

# DIFERENCIAS EN EL PATRÓN DE LAS LESIONES DE SURF DE NIEVE Y DE ESQUÍ: ANÁLISIS DE 9.147 VÍCTIMAS DURANTE CINCO TEMPORADAS

## DIFFERENCES IN THE PATTERN OF INJURIES BETWEEN SNOWBOARDING AND ALPINE SKIING: AN ANALYSIS OF 9,147 CASUALTIES DURING FIVE SEASONS

Enric Subirats<sup>1-3</sup>

Iñigo Soteras<sup>1,2</sup>

Gemma Subirats<sup>3,4</sup>

Sixtina Perarnau<sup>2,5</sup>

Franzina Riu<sup>1,2</sup>

Xavier Caralt<sup>2</sup>

<sup>1</sup>Service of Internal Medicine, Hospital Transfronterizo de Puigcerdà, Girona, Spain.

<sup>2</sup>Masella Medical Center, Girona, Spain.

<sup>3</sup>Department of Medical Sciences, Faculty of Medicine, University of Girona, Girona, Spain.

<sup>4</sup>Spanish National Ski Mountaineering Team.

<sup>5</sup>Emergency Department, Hospital de Vilafranca, Vilafranca del Penedés, Barcelona, Spain

### RESUMEN

**Objeto:** El objeto de este estudio es evaluar si la práctica del surf de nieve está asociada con un patrón diferente de lesiones, en comparación con la práctica del esquí alpino.

**Métodos:** Fueron analizadas todas las fichas de asistencia médica de los accidentados atendidos en el Centro Médico de la estación de esquí de Masella, durante cinco temporadas (2003-2008). Los grupos de surf de nieve y esquí alpino se compararon utilizando la prueba de chi-cuadrado o el test de Fischer para las variables categóricas y la prueba de t de Student o la prueba de Mann-Whitney para variables continuas. El análisis de varianza (ANOVA) se utilizó para la comparación de más de dos grupos. Cuando las variables no cumplían los supuestos de normalidad, se aplicó la prueba de Kruskal-Wallis se aplicó. La significación estadística se fijó en  $P < 0.05$ .

**Resultados:** Durante este período, fueron atendidas 9.147 víctimas (6.101 fueron esquiadores y 2.789 eran practicantes de surf de nieve). En comparación con los practicantes de esquí alpino, entre los accidentados durante la práctica de surf de nieve se observó que había un mayor número de principiantes (49,5 vs 41,5%), el uso del casco protector era menor (37,8% vs 44,9%), tenían menos heridas incisas y contusas (5,8 % vs 8,5%), menos lesiones de las extremidades inferiores (21,2% vs 47,4%), menos lesiones del dedo pulgar (3,2% vs 7,8%), y menos esguinces de rodilla (2,8% vs 14,7%). Por otra parte, presentaban un mayor porcentaje de fracturas óseas (18,6% vs 6,7%), de lesiones de extremidades superiores (57% vs 29,2%), de lesiones de muñeca en general (16,8% vs 2,5%), de fracturas distales de radio (12,3% vs 1,6%), de luxaciones de hombro (2,9% vs 1,6%), de fracturas de clavícula (2,4% vs 1,4%), y de lesiones del tronco (2,8% vs 2%). Todas estas comparaciones fueron estadísticamente significativas ( $P < 0.05$ ).

**Conclusión:** Los resultados de este trabajo demuestran que el surf de nieve tiene un patrón de lesiones distinto del que se observa en la práctica del esquí alpino, el conocimiento de las cuales puede influir en la prevención de accidentes de surf de nieve. Las estrategias propuestas para reducir las lesiones consisten en una revisión de la metodología de aprendizaje y entrenamiento, el uso rutinario del casco y la evaluación de los protectores de espalda para adaptarlos a los deportes de nieve.

**Palabras clave:** (MeSH terms): Lesiones de esquí. Deportes de nieve. Heridas y lesiones.

### SUMMARY

**Purpose:** The purpose of this study was to assess whether the practice of snowboarding is associated with a different pattern of injuries as compared with alpine skiing.

**Methods:** All consecutive patients with snow sports injuries attended at the Medical Center of Masella ski resort, during five ski seasons (2003–2008) were analyzed. A comparison was made of the groups of alpine skiers and snowboarders, using the chi-square ( $\chi^2$ ) test or the Fisher's exact test for categorical variables, and the Student's t test or the Mann-Whitney U test for continuous variables. The analysis of variance (ANOVA) was used for the comparison of more than two groups. When variables did not fulfill assumptions of normality, the Kruskal-Wallis test was applied. Statistical significance was set at  $P < 0.05$ .

**Results:** During this period, a total of 9,147 accident victims were attended (6,101 were alpine skiers and 2,789 were snowboarders). When injured snowboarders were compared with injured alpine skiers, it was noted that the percentage of beginners was larger (49.5% vs 41.5%) and snowboarders were less likely to use helmet (37.8% vs 44.9%), to have lacerations (5.8% vs 8.5%), to have lower extremity injuries (21.2% vs 47.4%), to have thumb lesions (3.2% vs 7.8%), and to have knee sprains (2.8% vs 14.7%). In addition snowboarding was associated with higher percentages of bone fractures (18.6% vs 6.7%), upper extremity injuries (57% vs 29.2%), wrist injuries in general (16.8% vs 2.5%), distal radius fractures (12.3% vs 1.6%), shoulder dislocations (2.9% vs 1.6%), clavicle fractures (2.4% vs 1.4%), and trunk injuries (2.8% vs 2%). All these comparisons were statistically significant ( $P < 0.05$ ).

**Conclusion:** This study show that snowboarding has a different pattern of injuries seen in alpine skiing, the knowledge of which could influence snowboarder accident prevention. Strategies for prevention consist of training courses, the routine use of helmets, and the evaluation of back protectors in order to adapt to snow sports.

**Key words:** (MeSH terms): Skiing/injuries. Snow Sports. Wounds and Injuries.

### CORRESPONDENCIA:

Enric Subirats  
Passeig del Bosquet 7, E-17520 Puigcerdà, Girona, Spain.  
E-mail: esubirats@telefonica.net

**Aceptado:** 04.10.2010 / Original n° 580

## INTRODUCTION

Snowboarding continues to gain in popularity with an increasing number of participants of varying ages and ski levels. Despite common resorts are being used, snowboarding and alpine skiing use distinctive equipment and techniques to descend down slopes. Snowboarders use their arms to balance and the shifts in weight cause the board to turn, slow down or stop; moreover, the majority of snowboards do not have a releasable binding system and both feet are fixed. Although there is a great deal of information describing ski injuries, data assessing snowboarding injuries as compared with skiing injuries in large study populations are limited<sup>1,7, 9,10,16,20,23</sup>.

Therefore, to further provide epidemiological data, injury pattern and clinical features of injuries related to alpine skiing and snowboarding, the database of all casualties treated at the Masella ski resort medical center in the Spanish Pyrenees over a 5-year winter season was reviewed. The aim of this retrospective study was to assess whether snowboarding is associated with a different pattern of injuries as compared with alpine skiing. The knowledge gained through the study could influence snowboarder education, equipment design and accident prevention.

## MATERIAL AND METHODS

The Alp 2500 (Masella-La Molina) ski resort is located in the Spanish Autonomous Community of Catalonia in the Oriental Pyrenean Mountains (altitude 1,600–2,535), this being the second biggest ski resort in the Spanish Pyrenees. The resort is immediately to the south east of Andorra and 175 kilometres from Barcelona. The skiable area includes 115 slopes (133 km), with 33 lifts (with a capacity to transport 40,880 skiers per hour), and more than 500 snow cannons. The Medical Service of the ski resort assists all skiers and snowboarders injured in its domains. This service consists of a general doctor trained in traumatology and vital support, a nurse and a team of first aid qualified pisters-lifeguards.

Data on each casualty are entered in a database, which includes the following salient items: demographics (age, gender), perceived ski level (classified as beginner, intermediate and expert), history of skiing accidents, type of skiing (alpine or downhill, snowboarding, snowblading), circumstances and time of the accident, hours spent skiing, mechanism of injury, site and severity of injury, use of helmet, use of renal equipment, and discharge destination.

For the purpose of this study, data from 2003–2004 to 2007–2008 winter seasons were collected. Because many injured patients attended firstly at medical center of the ski resort are transferred and treated at the Hospital of Puigcerdà (an acute-care 30-bed community hospital belonging to the Catalan Health System, with a reference population of approximately 30,000 inhabitants), which is the closest hospital to the ski station, the hospital database for these years was also reviewed. The Institutional Review Board approved the study. This study has been performed in accordance with the ethical standards<sup>13</sup>.

*Statistical analysis:* A comparison was made of the groups of alpine skiers and snowboarders, using the chi-square ( $\chi^2$ ) test or the Fisher's exact test for categorical variables, and the Student's *t* test or the Mann-Whitney U test for continuous variables. The analysis of variance (ANOVA) was used for the comparison of more than two groups. When variables did not fulfill assumptions of normality, the Kruskal-Wallis test was applied. Statistical significance was set at  $P < 0.05$ .

Institutional Review Board approval and written consent were obtained in June 5, 2002.

## RESULTS

During these five seasons, 9,147 accident victims were attended (41% women, median age 21.3 years [range 5–79]), which accounted for 4.6 injuries for every 1000 skiers per day, based on all purchased lift tickets. A total of 3,364 subjects (36.8%) were evacuated by ski-patrols, which

accounted for 1.76 evacuated accidents per 1000 skiers per day. The remaining 5,783 injured skiers reached the medical center by their own means. Accidents involved alpine ski in 6,101 cases (66.7%), snowboarding in 2,789 (30.5%), snowblading in 219 (2.4%) and telemark skiing or waking in 38 (0.4%). Forty-four percent of skiers were beginners, 49.6% rented ski equipment and 39.3% wore a helmet. The most common diagnoses were contusions (54.5%) followed by sprains (21%), fractures (7.8%), lacerations (7.8%) and dislocations (3.1%). The lower extremities were involved in 37.6% of the accidents ( $n = 3,439$ ) and the upper extremities in 36.6% ( $n = 3,347$ ). The most frequent injuries in the lower and upper extremities were knee injuries and the skier's thumb, respectively.

Potentially severe injuries occurred in 12.9% of victims, involving the head in 3.7% of the cases, spine in 3.8%, thorax in 2.3% and abdomen in 0.8%. Urgent hospitalization was required in 1.7% of the casualties (surgical operation in 0.9%). One alpine skier and one snowboarder

with blunt head trauma died, with an overall mortality rate of 0.02%. None of these skiers wore a helmet.

Snowboarders as compared with alpine skiers were more frequently men (74.3% vs 51.6%,  $P < 0.01$ ) and beginners (49.5% vs 41.5%,  $P < 0.01$ ) and used a helmet less frequently (37.8% vs 44.9%,  $P < 0.01$ ). The median age, however, was similar 21.7 vs 20.3 years. On the other hand, as shown in Table 1, snowboarders had a smaller number of lacerations and smaller number of injuries of lower extremities ( $P < 0.05$ ), although the number of fractures was greater ( $P < 0.05$ ). In addition, a greater number of upper extremities injuries (wrist injuries, shoulder dislocations and clavicle fractures) in snowboarders was found ( $P < 0.05$ ), but the skier's thumb was more common in alpine skiers ( $P < 0.01$ ). Regarding potentially severe injuries, similar percentages of head, spine and abdominal injuries were observed in both study groups, but thorax injuries were significantly more frequent among snowboarders.

**TABLE 1.**  
Differences in the  
distribution of  
injuries in alpine  
skiers and  
snowboarders

	Alpine skiers (n = 6,101)	Snowboarders (n = 2,789)	P value
Lacerations	518 (8.5)	162 (5.8)	< 0.05
Fractures	409 (6.7)	519 (18.6)	< 0.05
Lower extremity	2892 (47.4)	591 (21.2)	< 0.05
Ankle injuries	134 (2.2)	61 (2.2)	NS
Knee injuries	897 (14.7)	78 (2.8)	< 0.05
Femoral or hip fracture	18 (0.3)	6 (0.2)	NS
Upper extremity	1781 (29.2)	1590 (57)	< 0.05
Skier's thumb	476 (7.8)	89 (3.2)	< 0.01
Wrist sprain	55 (0.9)	125 (4.5)	< 0.05
Wrist fracture	98 (1.6)	343 (12.3)	< 0.05
Shoulder dislocation	98 (1.6)	81 (2.9)	< 0.05
Other sites			
Head	244 (4)	95 (3.4)	NS
Spine	214 (3.5)	112 (4)	NS
Thorax	122 (2)	78 (2.8)	< 0.05
Abdominal	43 (0.7)	28 (1)	NS
Potentially severe injuries	781 (12.8)	388 (13.9)	NS

Percentages in parenthesis.

## DISCUSSION

To our knowledge, the present study reports the largest series addressing the different injury pattern between snowboarding and alpine skiing in one single large resort. In this study, the injury rate per 1000 skier-days was 4.6 and remained constant during the five winter seasons. Other authors have found injury rates of 2 to 10 injuries per 1000 skier-days for alpine skiing, 1 to 6 injuries per 1000 snowboarding days, and 10.7 injuries per 1000 skier days for telemark skiing<sup>21,24</sup>. The sale of lift passes was used to calculate injuries per skiers days, although it has been recognized that is difficult to estimate the real use of each pass. The characteristic profile of snowboarders, --young men and beginners--, was also found in our series (74.3% were men, with a median age of 21.7 years, and 49.5% were beginners). In other studies, about 50% and 58% of the injured snowboarders are beginners<sup>3,17</sup>. Beginner snowboarders are at the highest risk group especially those trying snowboarding for the very first time.

A significantly lower rate of helmet use was observed in the victims of snowboarding accidents as compared with alpine skiers. Moreover, no helmets were worn in the two cases of fatality. In the study of Sacco, *et al*<sup>5</sup> that included 25 ski-related deaths over a 6.5 year period in Vermont, USA, helmets were not worn by those sustaining

head injuries or fatalities. In a case-control study at 8 major Norwegian alpine resorts during the 2002 winter season, involving 3,277 injured skiers and snowboarders and 2,992 non-injured controls, using a helmet was associated with 60% reduction in the risk for head injury<sup>23</sup>. In our study, like others<sup>2</sup>, there were no differences in the rate of head injury between snowboarding and alpine skiing, although injuries to the thorax were more frequent in snowboarders.

Injury patterns in snowboarding and alpine ski were significantly different. Upper extremity injuries were more frequent in snowboarders (57% vs 29%), whereas lower extremity injuries were more common in skiers (47% vs 21%). The incidence of fractures in snowboarders was 18.6% compared with 6.7% to skiers. The reasons for these differences can be explained by the design of the equipment and the way it is used. In other studies, the incidence of fractures in snowboarders is higher, ranging between 28% and 56%<sup>3,4,8</sup>. The lack of areas dedicated to acrobatic jumps in our ski resort may be one of the reasons for a lower incidence of snowboarding-associated fractures in our series.

The percentages of injuries in snowboarding reported in different studies published in the literature are summarized in Table 2. In our experien-

First author (reference)	No. cases	Fractures	Lower extremity	Ankle	Knee	Upper extremity	Skier's thumb	Wrist fracture	Wrist injury	Shoulder dislocation
Machold (16)	152								32	
Sacco (5)	40		38			24				
Pigozzi (17)	106					45				
Oberthaler (18)	437	31	34		16	51		10.5	27	
Abu-Laban (7)	132		49	20	14	32	1	10		1
Chow (19)	355		16	3.1	2.8	58			20.3	
Davidson (14)	931		38	16	17	40			19.9	
Made (20)	568					54		20	35	
Pino (21)	110		52.7	26.4	11.8	29.1			7.3	
Ganong (22)	415		43	16.9	18.1	44			23.9	
Bladin (11)	276		57	23	23	30				
Calle (23)	487		34.1	12.5	25	38			19.9	
Warne (8)	47			21	17					
Subirats (present study)	2,789		18.6	21.2	2.2	2.8	57	3.2	12.3	16.8 2.9

**TABLE 2.** Percentages of injuries in snowboarding reported in different published series

ce, the rate of ankle and knee injuries of 2.2% and 2.8%, respectively, are consistent with the study of Chow, *et al.*<sup>6</sup> but lower than rates reported in most studies<sup>1,3,5,6,8,11,12,20,24</sup>, ranging between 12.5% and 26.4% for ankle injuries and between 11.8% and 25% for knee injuries. Because both feet are fixed in non-releasable bindings, knees are not as frequently or as severely injured in snowboarding than in alpine skiing. The fixed binding of both feet to a snowboard probably decreases the possibility of valgus stress on the knee, a common cause of medial collateral ligament injury in alpine skiing. The total proportion of injuries of lower extremities in our series was 21.2%, which is somewhat lower than ranges between 34% and 57% found in other studies<sup>1,3,5,6,8,11,12,18,20,22</sup>, but higher than 16% reported by Chow, *et al.*<sup>6</sup>.

In agreement with different studies we have shown that snowboarding has a distinctly different pattern of injuries to alpine skiing. Compared to skiers, snowboarders are far more likely to sustain an injury to the upper limb and less likely to injure the lower limb<sup>7</sup>. In our study we found 57% of the injuries were of the upper extremities, which is similar to percentages between 51% and 58% reported in other series in which a large number of snowboarders were evaluated<sup>6,14,18</sup>. Snowboarders do frequently fall on to the outstretched hand after being catapulted forward or falling backwards while both legs are fixed to the board. This results in a high proportion of injuries to the upper extremities. We found a 12.3% rate of wrist fractures and 16.8% of wrist sprains, which are consistent with data reported in other studies<sup>1,3,8,5,6,11,15,18,20</sup>. Wearing wrist guards reduces the risk of wrist injury and may be recommended as part of a standard equipment, particularly for a beginner snowboard. A matched case-control study conducted at 19 ski areas in Quebec, Canada (1,066 cases and 970 controls) demonstrated that the use of wrist guards reduced the risk of hand, wrist, and forearm injuries by 85% (adjusted odds ratio = 0.15, 95% confidence interval 0.05–0.45)<sup>12</sup>. As can be expected because snowboarders do not use poles, injury to the ulnar collateral ligament (skier's thumb) was significantly more frequent among alpine skiers.

In our series, 13% of alpine skiers and 14% snowboarders presented potentially severe injuries, a percentage to the 15% found in the study of by Oberthaler, *et al.*<sup>18</sup> In addition, the frequency of spine injuries in our series (3.5% and 4% in alpine skiers and snowboarders, respectively) is consistent with previously reported data<sup>22</sup>.

This study has shown that the fast-growing sport of snowboarding has a notable different injury pattern from that in alpine skiing, including higher rates of upper extremities injuries, particularly, wrist fractures and a lower incidence of thumb injury. It was somewhat surprising to find a lower rate of ankle injury given that non-release bindings and soft boots have been shown to contribute to the higher incidence of ankle injuries in snowboarding<sup>1,20</sup>. The present results should be interpreted taking into account some limitations of the study, including the retrospective design and the lack of a control group. However, descriptive statistics based on a large population of alpine skiers and snowboarders, to our knowledge the largest reported so far, adds evidence of a different set of injuries that the sport of snowboarding brings as compared with alpine skiing.

Pattern of injuries from skiing and snowboarding accidents in the Spanish Pyrenees resemble those reported in other ski resorts of the world. Emphasis on training courses from a certified instructor for those who are considering taking up the sport of snowboarding could significantly lower their risk of trauma<sup>26</sup>. Proper physical training as appropriate exercises for the upper body, stationary and dynamic balance training drills and incorporate jump exercises with plyometric boxes

can strengthen joints, improve balance, and better prepare the body for the physical demands of this sport. Certain changes that could affect the reduction of injuries in the snowboard training and learning process are: proper warm up before exercise, slow first descent, resting regularly, eating frequently to avoid hypoglycemia, stretching at the end of activity and, in case of fall, learning how to roll forward as you fall, as done in judo<sup>27</sup>.

Nevertheless, other strategies for prevention are also needed. The routine use of helmets is associated with up to a 60% reduction in the risk of head injuries and<sup>28</sup>, and the use of back protectors may reduce spinal injuries<sup>29</sup>, although there is a mismatch between the capabilities of current back protectors to prevent spinal injury in snowboarding and the expectations users have of these protectors<sup>30</sup>.

## ACKNOWLEDGMENTS

This work was been presented at XXX FIMS World Congress of Sports Medicine. The au-

thors thank Mr. Santi Cirera, Mrs. Maria Arnela, Mrs. Eulalia Escolà, Mr. Josep Cozar, Mrs. Elisabet García, Mrs. Elisenda Vilaró, members of the Ski Injuries Study Group; ski patrol staff, medical, nursing, administrative and directive staff of Masella Medical Centre for their collaboration in this study; Mrs. Noemi Olona, MD, for data analysis; Mr. Josep Taberner and Mrs. Helen Macbeth (Oxford University) for reviewing the manuscript and Marta Pulido, MD, for editing the manuscript and editorial assistance.

**Conflict of interest:** None to be declared.

## B I B L I O G R A F Í A

1. **Abu-Laban RB.** Snowboarding injuries: an analysis and comparison with alpine skiing injuries. *CMAJ* 1991;145:1097-1103
2. **Ackery A, Hagel BE, Providenza C, Tator Ch.** An international review of head and spinal cord injuries in alpine skiing and snowboarding. *Inj Prev* 2007;13:368-375.
3. **Bladin C, Giddings P, Robinson M.** Australian snowboard injury data base study. A four-year prospective study. *Am J Sports Med* 1993;21:701-704.
4. **Bladin C, McCrory P.** Snowboarding injuries, an overview. *Sports Med* 1995;19:358-364.
5. **Calle SC; Evans JT.** Snowboarding trauma. *J Pediatr Surg* 1995;30:791-794.
6. **Chow TK, Corbett SW, Farstad DJ.** Spectrum of injuries from snowboarding. *J Trauma* 1996;41:321-325.
7. **Corra S, Conci A, Conforti G, Sacco G, De Giorgi F.** Skiing and snowboarding injuries and their impact on the emergency care system in South Tyrol: a retrospective analysis for the winter season 2001--2002. *Inj Control Saf Promot* 2004;11:281-285.
8. **Davidson TM, Laliotic AT.** Snowboarding injuries, a four-year study with comparison with alpine ski injuries. *Western J Med* 1996;164:231-237.
9. **Franz T, Hasler RM, Benneker L, Zimmermann H, Siebenrock KA, Exadaktylos AK.** Severe spinal injuries in alpine skiing and snowboarding: a 6-year review of a tertiary trauma centre for the Bernese Alps ski resorts, Switzerland. *Br J Sports Med* 2008;42:55-58.
10. **Fukuda O, Takaba M, Saito T, Endo S.** Head injuries in snowboarders compared with head injuries in skiers. A prospective analysis of 1076 patients from 1994 to 1999 in Niigata, Japan. *Am J Sports Med* 2001;29:437-440.
11. **Ganong RB, Heneveld EH, Beranek SR, Fry P.** Snowboarding injuries: a report of 415 patients. *Physician Sports Med* 1992;20:114-122.

12. Hagel B, Pless IB, Goulet C. The effect of wrist guard use on upper-extremity injuries in snowboarders. *Am J Epidemiol* 2005;162:149-156.
13. Harriss DJ, Atkinson G. International Journal of Sports Medicine - ethical standards in sport and exercise science research. *Int J Sports Med.* 2009;30:701-702
14. Machold W, Kwasny O, Eisenhardt P, Kolonja A, Bauer E, Lehr S, Mayr W, Fuchs M. Reduction of severe wrist injuries in snowboarding by an optimized wrist protection device: a prospective randomized trial. *J Trauma* 2002; 52: 517-520
15. Made C, Elmqvist LG. A 10-year study of snowboard injuries in Lapland Sweden. *Scand J Med Sci Sports* 2004;14:128-133.
16. McBeth PB, Ball CG, Mulloy RH, Kirkpatrick AV. Alpine ski and snowboarding traumatic injuries: incidence, injury patterns, and risk factors for 10 years. *Am J Surg* 2009;197:560-564.
17. Müller R, Brügger O, Mathys R, Stüssi E. Snowboarding accidents. *Sportverletz Sportschaden* 2000;14:121-127.
18. Oberthaler G, Primavera C, Niederweiser B, Hertz H. Snowboarding accidents 1991 to 1994 --an analysis. *Sportverletz Sportschaden* 1995;9:118-22
19. Pigozzi F, Santori N, Di Salvo V, Parisi A, De Luigi L. Snowboard traumatology: an epidemiological study. *Orthopedics* 1997;20:505-509.
20. Pino EC, Colville MR. Snowboard injuries. *Am J Sports Med* 1989;17:778-781.
21. Rønning R, Gerner T, Engebretsen L. Risk of injury during alpine and telemark skiing and snowboarding. The equipment-specific distance-correlated injury index. *Am J Sports Med* 2000;28:506-508.
22. Sacco DE, Sartorelli DH, Vane DW. Evaluation of alpine skiing and snowboarding injury in a northeastern state. *J Trauma* 1998;44:654-659.
23. Sulheim S, Holme I, Ekeland A, Bahr R. Helmet use and risk of head injuries in alpine skiers and snowboarders. *JAMA* 2006;295:919-924.
24. Warme WJ, Feagin JA Jr, King P, Lambert KL, Cunningham RR. Ski injury statistics, 1982 to 1993, Jackson Hole Ski Resort. *Am J Sports Med* 1995;23:597-600.
25. Wasden CC, McIntosh SE, Keith DS, McCowan C. An analysis of skiing and snowboarding injuries on Utah slopes. *J Trauma* 2009;67:1022-1026
26. Associació Catalana per a la Formació en Esports de Neu. Metodologia de l'ensenyament i de l'entrenament. Barcelona 2009;21-153.
27. Leopardi-Anderson K. Ski conditioning 6 - 8 week progressive training program: exercise that can be done with minimal equipment. *Performance Training Journal* 2003;2:22-27.
28. Michael D, Cusimano MD, Kwok J. Skiers, Snowboarders, and Safety Helmets. *JAMA* 2010;303:661-662.
29. Michel FI, Schmittb KU, Liechti B, Stämpfli R, Brühwiler P. Functionality of back protectors in snow sports concerning safety requirements. *Procedia Engineering* 2010;2:2869-2874
30. Schmitt KU, Liechti B, Michel FI, Stämpfli R, Brühwiler PA. Are current back protectors suitable to prevent spinal injury in recreational snowboarders? *Br J Sports Med* 2010;44:822-826.