

Robert Ropret

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Review paper

University of Belgrade, Faculty of Sports and Physical Education, Serbia

INJURIES IN SKIING AND SNOWBOARDING: EPIDEMIOLOGY AND RISK FACTORS AS A BASIS FOR PREVENTION MEASURES

Abstract

This paper deals with the subject of injury in alpine skiing and snowboarding and the aim was to define the characteristics of injuries and the risk factors as the basis for establishing preventive measures. The types of injuries and risk factors were analyzed by examining previous papers. During the last thirty years, the number of injuries has generally decreased by 50-70%. The changes were recorded in the types of injuries, and the number of certain injuries increased. It was found that there was a mutual difference in the number and structure of the injuries of skiers and snowboarders. Injuries can be classified topologically and according to risk factors. The risk factors may be manifold: the characteristics of the equipment, the characteristics of the trail and snow surface, protective equipment, age, gender, physical fitness, risky behaviours, time of day, skiing discipline, climate factors, the presence of other skiers and others. By the analysis of these factors it was concluded that there were three entities in the implementation of security measures: the state that stipulates laws (relevant ministries), owners or organizers who provide services in skiing (ski centres, ski services, ski schools, clubs) and skiers and snowboarders themselves.

Key words: RISK FACTORS / PROTECTIVE EQUIPMENT / SECURITY / RESPONSIBILITY

INTRODUCTION

Skiing is a widespread sports activity with approximately 200 million participants worldwide. The best known and the most widespread forms are alpine and snowboard skiing. Today's skiing, in both of these forms, is practiced as a recreational or competitive, on groomed ski trails, off-piste, and from not long ago in arranged snow parks. Snow parks contain various types of ski jumps and hurdles for skiing with acrobatic elements (jumps, spins, movements over hurdles, etc.) Skiing, in all professional and legal documents, is treated as a sport with an increased risk of injury. Despite the increased risk, in skiing injuries are much rarer than in some other sports (NSAA, 2013). External and internal factors can affect injuries in skiing. Staying on the increased alti-

tude, increased physical activity, climatic factors, the use of specific equipment and resources for vertical transport, the need for a certain level of motor abilities, skills and experience, increased movement speed on non-standard surfaces surrounded by other skiers create conditions for a large number of risks which can lead to injuries. Despite the efforts of researchers to further define the role of risk factors to injuries, it proved to be a complex problem. Some of the mentioned risk factors were not possible or were very difficult to estimate. Besides the statistical data on the type and number of injuries, it was difficult to make a deeper and more objective analysis because the data on injury factors are usually not known or precisely defined (skiing knowledge of the injured, conditions

of injuries, conditions of trails, weather conditions, etc.). The lack of previous studies is that the results were based on the data that were not completely realistic. The reasons are multiple. Some injuries (especially minor ones) are often not reported. Part of the injuries is reported to the Mountain Rescue Service (MRS), and some only to health care facilities within a ski centre. Some injuries are registered subsequently in various institutions outside the resort. Also, one of the drawbacks of the system is that there is no clear definition of injuries. What are injuries? Are they bruises, scratches or are they called injuries only when medical help is required? MRS reports on injuries do not include medical examinations and accurate diagnoses. MRS and medical institutions' reports protocols do not include information about the circumstances of injury. Therefore, it is necessary to accurately define risk factors, measures to prevent such risks as well as responsible institutions and individuals who would implement security measures.

The aim was, by going through previous studies, to observe the main causes/risks and mechanisms causing injuries, as well as the types and degrees of injuries. Based on the gathered data, it is possible to draw conclusions about the possible measures that can be taken by all participants, in order to reduce the number of injuries.

METHOD

The study included an overview of the papers databases *PubMed*, *Medline* and *Google* search engine. The papers were selected by keywords combining: *skiing*, *snowboard*, *injury*, *safety*, *prevention*, *protective guard*. The reviewed papers published in the period from July 1995 to July 2014 were selected in accordance with the subject.

INJURIES EPIDEMIOLOGY

In actual practice, the number of injuries in recreational skiing is calculated in two ways: 1) the number of injuries per thousand skiing days ($NITD = \text{no. of injuries} / \text{number of ski days} \times 1,000$) or, 2) the average number of days in relation to the injury ($ANDI = \text{number of ski days} / \text{no. of injuries}$). The number of ski days is calculated based on the number of skiers of

all ages, who skied during the day/week/month/season in a particular ski resort. The number of ski days is calculated based on the number of purchased ski passes for a number of days. The weakness of this approach is that it is calculated that each buyer of a ski pass skied every day, throughout the working hours of ski lifts. The procedure does not include seasonal ski tickets and the staff. Comparing the data on injuries over the past 50-60 years when skiing intensively developed, it is possible to detect changes which are significant for the further improvement of the security measures in skiing. According to some studies, the number of injuries, in various aspects, significantly decreased. During the last 30 years, the number of injuries has decreased by 50-70% depending on the type of injury (NSAA, 2013). In the period before 1970, the number of injuries ranged from around 5 to 8 injuries per 1,000 ski days. Over the next decade, that number was reduced to 3 to 6 per 1,000 ski days, and in the period from 1990 - 2000, the number of injuries stagnated ranging from 2 to 3 per 1,000 skiing days (Koehle, Lloyd-Smith, & Taunton, 2002). In an analysis from 2010 the number of injuries was 2.5 per 1,000 ski days (NSAA, 2013). The decreasing trend was not equally represented in all types of injuries. While the number of leg injuries decreased by 60%, the number of injuries of arms and shoulders increased and made 33% of all injuries. The ratio of injuries between the lower and the upper extremities in the period 1982-1993, from 4: 1 changed to 2: 1, which indicates a significant reduction in injuries of the lower but not the upper extremities (McCall & Safran, 2009). Within the structure of leg injuries, injuries of the lower leg and ankle were reduced by 70-90% while the number of knee injuries increased by 170-280% in the period 1970 to 1990 (St-Onge, Chevalier, Hagemeister, Van de Putte, & De Guise, 2004). The average number of serious injuries (paralysis, traumatic brain injuries, spinal cord injuries) was not significantly changed during this period and was 0.86 per million skiers. Fatal skiing injuries are rare and occurred, according to different authors, ranging from 0.5 to 1.9 cases per 1 million of ski days (Corra, Conci, Conforti, Sacco, & De Giorgi, 2004; Hiang et al., 2004). In the past 10 years, in the ski resorts in America, among 11.3 million skiers and snowboarders (57.6 million ski days) about 40 deaths per year were recorded (0.64 per million skiers) (Shea, Archibald-Seiffer, Murdock, Grimm, Jacobs, Willick, &

Van Houten, 2014). It is obvious that the structure of injuries over the years has changed significantly and that the general trend is a decrease in their number except for fatal injuries. These results can be attributed, primarily, to the advances in technology of the development and the characteristics of equipment for skiing, ski trails arrangement and taking measures for improving safety.

Types of injuries

Injuries in skiing can be viewed from several aspects: topological (head injuries, spinal cord injuries, injuries of upper and lower extremities); or according to risk factors: gender, age, skiing knowledge, equipment, trail conditions, physical fitness, etc.

Head and shoulders injuries

While the number of injuries of the lower extremities decreased, the number of injuries of arms and shoulders grew. The ratio of injuries of arms, shoulders and neck in relation to the legs, in the nineties was 35% to 55%, whereas in the early 2000s the ratio changed to 55% to 41% (Idzikowski, Janes, & Abbott, 2000; Meyers, Laurent, Higgins, & Skelly, 2007; McCall et al., 2009). In comparison to all the others, shoulder injuries constituted 11% (Kocher & Feagin, 1996; McCall et al., 2009), wrist injuries 21-29% (Idzikowski et al., 2000), the ulnar collateral ligament (UCL), also known as ski thumb 33%, which was the most common upper extremity injury. Injuries of arms and shoulders were twice as common in snowboarders (45%) than in skiers (22%) (Idzikowski et al., 2000). The most common causes of shoulder injuries were falls (93.9%), collisions (2.8%), incorrect use of the rod (2.3%) and collisions with objects off-piste (1%) and falls after jumps for snowboarders. According to the type, the most common injuries were shoulder rotator cuff ruptures (24%), glenohumeral dislocations and subluxations (22%), acromioclavicular separations (20%) and clavicular fractures (10.9%) (Kocher et al., 1996). Shoulder injuries were caused by one of three mechanisms: the load on the spread arm during fall, a direct hit to the shoulder or an eccentric load when resisting abduction. Younger than 30 years, advanced and good skiers (91%) were more prone to shoulder injuries compared to beginners (39%). The number of injuries of arms and shoulders in children was 23-37% of all injuries and the most common were in the age of 6-15 years.

Leg injuries

In the structure of leg injuries the most common were injuries of the knee and lower leg and less common of thigh and hips. The number of leg injuries in the last thirty years has decreased by 60% and the number of injuries of the lower leg and ankle by 70-90%. During the same period the number of knee injuries has increased by 170-280% (Deibert, Aronsson, & Johnson, 1998; St-Onge et al., 2004). Knee injuries (dislocations and ACL ruptures) represented 33% (NSAA) and 47.7% (Ruedl et al., 2011c) of all injuries in skiing. Left knee was more affected than the right one (Heneved, 2002). Causes of knee injuries, in 90% of cases, were the falls that were characterized by: external rotation of the knee (32.9%); internal rotation with hyperflexion 22.5%, hyperextension 19.0%, hyperextension with the pressure of a ski boot on the lower leg 7.8%. 2.02% of knee injuries were the consequences of a collision. There was no difference in the structure of knee injuries between children and adults. The trend of decreasing injuries of tibia and ankle joint can be attributed to the implementation of new boots which better protect the area of the ankle while the knee injuries can be linked to the functioning of bindings.

Head and spinal cord injuries

Head injuries were the least common and covered on average 11% of all injuries (Meyers et al., 2007; Xiang, Stallones, & Smith, 2004; Giovanis & Gompakis, 2011). Spinal cord injuries covered 13% (0.01 per 1,000 ski-days, 15 per one million skiers) and the injuries of peripheral nervous system less than 1% (Levi & Smith, 2000). Traumatic injuries of the head and neck were the most common causes of deaths and covered 8% of all injuries. In children and adolescents the percentage was higher and covered 11-20% of all injuries (Meyers et al., 2007). A longitudinal study, 1981-1994, determined a significant increase in the number of head injuries in adolescents from 5.7% to 8.9% of all injuries (Deibert et al., 1998). In Canada a relatively high percentage was determined - 17-22% of head and facial injuries in skiers aged 7-17 years (Cadman & Macnab, 1996). In Switzerland, during the period from 1984-1992, an increase from 12% to 19% in head injuries was recorded (Furrer, Erhart, & Frutiger, 1995). In the United States, in the period from 1993-1997 the percentage of head

injuries increased to 14%. Head injuries most commonly were the result of going off-piste (74% were the result of hitting the head in a snow surface, 13% collisions with fixed objects off-piste) while 10% were the consequences of collisions with other skiers. Falls in ski jumps were the cause of spinal cord injuries in 77% and head injuries in 30% of cases (Tarazi, Dvorak, & Wing, 1999). When it comes to the age of the injured, the percentage of head injuries was 42.2% of adults compared with 66.7% of children. Head injuries were more common among snowboarders (13%) than among skiers (8%). In the future it can be expected that, with the increase in the number of young people on skis in snow parks, the number of injuries of skiers will significantly come closer to the number of injuries in snowboarders in snow parks.

The differences in injuries between snowboarders and skiers

Snowboarders represent 26% of all ski slopes visitors. According to previous studies, there were indicators that pointed to some differences between the injuries of skiers and snowboarders. They were primarily the result of the different characteristics of equipment and different skiing techniques. The number of injuries among snowboarders was 2.5 times higher than among skiers. In the period from 1980 to the season 2010/11 the number of injuries in skiers decreased by 19.4% (from 3.1 to 2.5 injuries per 1,000 ski days). In snowboarding, that developed at the end of the 90s, the number of injuries decreased by 12.5% (from 6.9 to 6.1 injuries per 1,000 ski days). The number of injuries of arms and shoulders was double (McCall et al., 2009) and of the spinal cord four times higher in snowboarders compared to the alpine skiers (Tarazi et al., 1999). Snowboarders more frequently injured wrists, around 27% of all injuries, while skiers had only 4% of these injuries. The number of head injuries was twice higher in snowboarders (12%) than in skiers (6%). Knee injuries of skiers covered 33% of all injuries and the in snowboarders only 7% (Viola, Steadman, Mair, Briggs, & Sterett, 1999). The number of fatal injuries was somewhat higher among skiers than among snowboarders (0.75 compared to 0.53 per million skiers). Collisions with other skiers or snowboarders, as the cause of the injury, were relatively small and amounted to about

6.4% of all accidents. Only 1% of the injuries were the result of collisions of skiers and snowboarders, while 7.7% of injuries were due to collisions of two skiers and 2.6% were due to collisions of two snowboarders (Heneved, 2002). What is the reason for the difference in injuries? Snowboarders have legs tied to one board while skiers have significantly longer skis/levers on each foot which increases the intensity of the forces and loads on each leg individually. During falls, skiers, because of the possibility of an independent leg work and the use of rods, can increase the support and cushion the fall while snowboarders' hands or parts of the trunk are the only contact with the ground and suffer the greatest burden (spinal cord, head, shoulders). The increase in the number of individual injuries among snowboarders may be due to a significant increase in the number of snowboarders in relation to the increase in the number of skiers as well as the occurrence of new disciplines within the snowboarding like snow parks, skiing off-piste (*freeride*), etc.

RISK FACTORS

Causes of injuries in skiing and snowboarding can be various. By reviewing previous studies, it is possible to distinguish several divisions of risk factors. According to Urabe, Ochi, Onari, & Ikuta, 2002 and Burtscher et al., 2008 these were: the characteristics of snow surface, weight/complexity of the trail and weather conditions. According to Aschauer, Ritter, Resch, Thoeni, & Spatzenegger. (2007) these were the altitude, and the effect of temperature/cold. Giovanis et al. (2011) singled out: a) individual factors (age, gender, body height and weight); b) the method of preparation for skiing (the level of skiing knowledge, the quantity of skiing during the day and the year, the way of skiing organization: individual, group, with/without an instructor, previous warming up); c) physical condition; d) previous injuries. According to Erdmann, & Giovanis (1998) these could be the factors of a personal nature, coaching, equipment and clothing, weather, trail conditions, competition, while Meyers et al. (2007) considered the factors to be excessive fatigue, age, level of experience and inadequate and inappropriate equipment. According to Ilic, Ropret & Ilić (2010) the factors of injuries were more numerous (Table 1).

Table 1. External and Internal injuring factors (modified according to Ilić, Ropret & Ilić, 2010)

INTERNAL	EXTERNAL
Gender	Equipment
Age	Snow surface
Motor abilities	Altitude
Skills	Climate factors
Experience	Transportation means
Fatigue due to the increased physical activity	Presence of other skiers
Psychological conditions	Tasks on polygons/snow parks
Body characteristics	Safety measures of the organizer
	Instructor 's Methodic information

Gender

Previous studies pointed out that the number and structure of the injuries of women and men differed, and that gender had a significant role in injuries. In absolute amounts, the ratio of injuries between men and women was 3: 1 (Kocher et al., 1996) i.e. 74: 26% (Idzikowski et al., 2000). In snowboarders this ratio was similar - 70: 30%. Unfortunately, these numbers are not realistic indicators because the number of female skiers is lower than the number of male skiers. Women who are recreational skiers and also ski racers had a higher percentage of injuries (60-70%) of the knee joint than men (40-30%) (Burtscher et al., 2008; Ruedl, Linortner, Schranz, Fink, Schindelwig, Nachbauer & Burtscher, 2009, Ruedl, Fink, Schranz, Sommersacher, Nachbauer, & Burtscher 2011c; Shea et al., 2014). The most common causes of knee injuries were the falls (65% women, 35% men) or collisions (16% women, 83.3% men). The explanation may be that men, particularly adolescents, more often engage in risky behaviour than women.

Age

Children younger than 17 years make up a quarter of the ski population. The largest number of injuries with tragic outcome was noted in men at the age of later adolescence to the 30s, 14% of which were children and teenagers up to 17 years and 24.2% young people aged 18-24 (Xiang et al., 2004). The number of children under 10 and seniors over 50 years currently stands at about 16% of all skiers and their involvement in injuries is about 10%. In the United States in the season 2012/13, 18 deaths of skiers over

50 years were recorded, including two cases of over 80 years. As the number of children under the age of 10 and the elderly over 50 years is growing from year to year, we can expect an increased number of injuries in this age group. Children and adolescents are prone to injuries for many reasons. The development of bone and skeletal and muscular system is not complete, the coordinating ability may be impaired during the period of a rapid development, attention and concentration are not at the level of adults, the awareness of their abilities as well as the awareness of the responsibilities and consequences of risky behaviour are underdeveloped. This ability is acquired during development and especially during adolescence. From the onset of puberty until the early 20s, there is a time gap during which, because of the maturation of cognitive control, which regulates these impulses, young people are encouraged to activities that create excitement and risk-taking behaviour. When deciding to go down with greater speed, their power of assessment is „blurred” without the ability to accurately assess the risks and consequences. Here, their focus is on the awards, recognition and proving themselves in front of their friends instead on the consequences.

Physical fitness

Despite the absence of actual data, generally accepted view is that physical fitness helps to reduce the risk of injury - particularly muscular strength, which contributes to the stability and strength of the joints. The strength of the muscles in the knee region can significantly reduce the strain of the knee ligaments because by timely muscle activity the firmness of the joint increases up to 400% (Ettliger & Johnson,

1991). Recreational skiers usually come unprepared and unadapted to the altitude and increased physical effort. Wanting to utilize as much time on the snow they do not pay attention to fatigue. Also, due to an excess of free time they are often engaged in additional activities in the fitness and spa centres as well as evening entertainment. Hence, all amateurs are recommended a certain level of conditioning training (accent on leg and back muscles) as one of the prevention measures and also paying attention to fatigue during skiing.

Skiing knowledge

One of the factors, which largely correlates with injuries, is the skiing knowledge. In practice skiers are usually divided according to the knowledge of skiing into beginners, advanced and experts. Unfortunately, there are no clear criteria in this division, especially because the knowledge of skiing may include technical competency but also the experience in the reactions during high-risk situations. In skiers, 22% of the beginners and 35% of the advanced and in snowboarders 28% of the beginners and 36% of the advanced sustained injuries (Bridges, Johnston, & Rouah, 2003). This trend can be explained by the fact that the beginners, due to the lack of knowledge and the advanced due to the lack of estimation skills exceed the limits of their abilities. According to Shea et al. (2014) the maximum number of knee injuries was detected in medium experienced skiers (44.3%) and then in the good (33.9%) and in the beginners (21.8%). Good skiers collided most often (50%). Beginners who learned to ski with an instructor were less injured than the skiers who worked independently. The speed of movement was a possible cause of injury (Aschauer et al., 2007) because it was associated with the knowledge of skiing or ability to control and estimate the speed. In two studies (Shealy, Ettlinger, & Johnsonal, 2005; Ruedel et al., 2013) it was found that skiers generally poorly estimated their speed of movement and that they were wrong, on average, for about 5.8 km/h (8.1% lower than the actual speed). A couple cases were registered where they could not nearly estimate their speed (e.g. for skiing at the speed of 60 km/h they estimated that they were moving 20 km/h). Age, gender and experience are important for the ability of skiing speed estimation. Generally men and younger skiers ski faster than women and more

experienced skiers, while the older and more experienced men estimate the speed better than women and the younger.

Skiing equipment

The importance of adequate and properly maintained safety equipment for skiers is illustrated by the fact that 44% of all injuries resulted from the use of inadequate equipment! It was the development of equipment that contributed significantly to the safety of skiers and also to the change in the type of injuries. During the historical development of skiing, we can distinguish certain moments in the technological development of equipment that significantly influenced its development but also the safety of the skiers. Fixing the heel to the ski (1920) was of importance to the ability to manage the skis but also the cause of an increase in the number of ankle injuries. The development of deep ski boots (today's features and form were given at the end of 70s) and the construction of automatic bindings (main characteristics of today's bindings were reached at the end of 80s) have contributed to the reduction of ankle injuries but also to the increase in the number of injuries of the knee joint. The emergence of snowboarding (end of 70s) and later carving skis (*carving* - wider use in the second half of the 90s) have contributed to the diversity of skiing, faster training, more attractive skiing and also the changes in the type of injuries. The part of the standard equipment for skiing and snowboarding, in terms of security, are: bindings, helmet, wrists guards and spinal cord guards.

Bindings

The role of bindings is twofold: a) to fix the ski boot while transferring the movements of the lower leg to the ski and b) to release the boot in a situation where injuries may occur (when external loads exceed functional characteristics/capabilities of a muscle, bone and joint system of legs). According to a study by Goulet, Hagel, Hamel, & Legare (2007) it was found that 47% of skiers had incorrectly adjusted bindings, and according to Meyers et al. (2007), about 35% of leg injuries in children were the result of improperly set bindings. Despite the existence of international standards on the technical characteristics of the bindings, there are two reasons why the current characteristics of the bindings do not provide com-

plete protection of the knee joint: a) the load required to reach a hyperextension of the knee joint is lower than the load that occurs during normal turn while skiing and b) current bindings register and react to the forces that are manifested at the level of the ski boot and binding rather than at the level of loads that are manifested in the knee joint. The problem of knee injuries is that we have skis on our feet as extended levers which increase torque in the knee joints. Bindings do not have the ability to instantly adapt, which is possible when it comes to the joint-muscular system of the knee. The contraction of the muscles of the knee can increase its strength by 400% (Ettlinger & Johnson, 1991), which significantly increases the threshold of load that causes injury. If the bindings adjustments calculation do not take into account the mentioned characteristics of the knee system (muscular activity which increases the strength of the joint), it is possible that bindings react in situations of significantly lower load, below the threshold of injury. Unnecessary release of a boot causes losing control of movement, probable fall and possible injury. Conversely, if the adjustment of bindings is done at the level of the highest threshold of injury (maximum co-contraction of muscles in question) every move and external load in a relaxed muscle will cause overloading of the joint i.e. an injury because the binding will not release the boot.

Ski helmet

The role of the helmet is to transfer the external force of impact to a larger area for a longer period of time. In previous studies, most of the papers dealt with answering the following four questions: 1-whether wearing a helmet reduced the possibility and extent of injury; 2 whether wearing a helmet in children could cause injuries of the cervical spine (whether its shape, size and weight significantly changed the load of this body part); 3-whether wearing a helmet had an impact on the ability to evaluate the speed, visibility, hearing and sense of direction and 4-whether wearing a helmet influenced the increase in risky behaviour? Critics of wearing helmets show that a helmet can lead to an increase in risky behaviour because of the false sense of security. The studies of Macnab, Smith, Gagnon, (2002), Bridges et al. (2003), Hagel, Goulet, Platt, & Pless (2004), Hagel, Russell, Goulet, Nettel-Aguirre, & Pless (2010), Ruedel et al. (2013) confirmed that a helmet had a positive impact on re-

ducing injuries which is associated with the finding that 44% of head injuries included areas that were usually covered by a helmet. Wearing a helmet reduced the risk of a head injury by 35% in general and in children by 59% (Ruedl, Sommersacher, Woldrich, Kopp, Nachbauer, & Burtscher, 2010; Hagel et al., 2010). Of all the people with head injuries that were wearing a helmet, 48% were injured as a result of the fall and 10% after a collision. A small number of collisions against other causes suggest that the helmet is not a hindering factor during skiing. The study of Ruedl, Brunner, Woldrich, Faulhaber, Kopp, Nachbauer, & Burtscher (2013) indicated that wearing a helmet was not associated with a risky behaviour in skiing, or that those persons, despite expectations, showed no inclination to ski faster. The correlation of wearing a helmet and injuries refers only to the reduction in the size (severity) of injury but not to the injuries with death outcome. Of all the fatally injured who had a helmet only one-third had a head injury as the underlying cause of death. The number of deaths in the last 10 years has not been reduced despite a significantly higher number of skiers who wear a helmet. The cause of deaths is risky behaviour for which a helmet is not complete and appropriate solution! There was no difference in the role of the helmet between skiers and snowboarders. According to a study from 2010 in both cases, from the total number of injuries, 51% wore a helmet while 49% did not. According to the US National Ski Areas Association the number of skiers who wear helmets is constantly increasing. In the season 2012/13, 70% of skiers and snowboarders wore a helmet which is a significant increase of 180% compared to the first study from 2002/03 when only 25% of skiers used a helmet (NSAA, 2013).

Wrist guards and spinal cord guards

The use of wrist guards reduced the risk of injuries in snowboarders for up to 85% (Hagel, Pless, & Goulet, 2005). Despite doubts that the protection of the wrist increases the number of injuries of the elbow joint, upper arm and shoulder, the analysis of these injuries did not find that there was the stated interconnection (Russell, Hagel, & Francescutti, 2007; Hagel et al., 2005). Protectors of the spinal cord play an important role in the prevention of injuries in falls after jumping.

Snow surface conditions

The slopes for skiing imply groomed (beaten) trails, rough trails, snow parks (hurdles, jumps) and ski lifts. Depending on the type of injury according to Ruedl, Bilek, Ebner, Gabl, Kopp, & Burtscher, (2011a) over 90% of injuries happened on groomed trails, 1.1% happened in snow parks and 0.6% when skiing off-piste. The results of other studies are similar. According to Morrish & Groff (2012) 75% of injuries happened on groomed trails, 11% in snow parks, 10% off-piste and 4% during the use of ski lifts. In a study by Henrie, Aoki, Biggs, & Willick (2009) the number of injuries in snow parks was over 22%. According to data from 2010, 88% of injuries happened to skiers on groomed trails, 5% in snow parks, 4% on ski lifts (for 3% the place of injury was unknown). In snowboarders on the trails 77%, 17% in snow parks, 3% on ski lifts, and for 2% the place of injury was unknown.

Skiing on groomed trails

Trail conditions and the surface where the skiers move can affect the injuries of skiers and snowboarders (characteristics of snow surfaces; arrangement of trails). In practice almost nowhere is done an accurate classification of the snow surface and therefore it is not possible to analyze the causes of injuries according to the types of surfaces on which the injury occurred. According to Ilic, Ropret & Ilić (2010) the surfaces were divided into 1-compact (snow-frozen, beaten, soft) and 2-deep snow. Each surface had certain characteristics which required the application of certain skiing techniques. According to Ruedl, Brunner, Kopp, & Burtscher (2011b), the highest percentage of knee injuries occurred on wet snow 66.1-68.2%, on fresh snow 24.0-28.3%, on soft snow 4.8-6.8% and on frozen snow 0.7-1.4%. Obviously the snow surfaces with greater resistance conditioned greater number of injuries. According to the degree of trail difficulty, the largest number of injuries happened on moderate trails 49.1 to 52.9%, 35.8 to 43.2% on light trails and 7.7 to 11.3% on heavy trails. The results were expected because significantly less skiers were on the difficult trails than on the moderate trails. On icy surfaces the injuries of the upper limbs are more common and of legs less, due to the fact that on the ice it is harder to maintain contact with the ground and control the movements that cause falls. In the mentioned cases, knees were injured less because

the surfaces resistance was lower too. Going off trails and collisions with objects were stated as the most common causes of deaths. In the USA 60% of injuries were the consequences of hits in the trees off-piste.

Skiing off-piste

An interesting fact is that in skiing off-piste the number of knee injuries was significantly smaller than the number of injuries on other trails (0.6% to 3.8% in men and 1.0% to 2.5%).

Skiing in snow parks

Snow parks are specially arranged parts of the ski slopes with jumps and different hurdles for the performance of acrobatic elements. There, on skis or a snowboard, jumps with turns, crossings (skating) over hurdles in the form of long boxes (boxes) or bars/rails (rails) are performed. Overcoming these hurdles and tasks requires significant motor, and primarily coordination capacities. Approximately 26.7% of all injuries at ski resorts occurred in snow parks, where the majority of snowboarders were men younger than average skiers on ski trails (20.5 compared to 27.2 years). The most common injuries were fractures and contusions, including injuries to the head, face, back. Injuries in snow parks are of a serious nature and more often require evacuation from the track and hospitalization. These data indicate that terrain features or complexity of movements that are performed represent an important factor of injury in relation to the types of skis that are used (skis or snowboard).

Altitude

Staying in the mountains above 1500 m can affect the appearance of the high altitude syndrome which may manifest: dehydration, headache, stomach bloating, reduced working capacity due to the rarefied air (Slaney, Cook, & Weinstein., 2013). No results were found in papers that established direct impact of the high altitude syndrome on the injuries in skiing.

Weather and climate factors

The largest number of injuries occurred during sunny days (52.3 to 58.5%), followed by those during cloudy days (30.1 to 34.9%) and the least during the days with snowfall (8.6% -15.4%). During snowfall

twice as many knee injuries were recorded in women compared to other injuries (15.4% compared to 8.6%) (Ruedl et al., 2011c). The risk of injuries in women increased tenfold in the conditions of poor visibility (Ruedl et al., 2009). The difference in the number of injuries during sunny days (0.55%) and during heavy snowfalls (1.12%) Aschauer et al., (2007) associated with the factor of visibility.

Cold

By lowering the temperature grows the risk of knee injuries, from 49.7% at a temperature higher than 0°C to 61.2% at a temperature lower than -8°C. The cause of knee injuries while skiing can be explained by the knowledge that the skin temperature and the temperatures within the muscles of the knee significantly decreases after 60 minutes of skiing (Becher, Springer, Feil, Cerulli, & Paessler, 2008). Lowering the body temperature lowers the activity of H-reflex of *m. soleus*, which is an important mechanism in controlling the activity of the muscles of the lower leg (Oksa, Rintamäki, & Rissanen, 1997; Dewhurst, Riches, Nimmo, & De Vito, 2005). These physiological changes may reduce the ability of fast muscle activation and balance. Overall, the increased loss of body heat at low temperatures is higher in women compared to men due to greater percentage of area that gives off heat and less natural insulation structure due to less muscle mass (Piedrahita, Oksa, Rintamäki, & Malm, 2009).

Warming up

For preventing the negative effects of cold, adequate wardrobe and warm-up exercises are recommended. Bearing in mind the significant effects of cold on women, they are particularly recommended the above measures. Warming up for 15 min affects the increase and maintaining of temperature for the next 30-45 min, compared with persons who do not warm up (Whelan, Gass, & Moran, 1999).

Time of day

Based on many years of practical experience, it was argued that injuries usually occur in the after-

noon, on the third and seventh day, connecting all this with fatigue accumulation. According to Hiang (2004), the greatest number of injuries with lethal outcome occurred in children between the hours of 13 and 15 and in adults between 11 and 13. As for the week days, according to the number of injuries, Wednesday and Saturday stand out (the third and the last day) which exactly can be linked to the cycles of fatigue.

Skiing manner/ the way of skiing

Children who ski in a group within a school program or out of control of ski instructors had twice the chance of being injured (Cadman & Macnab, 1996). The authors explained this fact by the behaviour of children while skiing in the group and a desire to prove themselves, overcoming their capabilities and ignoring the rules. This attitude was confirmed by the fact that only one of 125 such injuries was sustained during a skiing under the supervision of instructors/teachers and all others during free skiing in a group.

CHARACTERISTICS OF INJURIES AT SKI RESORTS IN SERBIA

According to the Mountain Rescue Service in Kopaonik (Milosevic, 2014) the characteristics of injuries corresponded to world averages. Injuries were more common in men (55.7%) compared to women (44.3%). This information is relative because the relationship between women and men at the ski resort was not defined. The largest number of injuries included the injuries of legs (44%), arms (28.5%), head (15%) and torso with the spine (12%). The most critical were blue trails (54.6%), followed by red (32.7%) and black (12.7%). The most frequent injured were men aged 21-35 (34.1%), followed by young people aged 11-20 (23.4%), older than 36 to 50 years (22.7%), younger than 10 years (11.7%) and older than 50 years (8.1%). More severe injuries were more common on red trails, and of all the injuries to the head and spine, 43% and 47% of injuries happened on red trails. Of all injuries with a concussion the most were registered in children and young adults aged 11-20 (38,2%).

CONCLUSION

Skiing is defined as a sport with an increased risk of injury due to several factors: increased movement speed in non-standard conditions, the use of specific equipment and the necessity of possessing certain mental and physical abilities and motor skills. It is evident that during the last thirty years, the number of injuries decreased dramatically. The decreasing trend in the number of injuries is due to the improvement of the characteristics of ski equipment and better prepared trails. In addition to the general decrease in the number of injuries, there has been a change in the type of injuries, i.e. some injuries have been reduced but a number of injuries have increased. The reason is that by greater protection of individual body segments the load was transferred to other segments. Along with the protection of the ankle with high and hard boot, the load was transferred to the other joints and thus increased the number of injuries of the knee, arms and the shoulder girdle. Upgrading the equipment and trails enabled faster and more attractive skiing and the new disciplines (*freestyle, freeride*) brought a higher level of requirements for motor abilities and skills. It has also resulted in changes in the size and structure of the injuries. The number of falls after jumps was increased along with the number of head and spinal cord injuries. Characteristics of equipment and different techniques of skiing made skiing and snowboarding different in structure and number of injuries. The number and structure of the injuries were affected by gender, age, level of skiing knowledge, time of day, physical condition, psychological condition and suitability of equipment. A significant number of injuries were a result of

using unadjusted bearings. The increased use of protective equipment reduced the risk of injury but not the number of the most serious injuries and injuries with lethal outcome, the number of which has stagnated for years. Obviously the manufacturers of the equipment and the responsible for the preparation of trails are not the only responsible factors in the area of skiing security. The research results indicated that injuries to a large extent were the result of risk-taking behaviour of individuals, i.e. of personal responsibility for inadequate estimation: knowledge of skiing, trails choices, physical fitness and weather conditions. Young people are particularly prone to injuries due to risky behaviour because the characteristics of psychological development in adolescence.

By reviewing the above factors it can be seen that there are three entities in the implementation of security measures: the state that stipulates the laws (relevant ministries), owners or organizers who provide services and skiing (ski centres, ski services, ski schools, clubs) and skiers and snowboarders themselves. Each of these factors should have a prescribed duties and responsibilities that would regulate the area of security of skiers and snowboarders in an appropriate manner. After defining all the risk factors, it is also necessary to create a unified system of monitoring and analyzing the number and structure of injuries as well as the factors that contribute to injuries, which would create the conditions for long-term planning and implementation of appropriate procedures. Security measures, in addition to regulations and sanctions must include the area of education, information and promotional activities in order to act preventively and to develop awareness of the importance of security.

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VERLETZUNGEN IM SKI- UND SNOWBOARDLAUFEN: EPIDEMIOLOGIE UND RISIKOFAKTOREN ALS GRUNDLAGE FÜR PRÄVENTIONSMASSNAHMEN

Zusammenfassung

Gegenstand der Arbeit ist der Bereich der Verletzungen im alpinen Ski- und Snowboardlaufen, das Ziel ist die Bestimmung der Verletzungsmerkmale und Risikofaktoren als Grundlage für Präventionsmaßnahmen. Aufgrund der Betrachtung bisheriger Arbeiten wurden die Verletzungsarten und die Faktoren des Verletzungsrisikos analysiert. In den letzten dreißig Jahren hat sich die Anzahl der Verletzungen generell um 50 – 70% verringert. In Bezug auf den Verletzungstyp wurden Veränderungen registriert, sowie eine Steigerung einzelner Verletzungsarten. Es wurde festgestellt, dass es einen Unterschied bei der Anzahl und Struktur der Verletzungen von Skiläufern und Snowboardern gibt. Die Verletzungen können topologisch oder nach Risikofaktoren klassifiziert werden. Die Risikofaktoren können verschiedenartig sein: Charakteristiken der Ausstattung, Charakteristiken der Pisten und der Schneeunterlage, Schutzausrüstung, Alter, Geschlecht, körperliche Kondition, Risikoverhalten, Tageszeit, Skidisziplinen, Klimafaktoren, Umgebung anderer Skiläufer u.a. Die Analyse der angeführten Faktoren führte zum Schluss, dass es drei Subjekte in der Vorbereitung von Sicherheitsmaßnahmen gibt: den Staat, der Gesetze vorschreibt (zuständige Ministerien), den Eigentümer oder Organisator von Ski-Serviceleistungen (Ski-Zentren, Ski-Service, Ski-Schulen, Klubs) und die Skiläufer und Snowboarder selbst.

Schlüsselwörter: RISIKOFAKTOREN / SCHUTZAUSRÜSTUNG / SICHERHEIT / VERANTWORTUNG

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