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ORIGINAL ARTICLE

Is postural control affected by expertise in alpine skiing?

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Objectives: This study examined the postural performance of two groups of male skiers competing at different levels and the consequences on postural control of the suppression of visual afferences by eye closure.

Methods: Seven national level (NAT) skiers and 7 regional level (REG) skiers were asked to stand as still as possible on a force platform with eyes opened and closed and while wearing or not wearing their ski boots in a stable posture and in two unstable postures (in the sagittal or frontal plane). Postural performance was assessed with centre of foot pressure measurements.

Results: REG and NAT skiers were similarly influenced by the absence of visual information and presented similar postural performance when tests were performed with ski boots. However, without ski boots, REG skiers displayed better postural performance than NAT skiers.

Conclusions: The inferior postural performance of NAT skiers without ski boots could be a long term effect of repetitive wearing of ski boots, which impairs postural performance by restricting the range of motion of the ankle-foot complex. Since individuals with decreased postural performance are believed to be more susceptible to ankle injury than those with finer postural control, NAT skiers should benefit from specific training aimed at improving postural ability and preventing ankle injury.

Highly trained athletes systematically demonstrate better postural performance than sedentary subjects,^{1–4} in particular because physical training enhances their ability to use proprioceptive and somesthetic information.^{4,5} Nevertheless, few studies have analysed subjects' postural performance in order to discriminate the expertise level among highly skilled athletes of a specific discipline^{3,6} and results remain controversial. Indeed, Era *et al*³ showed that international rifle shooters stabilised their posture better than national level shooters, whereas Paillard *et al*⁶ revealed that postural performance was similar for judoists at different levels of competition. Nevertheless, Paillard *et al*⁶ showed that the highest level judoists were more dependent on visual information to maintain their posture than lower level judoists. They suggested that the importance of visual information in postural control increases with the level of competition.

Although alpine skiing is a sport which requires fine postural control to maintain balance in challenging conditions,⁷ studies on performance factors in alpine skiing have focused in particular on physiology, that is, on investigating muscular strength and aerobic and anaerobic power,^{8,9} and no study has been carried out to evaluate postural control in alpine skiers. Therefore, the purpose of the present study was to investigate (i) whether high postural performance is a criterion enabling the discrimination of the expertise level between skiers at different levels of competition (regional and national competition level), and (ii) if the contribution of vision in postural control is influenced by the expertise level in alpine skiing.

METHODS

Fourteen healthy male competition skiers voluntarily participated in the study and were divided in two groups. The first group consisted of seven regional level skiers (REG; age (mean \pm SD): 22 \pm 3 years, height: 175 \pm 5 cm, mass: 68 \pm 5 kg). The second group consisted of seven national/international level skiers either in the French junior national team or in the French senior reserve national team (NAT; age (mean \pm SD): 18 \pm 1 years, height 177 \pm 4 cm, mass

71 \pm 5 kg). Subjects in both groups had >10 years' experience of training in alpine skiing. REG and NAT skiers train for 12 and 25 h a week, respectively. Participant exclusion criteria included a documented balance disorder or a medical condition that might affect postural control, a neurological or a musculoskeletal impairment in the past 2 years, or current injury preventing the subject from competing. The experiment was conducted at the end of the competition season. Participants signed an informed consent as required by the Helsinki Declaration (1964) and the local ethics committee.

A force platform (PostureWIN, Techno Concept, Cereste, France; sampling frequency: 40 Hz; 12 bits A/D conversion) was used to calculate the centre of foot pressure (COP) positions. Three different postures were analysed with eyes opened (EO) and closed (EC): a stable posture on a rigid floor (STA posture), an unstable posture on a seesaw device (Stabilomètre, Techno Concept) generating instability in the antero/posterior direction (AP posture), and an unstable posture where the seesaw device generated instability in the medio/lateral direction. Subjects were also tested (i) in a reference condition (REF) with the knees extended and without shoes and (ii) in a postural conditions specific to the activity⁶ (SKI condition), while wearing the ski boots they usually used in competition and with the knees flexed at 100° angle.¹⁰ In the STA posture, subjects were asked to remain as still as possible for 51.2 s.⁶ When the posture was unstable (ML and AP postures), they were instructed to maintain the platform as horizontal as possible for 25.6 s.⁵ With unstable postures, recording time was shorter because of the difficulty of the postural tasks.⁵

The COP surface (90% confidence ellipse) and the COP velocity (sum of the cumulated COP displacement divided by the total time) were calculated. The COP surface is correlated to the centre of gravity and can be viewed as an indicator of the subject's performance¹¹: the smaller the surface, the

Abbreviations: ANOVA, analysis of variance; AP, antero/posterior; COP, centre of foot pressure; EC, eyes closed; EO, eyes opened; NAT, national level; REF, reference condition; REG, regional level; SD, standard deviation; STA, stable

Table 1 Comparison between regional level (REG) and national level (NAT) groups of skiers performing postural tests with eyes open (EO) or closed (EC) in the REF condition

| Posture | Group | Vision | S (mm ²) | V (mm s ⁻¹) |
|---------|-------|--------|----------------------|-------------------------|
| STA | REG | EO | 72.3 ± 50.3 | 5.0 ± 1.7 |
| | | EC | 156.5 ± 138.6 | 8.0 ± 3.4† |
| | NAT | EO | 178.9 ± 93.3* | 6.1 ± 1.2 |
| | | EC | 191.3 ± 85.0* | 8.7 ± 1.9† |
| ML | REG | EO | 278.9 ± 95.3 | 14.9 ± 1.6 |
| | | EC | 1176.1 ± 435.4† | 37.1 ± 10.3† |
| | NAT | EO | 519.7 ± 329.9* | 18.1 ± 3.1 |
| | | EC | 2063.0 ± 979.5*† | 39.7 ± 7.0† |
| AP | REG | EO | 247.4 ± 125.2 | 11.7 ± 2.9 |
| | | EC | 892.1 ± 425.6† | 32.0 ± 8.9† |
| | NAT | EO | 327.1 ± 171.7 | 18.1 ± 3.9 |
| | | EC | 1268.1 ± 473.8† | 37.5 ± 9.5† |

Values are mean ± SD in the STA, ML, and AP postures. S, surface of the COP; V, COP velocity.

*Significant group effect (REG or NAT); †significant vision effect (EO or EC) (p < 0.05).

Table 2 Comparison between regional level (REG) and national level (NAT) groups of skiers performing postural tests with eyes open (EO) or closed (EC) in the SKI condition

| Posture | Group | Vision | S (mm ²) | V (mm s ⁻¹) |
|---------|-------|--------|----------------------|-------------------------|
| STA | REG | EO | 121.2 ± 99.4 | 9.1 ± 6.2 |
| | | EC | 144.0 ± 160.7 | 9.5 ± 5.9 |
| | NAT | EO | 57.4 ± 41.0 | 7.5 ± 4.0 |
| | | EC | 72.0 ± 39.6 | 7.8 ± 3.5 |
| ML | REG | EO | 266.6 ± 84.3 | 13.2 ± 3.0 |
| | | EC | 1301.3 ± 709.9† | 33.2 ± 9.2† |
| | NAT | EO | 470.9 ± 422.8 | 17.6 ± 4.7 |
| | | EC | 1469.3 ± 629.5† | 38.9 ± 4.1† |
| AP | REG | EO | 146.8 ± 74.5 | 12.9 ± 2.1 |
| | | EC | 629.8 ± 317.6† | 26.5 ± 6.2† |
| | NAT | EO | 191.9 ± 83.2 | 16.8 ± 4.1* |
| | | EC | 1038.1 ± 701.4† | 43.3 ± 11.9*† |

Values are mean ± SD in the STA, ML, and AP postures. S, surface of the COP; V, COP velocity.

*Significant group effect (REG or NAT); †significant vision effect (EO or EC) (p < 0.05).

better the performance. The COP velocity is an estimate of the net muscular force variations and evaluates the subject's postural control.¹²

For statistical purposes, a two factor analysis of variance (ANOVA) was conducted on the COP surface and the COP velocity with group (REG/NAT) as unreplicated factor and vision (EO/EC) as repeated factor. The ANOVA also gives possible interactions between these two factors. The three postures (STA, ML, and AP) and the two conditions (REF and SKI) were independently analysed. The level of significance chosen was p < 0.05.

RESULTS

In the REF condition, even though the analysis revealed no significant group effect in the AP posture, significant differences were observed in the STA and ML postures (table 1). The surface of the COP was significantly greater for the NAT skiers than for the REG skiers in the STA ($F_{1,24} = 4.31$, p < 0.05) and the ML ($F_{1,24} = 4.45$, p < 0.05) postures. The COP velocity was significantly increased in the two groups when subjects had their eyes closed in the STA ($F_{1,24} = 8.67$, p < 0.05), ML ($F_{1,24} = 25.65$, p < 0.05), and AP postures ($F_{1,24} = 24.47$, p < 0.05). Suppression of vision also significantly increased the COP surface in the ML ($F_{1,24} = 19.10$, p < 0.05) and AP ($F_{1,24} = 17.94$, p < 0.05) postures. Whatever the posture and variable considered, ANOVA analysis did not reveal significant vision × group interaction in the REF condition.

In the SKI condition (table 2), ANOVA analysis revealed an effect of the group factor only in the AP posture, characterised by higher values of COP velocity ($F_{1,24} = 6.95$, p < 0.05) for NAT subjects than for REG subjects. No significant group effect was observed in either the STA or ML posture. As in the REF condition, the COP velocity was significantly increased in the two groups when subjects had their eyes closed in the ML ($F_{1,24} = 46.64$, p < 0.05) and AP postures ($F_{1,24} = 22.24$, p < 0.05). The COP surface was also increased in both groups when eyes were closed in the ML ($F_{1,24} = 16.89$, p < 0.05) and AP ($F_{1,24} = 12.18$, p < 0.05) postures. Nevertheless, no significant vision × group interaction was observed in the SKI condition, whatever the posture and variable considered.

DISCUSSION

The present study showed that in postural conditions close to those encountered during skiing (SKI condition), both REG and NAT skiers demonstrated similar postural performance,

since there was no significant difference in the COP surface between both groups in the STA, ML, and AP postures. However, in the REF condition, the COP surface was significantly greater for NAT subjects in the STA and ML postures and so REG skiers could be considered to have shown the best postural performance in these positions.¹¹ However, this effect was not observed in the AP posture. The results obtained in the REF condition are not in agreement with previous studies concerning expertise in sport and postural ability^{3, 6, 13} since they illustrate reduced postural performance as the level of competition increases. However, the results can be explained by considering the specificity of alpine skiing, which involves the necessary use of ski boots over most of the training period. As Schaff and Hauser⁷ demonstrated, very stiff ski boots as used by competition skiers act as an external ankle support which mechanically restricts ankle joint motion. The effects of such ankle immobilisation are similar to those induced by ankle braces, and it is known that restriction of ankle movement has a significant detrimental effect on postural control.^{14, 15} Hence, the inferior postural performance observed with NAT skiers in the REF condition may illustrate a long term effect of repetitive wearing of ski boots, which impairs postural performance by restricting the range of motion of the ankle-foot complex. REG skiers may be less affected by this long term effect since they spend less time training. This effect was not observed when instability concerned the sagittal plane (AP posture), most likely because ski boots, despite a limited range of angular motion in flexion and extension at the ankle, can be slightly moved along the antero/posterior axis into a leaning forward position.⁷ Since AP posture is mainly under the control of ankle dorsiflexors/plantarflexors,^{16, 17} this result suggests that ankle dorsiflexors/plantarflexors are not involved in postural adjustment, resulting in the inferior postural performance of NAT skiers. Still, one can hypothesise that the differences between REG and NAT skiers in the STA and ML postures in the REF condition arise from the action of ankle invertors/evertors, which are mainly involved in postural control in the case of medio/lateral instability and together with ankle dorsiflexors/plantarflexors control stable posture.^{16, 18}

Moreover, the present study is unable to confirm a relationship between the contribution of vision in postural control and the expertise level in alpine skiing. Indeed, our results revealed no interaction between the expertise level and visual condition factors. This finding contrasts with that of Paillard *et al*⁶ and suggests, in agreement with Perrin *et al*,⁴

What is already known on this topic

Studies on performance factors in alpine skiing have mainly focused on physiology, but no study has analysed the postural performance of alpine skiers, even though alpine skiing is a sport which requires fine postural control.

that such a relationship is specific to disciplines characterised by a strong sensorimotor dominance of vision. Nevertheless, future studies are needed to validate such a hypothesis.

CONCLUSION

This study shows that NAT skiers did not present better postural performance than REG skiers. More surprisingly, NAT skiers displayed postural performance inferior to that of the REG skiers in the condition of standing posture (that is, without ski boots). According to McGuine *et al.*,¹⁹ individuals with decreased postural performance are believed to be more susceptible to ankle injury than those with finer postural control. Hence, high level skiers should benefit from specific training aimed at improving postural ability in order to prevent ankle injury.

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What this study adds

The present study shows that skiers at the highest level of competition presented inferior postural performance compared to lower level skiers when standing without ski boots. This result illustrates a long term effect of repetitive wearing of ski boots which impairs the postural performance of high level skiers.

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