

INJURIES, CAUSES OF INJURIES AND REHABILITATION OF ALPINE SKIERS – SYSTEMATIC REVIEW

Berina Turković, Rasim Lakota, Ivor Doder, Eldin Jelešković, Amila Hodžić and Merima Merdan

Abstract: One of the ways to prevent injury and to rehabilitate after an injury in alpine skiing is to psychophysically prepare the athlete to safely go through the ski season. The aim of this research was to collect, analyze and critically review data from relevant research studies that are closely related to the prevention, causes and rehabilitation of alpine skiers. Data selection, analyzing and critical review was done according to "PRISMA" methodology. The systematic search for relevant articles (Google Scholar, PubMed, MEDLINE, etc.) related to the prevention, causes and rehabilitation of alpine skiers will create comprehensiveness in knowing the basic principles of self-management (self-control) on a mountain trail. The results indicated that the most common injuries among alpine skiers are ACL injuries. However, good physical preparation, a very stable mental health, appropriate ski behavior on the track and compliance with the "International Ski Federation" rules and obligations are the main aspects of injury prevention. This review study has collected and classified data taken from relevant databases that were based on injuries, causes of injury and rehabilitation of alpine skiers. The most common injuries classified in this study are ACL injuries, as the ACL injury patterns and post-injury rehabilitation.

Keywords: Measurement, biomechanics, turn, learning model, beginners, activity, challenge, moving stereotype, program, exercises, judges, mistakes.

INTRODUCTION

When we talk about skiing, we are talking about development of skiing in our region. Skiing in Bosnia and Herzegovina was developed during the Austro-Hungarian occupation, in 1978. Austro-Hungarian soldiers and citizens brought skiing in our areas. Before that they performed this sport in Alps. During that time local population didn't practice this sport and saw it as something new. Significant development of skiing in our area among local population occurred in April, 4 1905. when tourist association "Nature friend" was established, in Sarajevo. With the establishment of this association skiing became the most attractive entertainment and recreation among local population. Ministry of physical education, in period between 13-16 February, organized first jamboree skiers of Yugoslavia on Jahorina, Bosnian mountain. Opening ceremony of this event was performed in City Hall on February, 13 in 8:00 p.m., where skiers from all over ex Republic of Yugoslavia were present. Participants of this event came from Ljubljana, Sarajevo, Zagreb, Maribor, Skopje, and other cities of ex Yugoslavia. "XVI Winter Olympic games", which were opened in 1984, in Sarajevo, the capital of B&H, a member of ex Yugoslavia, were significant factor for development of skiing in Bosnia and Herzegovina. Olympics brought expansion of development of skiing in Bosnia and Herzegovina and it is considered to be one of the most beautifully developed sports in Bosnia and Herzegovina, today. The one thing that is specific not only for skiing but for any type of professional or recreative sport are injuries. Injuries are part of any sport and skiing as well. Bad technique, tactic or general preparation for going on the snow, leads to many injuries of many people and athletes in terms of knee injuries, head injuries, neck injuries etc. which luckily do not demand long and demanding treatment. Going to ski tracks increases number of injuries, today, which usually involves long and demanding treatment. It includes injuries of tibia in the past, but development of technology and improvement of equipment reduced appearance of injuries. However, today the most common injuries are knee injuries and injuries of upper extremities such as thumb and shoulder injuries. Injuries of knee, shoulder and thumb and other body parts are reduced due to better standards and conditions on ski tracks and the equipment which is improved to perfection. The most common causes of injuries on ski tracks are weariness, bad visibility, speed, and bad weather conditions. The most common injuries are injuries of beginners, due to lack of knowledge and injuries of professionals whose aggressive ride leads to serious injuries, which include long recovery which can last over a year. This paper analyses studies which dealt with injuries of Alpine skiers, their rehabilitation and cause of those injuries.

METHODS

Sample of subjects

Paper presents common paper review. Primary source of research and reference reviews were: Google scholar, ResearchGate, Cambridge Journals, Emerald Library, Journal The Physician and Sportsmedicine by entering the key words: isokinetic, muscle, rehabilitation, skier, knee, rotation, angle speed, biodex. Search of literature identified 100 reference units. After analyzing headlines, abstracts, key words, and unmatched of complete text, 70 papers were excluded. Other papers that fulfilled criteria are analyzed, in detail, by reading and analyzing content. Criterion of inclusion, included studies that treated mechanisms of prevention, cause and rehabilitation of Alpine skiers. Criterion of exclusion were directly valorized data opposite to set hypothesis.

Graph 1. Diagram of selection of studies

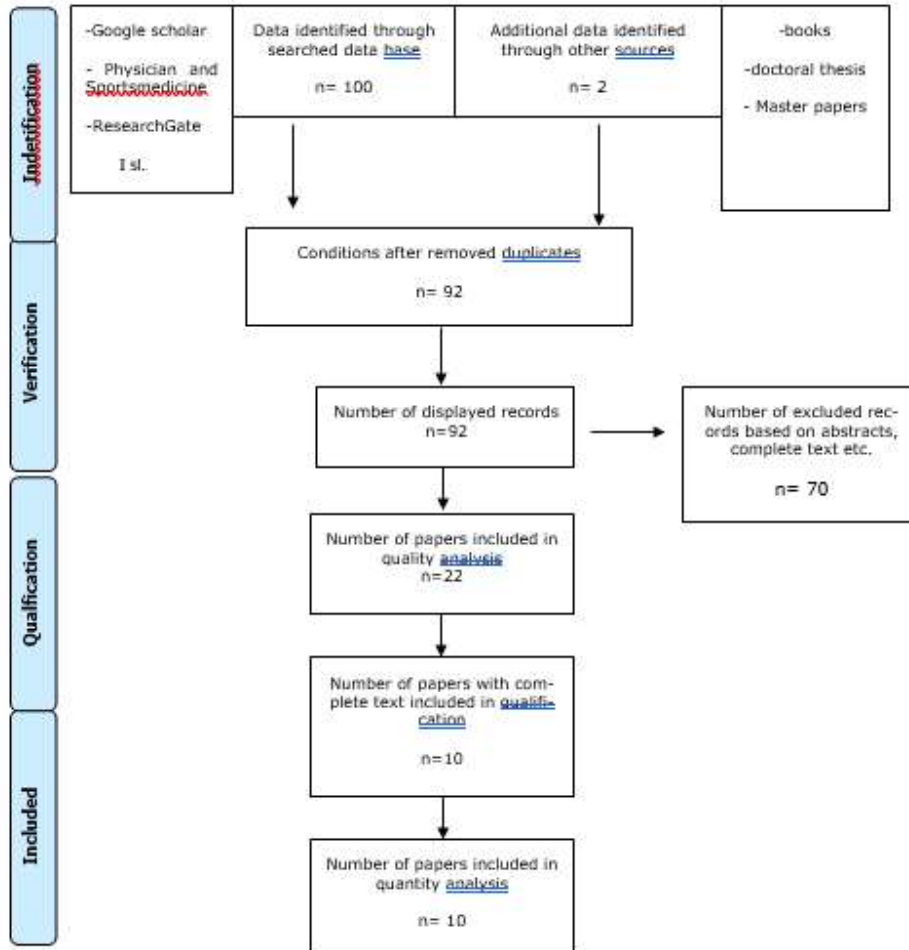


Table 2. Results

Author name and surname	Sample subjects	Description of study procedure	Results
Edoardo Monaco, Andrea Redler, Mattia Fabbri, Lorenzo Proietti, Edoardo Gaj, Matthew Dagget (2018)	A=22 B= 22	Research was conducted on sample of 44 subjects. All samples had injury of ACL. Group A is subjected to reconstruction of ACL which is performed by ALL technique-insade graft, and group B is subjected to reconstruction of ACL OUT-IN technique and DGST graft.	Subjects of A group , median difference at maximal flexion of turning moment from one side to another between operated and helathy extremities is -3%, and median moving moment at 30° was -7,5 % at high angular speed of 180 °/s. Median peak angular flexion was 7,2% median moving moment at 30° was 3,1 % at low angular speed. Subject of group B In Group B means of maximal turning moment at bending was -3,5%. Median movement moment at 30° was -7,6 % at high angular speed of 180°/s; Median peak moment of bending was 7,2%, and median turning moment at 30 ° was 3,1% at low angular speed (60 ° / s). statistically significant difference is determined between two groups at lower angular speed and at median peak turning moment at 30 ° ($p = 0,009$), with better results in subject group.
M.V.Narici & sar; (2011)	n= 22	22 subjects were subjected to testing, whether they can regularly practice skiing, reduce sarcopenia and muscle weakness of men and women of average age 67 ± 2 .	Dynamometria is measured by maximal isokinetic stretching of knees at angular speed of 60° Results showed that Alpen skiing and usage of isokinetic procedure in rehabilitation, efficient intervention in emergence of sarcopenia and muscle weakness in elderly men and women.
Matthew J. Jordan, Per Aagaard, Walter Herzog (2014)	n= 13 M / un n= 8 Ž / un n= 3 M / ACL n= 5 Ž / ACL	This study included sample subjects of control group which included 13 male Alpen skiers, who haven't had any injuries and 8 female Alpen skiers, who also haven't had injuries of any kind. Experimental group of this study included sample subjects of 3 male Alpen skiers and 5 female Alpen skiers with ACL injury.	Analyzing and processing data of 5 tests, which were conducted on these samples of data, showed that although these are only examples of several cases, ACL injuries are great problem in strength recovery and strengthening muscles of quadriceps. Therefore it presents great precentage of failure when returning to the track.
Josef Kroll & sar ; (2015)	n= 7 n= 13 n= 15	This study included sample subjects of three subjects. The first group included sample subjects of 7 athletes, which performed Alpen skiing dicipline technique on three prototypes and on Pref. The second group included sample subjects of 15 students of sport evaluated several video clips in order to evaluate external	Analysis and data processing authors got to the result of this study, which showed that kinematic variables are set in the paper and that qualified agressivness of skiing, showed reduce of means for P35 and P40 in u comparison to Prefo an+ <d P30.

		attractivness of G slalom performance.	
Csapo R¹ , Hoser C² , Gföller P² , Raschner C³ , Fink C² (2018)	n=541	This paper is based on search of data base of professional Alpen skiers with ACL injuries and its reconstruction. Questionnaire, which reflects subjective perception of pain, function in everyday life and various physical activities which are performed after the injury, is conducted. Web page of „International Skiing Federation“ is used for getting FIS points, which showed results of these skiers before the injury, after recovery, and a year after the reconstruction of ACL.	Questionnaire results of subjective assessment of pain, function in everyday life and various physical activities after injuries, showed patient's satisfaction. Measurement conducted 161,5 ±24,2 days after operation showed existence of muscle strength and its deficit. FIS points were increased weight after return among competitors 364,3 ± 142,5 days after operation procedure, but the final results showed significant decrease of personal results on ranking list, a year after the procedure and a year before the injury.
S Ravi (2016)	n= 176 M n= 163 Ž	This research was conducted on sample subject of 339 Alpen skiers, where 176 of them are men and 163 are women from Swedish high schools.	Authors came to results, through collecting, analysing and data processing, that 11 male subjects and 14 female subjects had 25 ACL injuries, in total, during the first testing. Most injuries occurred on left knees. Skiers, who participated in Alpen skiing about 13 years, had low risk of ACL injury. 16 ACL injuries happened during training, 12 in great slalom and 8 in slalom. 14 female subjects said that they didn't feel tired before injury occurred and 8 of them said they were a bit tired.
Kevin. G. Shea & sar;	n= 541	This research included sample of 514 subjects of both gender of Alpen skiers and it lasted for 6 years. Patients chose one of six classifications of injuries.	Results of this 6 year study showed the following: causes of injuries were valgus rotation and it was 32,9%, phantom foot 22,5%, hiperextension 19, 0%, inadequate footwear 7,8%, collision and other 15,6 %. Adult and young skiers that were identified as „advanced“ skiers, had bigger prevalence valgus external rotation than less experienced skiers (51,5% of total valgus injuries P <.01). Correlations appeared in 19.3% in adults and 53.7% in young (P <.01) during the injury. Female skiers were 60,0% of total number of subjects, but only 39,7% of injuries occurred in female children.
S Ravi (2016)	n= 1	This research was conducted on one of the skiers in Yoga center of Academy of sport education in Latvia. An athlete was subjected to 30-minute Yoga , as additional intervention, three times a week with 90-minute physical therapy,	Results of this program showed that IKDC was improved from 49,4 to 63,2. Volume of movement of injured knee is improved from -3 to normal. Flexion of knee is increased for 20 degrees. Enhanced external rotation active 20 degrees, passive 10 degrees.) Passive hip flexion is increased for 10 degrees. Muscle test for

		by designed programme for rehabilitation after the injury.	flexion and extension gave the following results: flexion of the knee from 3 to 4 and extension from 3 to 5.
T W Florenes & sar (2009)	n= 521	Reserach was conducted on sample of 521 subjects of World Cup in Alpen skiing.	Results showed 191 acute injury among 521 Alpen skiers of the World Cup. Number of injuries is increased with the increase of speed (slalom 4,9 injuries on 1000 running, 95% CI 2,5 do 7,4 – giant slalom 9,2, 5,1 to 13,3 - super-G 11,0, 5,2 to 16,8 - downhill 17,2, 11,6 to 22,7). Most commonly injured body part is knee, with 68 injuries (36%), and 37 of them are serious. Total rate of injuries was higher in men than in women but that's not the case with knee injuries.
Toni Bere & sar (2011)	n= 20	Reserch was conducted on sample of 20 subjects, Alpen skiers registered through System of monitoring of injuries „International skiing federation“, who were participantd of the World Cup of three seasons in a row. Methods of data prpcessing were analyzed through video clips. Members of commision for visaulization and opinion, were experts from the field of biomechanics of skiing and doctors of spor medicine, who did separate analysis of each video and explained mechanisms of injuries, in detail (skiing situation, behaviour of skiers and biomechanic features).	Results of analysis of video clips, showed that mechanism of skating of skaters was the biggest cause of injuries during the rotation, before the fall.(n=10). Three subjects were injured by demonstration of dynamic snow plough. Category of the fall backwards was n= 4.where skier was out of balance, and during which he fell backwards and at the tail of skies with knees completely straighten knees. Suggested mechanism for recovery was combination of tibiofemoral compression, test of stability of knees and active test of quadriceps.

DISCUSSION

Table 1 shows 10 papers of different studies closely related to injuries, causes of injuries and rehabilitation of injuries during performance of skiing elements, in Alpen skiing.

Edoardo M, Andrea R, Mattia Fabbri, Lorenzo Proietti, Edoardo Gaj, Matthew Dagget (2018) researched isokinetic diagnostics in recovery of strength of flexion after reconstruction of ACL. Their research included 2 groups, control and experimental group. Control group, A group included 22 patients and experimental group also included 22 subjects. Isokinetic procedure determined statistically significant difference between these two groups and those are: speed of performing flexion, where experimental group had better speed, median peak angle and median rotation movement at 30°, where p was 0,009. Sacral ligaments, ACL (knee) had main role in stabilization of knee and ensuring

partial „sliding and rolling“ of joints, which is one of the most important segments for Alpen skier. This study can affect recovery of ACL after the injury and due to many tests, in very short amount of time we can recover and improve our condition, after the reconstruction of ACL. M.V Navici et al, (2011) examined whether and to the what amount skiing can switch the condition of sarcopenia and muscle weakness in elderly people (22 of sample subjects of average age 67 ±2). Model of this study included 12 weeks of recreative skiing, for 3 weeks of training, which lasted 3,5 hours, in average. Control group included inactive group of subjects (n=20) aged 67±4. Two subjects were selected as a sample subjects of experimental group. Before and after training thickness of muscle extensors penation angle and angle of muscle fibers consist vastus lateralis muscle, measured by ultrasound. Ultrasound analysis showed significantly different condition where thickness was

increased for $T_m = 7,1\%$, $L_f = 4\%$, $i\theta = 3,4\%$. Inactive group of subjects did not show any significant changes except for angle of length of muscle fibre θ ($2,1\%$, $P < 0,02$). Subject of the second group, training group, showed significant connection in the increase of kinase focal adhesion, indicating primary role of this mechanic-sensitive protein in remodeling sarcomer with hypertrophy of muscles. Final results showed that Alpen skiing has a positive influence in defeating sarcopenia and muscle weakness in elderly individuals. Third age of life is considered as special period in life of every individual. Recreation in this period of life is important because it enables maintenance of body weight, helps in development of flexibility and increases serotonin pouding also called „hormone of happiness“. Some studies say that elderly people who practice sport and lead healthy way of life, can influence on biological aging of a human, even 25 years less. Therefore, skiing is one of the good ways of recreation, because it improves motor abilities of a human and also affects those biological ones. Matthew J et al. (2014) conducted research which included 21 subjects, members of ski representation, where some of the members won medals on World skiing cup, where skiers on training, before going on a track, were tested. 3 groups were taken from this sample and those are: first group included sample subjects $n = 3$ men, $n = 5$ women; of 8 skiers with ACL injury, 5 of which were operated, with knee transplant. Also, 5 out of 8 skiers were injured in non-dominant part of lower extremity, while one subject had external or isolated fracture of ACL. All subjects before training, were subjected to medical exam, in order for them to be prepared for the competition. Subjects, who had injury in lumbal area and injuries i.e. fractures of lower extremities, are excluded from this study. Subjects who took medical exam were subjected to scanning by DXA scanner of double energy of absorption of X-ray, according to instructions of manufacturers (Discovery A QDR, verzija softvera 12.6.2., Hologic, Inc.; Waltham, MA). Technician who was in charge of this testing and responsible for collecting, analyzing and data processing was an expert-technician for all DXA scanning. Testing and determining the relation of bilateral limbs of injured and non injured skiers, showed no significant difference, despite of set hypothesis of this study. Skiers of ACL didn't show significant difference in muscle mass of lower limbs. ACL skiers showed significant deficits in sinew of knee and maximal strength of quadriceps and injury of thumb bone. As assumed in hypothesis of this study, female subjects, who weren't injured didn't show statistically significant differences in bilateral extremities in relation to sinews of knee and injury of thumb bone. Results of this study showed significant deficits in volume of maximal strength of quadriceps of injured sinew and metatarsal bones of feet. Final results of this study, strength recovery QUAD, after ACL injury, showed unsuccessful for recovery and return to the

track. Josef Kroll et al. (2009) based their study on aggressiveness on skis, which is categorized by direct force of transmission on the edge of the ski, which leads skiers to disbalance, which is, very often, cause of injuries on the track. Sample subject included 3 groups of subjects. First group included sample of 7 Alpen skiers, who skied on prototype giant slalom skie (GS skies), which were compared to standard skis for giant slalom race. In comparison to standard giant slalom skis, prototype of new ski for giant slalom is changed and was a bit longer than standard ski Radius of PREF skie was $\geq 27m$, and radius of new giant slalom ski was 35 m, 40 m and 45 m, which is increased for 74,07%. Sample subjects included 7 Alpen skiers, who skied on each of these prototypes and on standard giant slalom skis, as well. Sample subjects of second group, 13 of them, based on subjective assessment, they evaluated their behaviour and aggressiveness on skis, by standard questionnaire. Samples of third group included 15 subjects, students of sport, who evaluated rides on these three prototypes, by looking at videos, and positive external conditions, which include ride in natural tracks. Bigger side radius had positive effect on subjects, and influenced on reduce of aggressiveness when giant slalom race. Kinetic variables, who are set in the papered which qualified aggressiveness during the ride, showed reduced values for radius of 35m and radius of 40m in relation to standard giant slalom skies and new prototype GS skies, with radius of 30m. these prototypes are made as a prevention of injuries, where prototype of radius GS skis 40m, showed significant preventive measure and the least attraction of the subject. Csapo et al (2018) in their study included sample of 541 subjects, where they wanted to examine subjective assessment of the pain, function in everyday life and level of physical activity after the injury. Collecting, analyzing and processing data was conducted by questionnaire, where questions about subjective assessment of the subjects resulted with satisfaction. Questions related to the level of activities after the injury showed that it was statistically good, however a year after the operation, patients (subjects) responded physical activity was significantly smaller than the one before the injury. With this study, authors wanted to show how injury can affect physical activity after the ACL injury and other injuries. S Ravi (2016) conducted a study which took 6 years and which included 176 male subjects, and 163 female subjects. Subjects were selected through questionnaire, where they were classified according to their injuries, when skiing. Authors got the results where 11 subjects of male population and 14 female population had 25 ACL injuries, in total, during the first testing. Skiers, who performed in Alpen skiing for 13 years, had reduced risk of ACL injury. 18 ACL injury occurred during the training, 12 in giant slalom and 8 in slalom. 14 female subjects stated that they weren't tired when injury occurred and 8 stated that they were. This paper is intended to show how often

tiredness or weariness causes ACL injuries in Alpen skiing. This study proved that tiredness or weariness isn't statistically significant indicators of ACL injuries, during the ski season and preparation of the race.

Kevin G Shea et al. (2014) did the research which lasted for 6 years, which included 541 subjects patients, Alpen skiers, who had knee injuries, caused by Alpen skiing. Subjects were selected by gender, age, weight, height, level of capabilities, and loosening ski bindings. Study was conducted through survey, which gave final results. Study of six seasons, was finished with the survey filled by 541 subjects (patients), who during this 6 years, gained acute injuries when skiing. 459 of adults and 79 young skiers were sample subjects. Measurements taken from the survey, included the following injuries with the percentage of replies: 1) valgus external rotation 32,9 %, 2) phantom foot 22,5 %, 3) hyper-extension 19,0 %, 4) unfitted footwear 7,8 %, 5) collision 2,2%, 6) other 15,6 %. This study showed that injury „phantom foot“ is common injury in individuals aged from 30-40, in comparison to other injuries. The highest percentage i.e. the most common injury is valgus external rotation (35,4 %). Phantom foot, according to the survey was 25,3 % , unfit footwear 3,8% , and other 16,8 %. There were no statistically significant differences in relation to the injuries in younger and older skiers. S Ravi (2016) worked in his study to program model of rehabilitation after the injury and reconstruction of ACL of front sacral ligament. Subject was a skier who, by adjusted program designed for rehabilitation after reconstruction, performed 12 week program for improvement and return to physical activities. Program was performed 3 times a week, 30 minutes each and 90 minutes of physical therapy. IKDC result was improved from 49,4 to 63,2 which is statistically significant improvement. This study proved that yoga is one of the best ways of recovery after the reconstruction of ACL, of front sacral ligament. This study should be guidance to the future studies, in order to present yoga as rehabilitation program after the injury and operation caused by skiing and other sports. T W Florenes et al. (2009) included 521 subjects, participants of World Cup in skiing, in their study. They conducted retrospective interviews on 191 subjects. When there were no coaches and athletes in interviews, they interviewed medical staff. Results of this study showed that, during one season, there was 191 acute injury in 521 subjects of World Cup in Alpen skiing. 86 injuries occurred during the World cup which is about 45% of total number of subjects. The most common injury is knee injury, 68, 63% precisely, and 37 of them were serious. Total rate of injuries was bigger in men than in women. These injuries are caused by tiredness, unfortunately, non standardized equipment, lack of concentration and aggressive ride.

Toni Bere et al. (2011) conducted their study because of limited insight into mechanisms of injuries of front

sacral ligament in Alpen skiing, which is very common in professional Alpen skiers. This paper included sample of 20 subjects, skiers of the World cup in skiing. Access to the injuries was gained by „International Ski Federation Injury Surveillance System“ which deals with the reduction and analysis of injuries on World championships in Alpen skiing. Processed videos in this paper are videos from three ski seasons of World cup in Alpen skiing, where seven international experts from the field of kinematics, biomechanics, ski and sport medicine, conducted visual analysis of each registered case on International Ski Federation Injury Surveillance System, in order for each one of them to describe mechanisms of injury, and variables, which were analyzed and processed were skiing situation in which injury occurred, skiers actions during rotation on skis, with or without fall. Main cause of injuries is identified during the rotation, because skier in that moment uses full strength of right or left leg, and makes rotation during the twist, and all weight is transferred to the leg which makes the twist. During the twisting skiers often make so called snow plough, therefore in this analysis, is shown as cause of injury of skiers and identified in 3 subjects. Suggested mechanisms of recovery are mechanisms of combination of tibiofemoral compression and combination of isokinetic tests for strengthening quadriceps.

CONCLUSION

This paper included research review, which was based on prevention, causes, and rehabilitation after injury in Alpen skiing. Analyzing papers which were selected for this paper, we came to a conclusion that apart from good preparation, preventive aspects of causes of injury is, to the great extent, psychological capacity of an Alpen skiing athlete. Skiing is a sport which demands strength, endurance, flexibility, and well preparedness before going to snow. The most common injuries of athletes are knee injuries, shoulder injuries, phantom foot, and thumb injuries. This study shows the way of analyzing of papers, which were based on preventive aspects of injuries, and it gives useful pieces of advice in terms of prevention of cause of injury and rehabilitation after the injury.

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Corresponding author:

Berina Turković

Faculty of Sport and Physical Education, University of Sarajevo
berina.turkovic@fasto.unsa.ba