muscle motor tasks, Res. Quat., 32 (1961) 3–11.
[3] Bardy, B.G. and Laurent, M., How is body orientation controlled during somersaulting? J. Exp. Psych. (HPP), 24 (1998) 963–977.
[4] Berger, W., Trippel, M., Discher, M. and Dietz, V., Influence of subjects' height on the stabilization of posture, Acta Otolaryng. (Stockh.), 112 (1992) 22–30.
[5] Berthoz, A., Regard et posture. Influence de la direction du regard sur le contrôle de la posture, Aggression, 28 (1987) 893–895.
[6] Crémieux, J., Mesure, S. and Amblard, B., Does the role of vision increase with the difficulty of the postural task? In K. Taguchi, M. Igarashi and S. Mori (Eds.), Vestibular and Neural Front, International Congress Series, vol. 1070, Elsevier Science BV, Amsterdam, 1994, pp. 267–270.
[7] Danion, F., Boyadjian, A. and Marin, L., Control of locomotion in expert gymnasts in the absence of vision, J. Sports Sci., 18 (2000) 809–814.
[8] Day, B.L., Steiger, M.J., Thompson, P.D. and Marsden, C.D., Effect of vision and stance width on human body motion when standing: implications for afferent control of lateral sway, J. Physiol., 469 (1993) 479–499.
[9] Golomer, E., Dupui, P. and Monod, H., The effects of maturation on self-induced dynamic body sway frequencies of girls performing acrobatics or classical dance, Eur. J. App. Physiol. Occup. Physiol., 76 (1997) 140–144.
[10] Golomer, E., Dupui, P., Sereni, P. and Monod, H., The contribution of vision in dynamic spontaneous sways of male classical dancers according to student or professional level, J. Physiol. (Paris), 93 (1999) 233–237.
[11] Henry, F.M., Specificity versus generality in learning motor skill, In R.C. Brown and G.S. Kenyon (Eds.), Classical Studies on Physical Activity, Prentice Hall, Englewood Cliffs (NJ), 1968, pp. 340–350 (original work published 1958).
[12] Hugel, F., Cadopi, M., Kohler, F. and Perrin, P., Postural control of ballet dancers: a specific use of visual input for artistic purposes, Int. J. Sports Med., 20 (1999) 86–92.
[13] Kioumourtzoglou, E., Derri, V., Mertzanidou, O. and Tzetzis, G., Experience with perceptual and motor skills in rhythmic gymnastics, Percept. Mot. Skills, 84 (1997) 1363–1372.
[14] Lee, D.N., Visuo-motor coordination in space-time, In Stelmach, G.E., Requin, J. (Eds.), Tutorials in Motor Behavior, Elsevier, Amsterdam, 1980, pp. 281–295.
[15] Massion, J., Postural control system, Curr. Opin. Neurobiol., 4 (1994) 877–887.
[16] Mouchnino, L., Aurenty, R., Massion, J. and Pedotti, A., Coordination between equilibrium and head-trunk orientation during leg movement: a new strategy build up by training, J. Neurophys., 67 (1992) 1587–1598.
[17] Robertson, S., Collins, J., Elliot, D. and Starkes, J., The influence of skill and intermittent vision on dynamic balance, J. Mot. Behav., 26 (1994) 333–339.
[18] Robertson, S. and Elliott, D., The influence of skill in gymnastics and vision on dynamic balance, Int. J. Sport Psychol., 27 (1996) 361–368.
[19] Schmidt, R.A. and Young, D.E., Transfer of movement control in motor learning, In S.M. Cormier and J.D. Hagman (Eds.), Transfer of Learning, Academic Press, Orlando, FL, 1987, pp. 47–79.
[20] Teasdale, N., Stelmach, G.E. and Breunig, A., Postural sway characteristics of the elderly under normal and altered visual and support surface conditions, J. Gerontol., 46 (1991) B238–B244.