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Injury pattern in a Chinese ski resort in the host city of 2022 Winter Olympic Games

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Running title: Injury pattern in Chinese ski resort

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Abstract

Objective: This study is to investigate the current injury pattern in skiing/snowboarding population in China, and to provide evidence for better practice in mountainside hospital near ski resort.

Design: A retrospective cohort study

Methods: A retrospective study was performed in WanLong Ski Resort in ChongLi. The data of all injured skiers and snowboarders seen in the clinic of Wanlong Ski Resort in season 2018-2019 was collected. Patients information including gender, age, equipment, ski level, injury type was analyzed.

Results: A total of 753 sports injuries were recorded. The estimated incidence of injury was 1.94 per 1000 skier days. 453 cases (60.2%) were associated with skiing. The mean age of skiers was older than snowboarders (35.1±14.5 vs. 29.0±8.9, $p<0.01$). Self-inflicted accident took up 67.9% of all injuries. The most common type of injury in skiers was lower extremity injuries; while in snowboarders, it was upper extremity injuries. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders.

Conclusion: The incidence of skiing/snowboarding injury in China is similar to previous studies. The injury pattern differs according to different sports and cause of injury.

Key words: Sports injury, Skiing, Snowboarding

Article summary

A booming of Chinese skiing and snowboarding population has been seen

since China was selected to host the 2022 Winter Olympics in 2015. Contradicted to the boom is the insufficient knowledge of the current injury pattern in winter sports population in China, and lack of capability dealing with traumatic patients in mountainside hospitals in major ski town. This study is to investigate the current injury pattern in skiing/snowboarding population in China, and to provide evidence for better practice in mountainside hospital near popular ski resorts.

Strengths and limitations of this study

·The collection of injury cases was nearly thorough due to the regulations in the ski resort.

·The severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis.

·Although medical providers in ski resort have collected injury cases as through as possible, there were still patients who went to local or superior hospitals without primary care in ski resort clinics, or did not receive any type of medical help for mild injuries.

1. Introduction

Skiing and snowboarding are popular winter sports world-wide but have a substantial risk of sports injuries, with reported incidence of 1.35 injuries per 1000 skier/snowboarder days in recreational skiers[1] and 6.9 injuries per 1000 runs (or 26.8 injuries per 100 athletes per season)[2] in professional alpine skiers. In the latest Winter Olympic Games in PyeongChang, 12% of the athletes incurred at least one injury, equaling 12.6 injuries per 100 athletes over the 17-day period[3].

Since Beijing was selected to host the 2022 Winter Olympics, a booming of skiing and snowboarding population in China has been seen, from 8 million in 2015 to 13.2 million in 2018 (industry annual report, 2019). Undoubtfully, hospitals close to ski resorts have confronted a sharp increase of burden of traumatic patients in winter. Unfortunately, large-scale ski resorts are often located in areas away from major cities, with nearby hospitals uncapable to ingest large number of patients or manage severe injuries. In order to address this dilemma, local hospital should extend scale, set up specific department and recruit talents according to the injury pattern in Chinese ski resorts.

The purpose of our study is to explore the injury pattern of skiers and snowboarders in China, and to provide the primitive data to guide the reform of the hospital near the venues of the 2022 Winter Olympics.

2. Patients and Methods

The present study was carried out at Wanlong Ski Resort in Chongli, China. It is the biggest ski resort in northern China according to the annual number of visitors (over 388 thousand visits in the season of 2018-2019), with an average ski season of more than 150 days.

Prior to the season of 2018-2019, the Wanlong Ski Resort reinforced their first-aid patrol and clinics by means of reformation, including:

1. Enroll more patrol members to inspect for potential risk and off-piste injured skiers, and to response to rescue calls as quickly as possible;

2. Employ one registered general practitioner and one nurse as primary care provider to manage mild injury and other common diseases, refer patients to local hospital and to carry out basic life support for life-threatening injuries;

3. Record every injury that is seen by patrol or doctor, including basic information and specific information such as the cause of injury, the location of the accident, type of injury, etc.

This retrospective study was based on these records. Besides patient's name, gender and age, we also recorded ski equipment, skiing level, the date and time of injury, the cause of injury, the location of the accident and the type of injury. Ski equipment was classified into skis and snowboards. Special equipment, such as cross-country skis, skiboards, was rare in China and not seen in recorded injured people. Patients were asked to report their years of participation in the sports, according to which, beginner (first season), medium

(1-5 years), advanced (5-10 years) and expert (≥10 years) were assigned to each patient.

The date of injury was divided into weekdays and weekends/holidays according to the Chinese government holiday arrangement. The business hour of Wanlong Ski Resort is 8:00-16:00, so we split the time of injury into 4 periods with 2 hours each, morning (first 2 hours of business), noon, afternoon and late afternoon (last 2 hours of business). According to the subjective description of injury scene, we summarized 2 types of causes of injury: self-inflicted, defined as falling or crashing without any body contact with others; and crash, defined as crashing involving 2 or more people. The location of the accident was also collected, and was categorized into beginner trail, medium trail and advanced trail according to the official data of slope inclination angle.

We categorized the type of injury into 4 groups: (1) head/cervical, (2) torso, (3) upper extremity, and (4) lower extremity. Whether patients have multi-part injuries was also recorded, while each injured body part was counted in one of the above groups. Acromioclavicular joint injuries were classified as upper limb injury, while other clavicle injures were classified as torso injuries.[4] Injuries involving gluteal region were classified as torso injury.

This study was approved by Peking University Third Hospital Medical Science Research Ethics Committee.

Statistical analysis

All statistical analysis was performed with SPSS (v 24.0; IBM Corp). Chi-squared test was used to compare categorical variables. Wilcoxon signed-rank test was used for non-parametric data. Student t test was used for parametric data. P<0.05 was considered statistically significant.

3. Results

Demographic

During the season of 2018-2019, there were 388606 visits and 753 sports injuries recorded in Wanlong Ski Resort. There were other 2 skiers suffered from fatal cardiac arrest, and not included in our study. The estimated incidence of injury was 1.94 per 1000 skier days.

Among these injuries, 453 cases (60.2%) were associated with skiing. The mean age of skiers was 35.1±14.5 years, whereas the mean age of snowboarders was 29.0±8.9 years (p<0.01). There were 68 patients (9.3%) under the age of 15, 22 patients (3.0%) over the age of 60. There was no significant difference in the sex profile in both groups, with 63.4% of skiers male and 62.6% of snowboarders male. 32.8% of the injured were beginners, while 38.3% of them were medium level, 19.0% were advanced, and 10.0% were expert. Table 1 shows more detailed demographic profiles of these injuries.

The features of injury

The season of 2018-2019 in Wanlong Ski Resort lasted for 158 days, from 2018/11/1-2019/4/7, consisting of 107 weekdays and 51 weekends/holidays according to the Chinese government arrangement. The average daily number

of injuries was 3.38 on weekdays and 7.65 on weekends/holidays. Within a day, 9.7% of the injury happened in the first 2 hours of business, 31.6% in noon, 22.0% in afternoon, and 36.7% in the last 2 hours of business.

Self-inflicted accident took up 67.9% of all injuries. The percentage of injuries happened on beginner, medium and advanced trail were 15%, 27.8% and 57.2% respectively. On beginner and advanced trail, the self-inflicted accident resulted in significantly more injuries than crash accident, while on medium trail, the percentage was similar. (Table 2)

The type of injury showed different patterns between skiers and snowboarders. More than half of the patients injured while skiing sustained lower extremity injuries, while the most common injury in snowboarders was upper extremity injury. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders. multipart injury took up 5.3% in skiers and 3.4% in snowboarders. (Table 3)

4. Discussion

The history of skiing industry in China is relatively short compared with European and North American countries. The skiing population in China concentrates in developed areas; however, the condition of terrain and climate in these areas are not suitable for large-scale ski resort. These environmental and socioeconomic factors bestow some specific characteristics on this novel sport in China. Inevitably, these characteristics are closely related to the injury pattern in Chinese skiers and snowboarders.

We found the incidence of sports injuries of recreational skiing and snowboarding to be 1.94 per 1000 skier days in China, which is similar to reported injury incidence of 1.35-3.7 per 1000 skier days in European and North American countries.[5-7]

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years), with 9.3% younger than 15 year-old and 3.0% older than 60 year-old. The mean age of skiers was older than snowboarders, which is consistent with other studies.[5,8] Suezie K et al.[5] conducted a study where they listed the top 10 injuries in adult and children/adolescent skiers and snowboarders. They found the overall injury pattern was similar between adults and children. However, wrist injury and lower extremity fracture were more likely to be seen in young injured snowboarders. In young skiers, anterior cruciate ligament tear was not prevalent, while tibial fracture was the fifth common injuries in children and adolescent skiers. In china, winter vocation for teenage students lasts for about 4 weeks around Chinese New Year, which creates a peak of teenage visitors to Chongli in January and February. Our results showed sports injury in teenagers concentrate in these two months, and took up nearly 9% of all injures.

Our results showed no significant difference in the sex profile between skiers and snowboarders, with male comprising the majority of the injured cases. Previous studies found female skiers are more susceptible to lower extremity injury, especially knee injuries, with nearly 50% of injured females

suffer from knee injury.[9] However, the present study found no predominance of female in lower extremity injuries in both sports groups. Paolo G et al.[10] found that men experienced more severe injuries than women, which may result from higher speed, body weight and trail difficulty in men.

Due to the small number of participants in other winter sports, such as cross-country, mountaineering, telemark and skiboarding, we divided the injured visitors from Wanlong Ski Resort into 2 categories: skiing and snowboarding. In fact, none of the injuries in our study took place during sports other than skiing or snowboarding. Snowboarding accounted for nearly 40% of the injured population in the latest season. Based on the previously published data, an increase of the percentage of snowboarders in total and injured winter sport population has been noticed.[5,11] Derived from skateboarding in 1970s, this young sport appeals to more young people and at the same time, reshapes the injury profile. In a study conducted in Big Sky area in United States, snowboarders took up 42.8% of injured visitors in the 2009-2010 season, while the number was 23.0% during the ski seasons from 1995-2000.[11] A number of research have found that snowboarders had significantly more injuries to the head, spine and upper extremity when compared with skiers, whereas skiers sustained significantly more lower extremity injures.[5,8] Our results revealed the same patterns, with higher rate of head, upper extremity injuries in snowboarders, and lower rate of lower extremity injuries. The injury severity in different sports was also compared in a study where the authors found the

percentage of mild, moderate and severe injuries in skiing to be 41%, 44% and 15% respectively, while the percentage in snowboarding to be 34%, 53% and 13%.[7] Concerning to head injury, Chad C.W et al. [8] found there was no significant difference in Glasgow Coma Scale between skiers and snowboarders with head injury.

Beginners and medium level skiers (63.5%) and snowboarders (81.4%) made up the majority of injured visitors; while in skiing population, advanced and expert skiers also took a remarkable portion of injuries. When comparing the type of injury between different level groups, no significant difference was found in neither skiers or snowboarders. In a study involving 19, 539 injured snowboarders in Japan, proportions of the trunk and multiple injuries were found to increase with increase in skill level; the injury severity was also found to increase with skill level.[12] Another study found no relationship between skill level and injury severity in skiing and snowboarding population once unconscious patients (who cannot report their skill level) were ruled out.[10]

Over two thirds of the injuries were self-inflicted, which is similar to the reported rate of self-inflicted injury on Austrian ski slopes.[13] Although the density of skiers/snowboarders on the slope in China is greater than in other countries, the composition of injury shares the same pattern, yet no available studies provide evidence of the influence factors of self-inflicted and crash injury rate.[14] The cause of injury was also found to be related with the type of injury in both skiers and snowboarders. Head injury took up a significantly

more portion in crash accident than in self-inflicted accident. In skiers, lower extremity injury had the highest rate in both self-inflicted accident and crash accident, while the rate was significantly higher in self-inflicted accident than in crash accident (Table 4). In snowboarders, upper extremity injury was no longer the most frequent injury in crash accident (Table 5).

The injury incidence calculated in our study is reported incidence in a ski resort clinic, which means the local hospital will be confronting potentially more traumatic cases. According to the government report, the total number of visits in ski resorts in Chongli hit nearly 1 million in the last season, which means an estimated number of more than 2,000 sports injuries in one season. From an epidemiological view, the present study provides strategies that can unload the burden and should be applied to other mountainside hospitals. First, establish pediatric orthopedic department to cope with the pediatric patients who take up nearly 10% of the whole injury population. Second, establish department of neurosurgery and oral and maxillofacial surgery in order to deal with the head injury. Third, rearrange the worktime schedule according to the time-related pattern of winter sports injury to increase effectiveness with limited manpower. Fourth, set up cardiovascular department to provide emergent care for major adverse cardiovascular events.

There existed several limitations in this study. First, the severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. Second, although medical providers in ski resort have collected

injury cases as through as possible, there were still patients who went to local or superior hospitals without primary care in ski resort clinics, or did not receive any type of medical help for mild injuries. Currently, we are conducting a large-scale survey on the demography of Chinese winter sports participants, and a prospective research of winter sports injury in skiing population in China to fill the gap of epidemiological study of winter sports injury in China.

5. Patient and public involvement

It was not appropriate to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

6. Acknowledgement

The medical director of Wanlong Ski Resort, Zhang Jinwei, provided help in the collection of injury data.

7. Funding

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8. Conflicts of interest

The author states no conflicts of interest.

9. Author Contributions

Chen Nayun carried out the data analysis and drafted the manuscript. Yang Yuping carried out the design of patient information registration chart, and helped to draft the manuscript. Ao Yingfang conceived of the study, and participated in its design.

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Tables and Figures

Table 1. Details of injured skiers and snowboarders

	Skiers (n=453)	Snowboarders (n=294)	P value
Sex, n (%)			
Male	281 (63.3%)	184 (62.6%)	0.846
Female	163` (36.7%)	110 (37.4%)	
Age, y	35.1±14.5	29.0±8.9	<0.01*
Skill level, n (%)			
Beginner	110 (29.5%)	101 (37.5%)	<0.01*
Medium	127 (34.0%)	118 (43.9%)	
Advanced	85 (22.8%)	37 (13.8%)	
Expert	51 (13.7%)	13 (4.8%)	

Table 2. Cause and location of accident

	Self-inflicted (n=486)	Crash (n=226)	P value
Beginner trail	93	18	<0.01*
Medium trail	103	87	
Advanced trail	292	121	

Table 3. Type of injuries in skiers and snowboarders

	Skiers (n=417)	Snowboarders (n=265)	P value
Head and cervical	57 (13.7%)	36 (13.6%)	<0.01*
Torso	83 (19.9%)	63 (23.8%)	
Upper extremity	79 (18.9%)	125 (47.2%)	

Lower extremity	222 (53.2%)	50 (18.9%)
Multipart	22 (5.3%)	9 (3.4%)

Table 4. The relationship between cause of injury and type of injury in skiers

	Head and cervical	Torso	Upper extremity	Lower extremity	Multipart injury	P value
Self-inflicted	21	53	53	171	9	<0.01
Crash	31	26	24	48	12	

Table 5. The relationship between cause of injury and type of injury in snowboarders

	Head and cervical	Torso	Upper extremity	Lower extremity	Multipart injury	P value
Self-inflicted	17	39	107	37	3	<0.01
Crash	19	22	16	12	6	

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	5-6
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-8

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8 NA NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

北京大学第三医院医学科学研究伦理委员会

Peking University Third Hospital Medical Science Research Ethics Committee

伦理审查批件

Ethical Review Approval Notice

（2019）医伦审第（516-01）号

项目编号	IRB00006761-M2019456	
临床试验项目名称	中国滑雪人群滑雪运动损伤研究	
项目来源	研究者自发	
试验类型	流调类	
产品名称	通用名：无	商品名：无
药物注册分类		期别：
CFDA药物临床试验批件号		
申办者/资助企业	无	
CRO公司	无	
临床试验单位及专业 /科室	北京大学第三医院/ 运动医学研究所	
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审查文件（必要可附表）	签名页 1-试验方案及参考文献 版本号2.0 版本日期2019.11.27 2-知情同意书豁免申请 3-保密说明 4-质量管理方案 5-项目风险的预评估及风险处置预案 版本号1.0 版本日期2019.11.20 6-经费来源保障说明 大众滑雪爱好者人口学调查问卷 版本1.0 2019.11.20	

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投票结果	同意1票	作必要修改后同意0票	转会议审查0票
审查决定	同意		
审查声明	确认伦理委员会组成和执行符合根据中华人民共和国国家食品药品监督管理总局2003年颁布实施的《药物临床试验质量管理规范》、ICH-GCP、卫计委2016年颁布实施的《涉及人的生物医学研究伦理审查办法》以及《赫尔辛基宣言》和国际医学科学组织委员会颁布的《人体生物医学研究国际道德指南》的伦理原则。 A statement confirming that the Ethics Committee is organized and operates according to Good Clinical Practice which is passed by CFDA in 2003, ICH-GCP, Biomedical Research Ethics Review involving human which is passed by Ministry of Health in 2007, HelsinkiDeclaration and ethical principles of International ethical guidelines for biomedical research involving human subjects which is passed by Council for International Organizations of Medical Science (CIOMS).		
审查意见	该研究符合伦理审查要求，同意开展。		
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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective study

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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective study

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Abstract

Objective: The aim of the study is to investigate the current injury patterns in skiing/snowboarding population in China, and to provide evidence for better practice in mountainside hospital near ski resort.

Design: Retrospective study

Methods: A retrospective study was performed in Wanlong Ski Resort in Chongli. The data of all injured skiers and snowboarders treated in the resort clinic during season 2018-2019 was collected. Patients information, including sex, age, equipment, ski level, injured body part was analyzed.

Results: A total of 753 sports injuries were recorded. The estimated incidence of injury was 1.94 per 1000 skier days. 453 cases (60.2%) were associated with skiing. The mean age of skiers was older than snowboarders (35.1±14.5 vs. 29.0±8.9, $p<0.01$). Injury not involving others took up 67.9% of all injuries. The most common injured body part in skiers was lower extremity injuries; while in snowboarders, it was upper extremity injuries. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders.

Conclusion: The incidence of skiing/snowboarding injury in China is similar to previous studies. The injury pattern differs according to different sports and cause of injury.

Key words: Sports injury, Skiing, Snowboarding

Strength and limitations of this study:

1. Since Beijing was selected to host the 2022 Winter Olympics, skiing and snowboarding population in China has risen rapidly. The present study is the first epidemiological study investigating the injury patterns in Chinese ski resort.

2. This study provided evidence for restructuring the local hospital in the host city of 2022 Winter Olympic Games.

3. Several limitations exist in this study. The severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. There were still patients who went to local or superior hospitals directly, or did not receive any type of medical help for mild injuries. In this case, the incidence of injury may be underestimated.

1. Introduction

Skiing and snowboarding are popular winter sports world-wide but have a substantial risk of sports injuries, with reported incidence of 0.5-1.35 injuries per 1000 skier/snowboarder days in recreational skiers/snowboarders[1-3] and 6.9 injuries per 1000 runs (or 26.8 injuries per 100 athletes per season)[4] in professional alpine skiers in recent years. In the latest Winter Olympic Games in PyeongChang, 12% of the athletes incurred at least one injury, equaling 12.6 injuries per 100 athletes over the 17-day period[5].

The history of skiing industry in China is relatively short compared with European and North American countries. Since Beijing was selected to host the 2022 Winter Olympics, skiing and snowboarding population in China has risen from 8 million in 2015 to 13.2 million in 2018 (industry annual report, 2019). The skiing population in China concentrates in developed areas; however, large-scale ski resorts in China are often located in areas far away from major cities. Undoubtfully, hospitals close to ski resorts have been confronted an increasing amount of injured skiers and snowboarders; yet they are uncapable to ingest large number of patients or manage the treatment of severe injuries.

To the best of our knowledge, there is no epidemiological study investigating current injury patterns in recreational skiers and snowboarders in

China. The purpose of the study is to explore the injury patterns of skiers and snowboarders in China by investigating the largest ski resort in the host city of 2022 Winter Olympic Games, and to provide the primitive data to guide the restructure of the hospital near the venues of the 2022 Winter Olympic Games.

2. Patients and Methods

The data of this retrospective study was collected from the resort clinic of Wanlong Ski Resort in Chongli during ski season 2018-2019 (Figure 1). The resort clinic is responsible for treating mild injury and other common diseases, transferring patients to local hospital, carrying out basic life support for life-threatening injuries, and recording every injury that is seen by patrol or clinic staff.

Besides patient's name, sex and age, we also recorded equipment, skill level, the date and time of injury, the cause of injury, the slope difficulty and the injured body part. Equipment was classified into skis and snowboards. Special equipment, such as cross-country skis, skiboards, was rare in China and not seen in recorded injured people. According to self-reported years of participation in skiing and snowboarding, patients were classified as beginner (first season), medium (1-5 years), advanced (5-10 years) and expert (≥10 years). The date of injury was divided into weekdays and weekends/holidays according to the Chinese government holiday arrangement. The business hour of Wanlong Ski Resort is 8:00-16:00, so we split the time of injury into 4

periods with 2 hours each, morning (first 2 hours of business), noon, afternoon and late afternoon (last 2 hours of business). According to the subjective description of injury scene, we summarized 2 types of causes of injury: not involving others, defined as falling or crashing without any body contact with others; and involving others, defined as crashing involving 2 or more people. The slope difficulty was also collected and categorized into beginner trail, medium trail and advanced trail according to the official data of slope inclination angle. Injured body part was categorized into the following 4 anatomical body regions: (1) head/cervical, (2) torso, (3) upper extremity, and (4) lower extremity. Acromioclavicular joint injuries were classified as upper limb injury, while other clavicle injures were classified as torso injuries.[6] Injuries involving gluteal region were classified as torso injury. Whether patients have multi-part injuries was also recorded, while each injured body part was counted in one of the above groups. The relationship between injured body part and sex, age, equipment and cause of injury was further determined by subgroup analysis.

This study was approved by Peking University Third Hospital Medical Science Research Ethics Committee.

Statistical analysis

All statistical analysis was performed with SPSS (v 24.0; IBM Corp). Sex, skill level and injured body part were compared between skiers and snowboarders using Chi-squared test. Injured body part and slope difficulty

were compared between injury involving others and injury not involving others using Chi-squared test. Student t test was used to compare age between skiers and snowboarders. When there is missing data, the available case was analyzed to determine difference between groups. P<0.05 was considered to indicate statistical significance.

3. Results

Demographic

During the season of 2018-2019, there were 388606 visits and 753 sports injuries recorded in Wanlong Ski Resort. The estimated incidence of injury was 1.94 per 1000 skier days.

Among these injuries, 453 cases (60.2%) were associated with skiing. The mean age of skiers was 35.1±14.5 years, whereas the mean age of snowboarders was 29.0±8.9 years (p<0.01). There were 78 patients (10.4%) under 18 years old, 22 patients (3.0%) over the age of 60. There was no significant difference in the sex profile between skiers and snowboarders, with 63.4% of skiers and 62.6% of snowboarders being male. Among the whole injury population, 32.8% were beginners, while 38.3% of them were medium level, 19.0% were advanced, and 10.0% were expert. Table 1 shows more detailed demographic profiles of these injuries.

The features of injury

The season of 2018-2019 in Wanlong Ski Resort lasted for 158 days, from 2018/11/1-2019/4/7, consisting of 107 weekdays and 51 weekends/holidays according to the Chinese government arrangement. The average daily number of injuries was 3.38 on weekdays and 7.65 on weekends/holidays. Within a day, 9.7% of the injury occurred in the first 2 hours of business, 31.6% in noon, 22.0% in afternoon, and 36.7% in the last 2 hours of business.

The percentage of injuries happened on beginner, medium and advanced trails were 15%, 27.8% and 57.2% respectively. Accident not involving others took up 67.9% of all injuries. On beginner and advanced trails, the accident not involving others resulted in significantly more injuries, while on medium trail, the proportion of accident involving others or not was similar. (Table 2)

The injured body part showed different patterns between skiers and snowboarders. More than half of the patients injured while skiing sustained lower extremity injuries, while the most common injury in snowboarders was upper extremity injury. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders. multipart injury took up 5.3% in skiers and 3.4% in snowboarders (Table 3). The cause of injury was also found to be related with the injured body part in both skiers and snowboarders. Head injury took up a significantly more portion in accident involving others. In skiers, lower extremity injury had the highest rate in both accident involving others and accident not involving others, while the rate was significantly higher in accident not involving others (Table 4). In snowboarders, upper

extremity injury was no longer the most frequent injury in accident involving others (Table 5). The correlation between age, sex, skill level and injured body part was not significant. (Supplementary Tables 1-6)

4. Discussion

The aim of the present study is to explore the injury patterns of skiers and snowboarders in China by investigating the largest ski resort in the host city of 2022 Winter Olympic Games, and to provide the primitive data to guide the restructure of the hospital near the venues of the 2022 Winter Olympic Games.

Injury incidence

It is found that the incidence of sports injuries of recreational skiing and snowboarding is 1.94 per 1000 skier days in Wanlong ski resort, which lies between the reported injury incidence of 0.5-3.7 per 1000 skier days in European and North American countries in recent years.[1,7-9] According to the government report, the total number of visits in ski resorts in Chongli hit nearly 1 million in the 2018-19 ski season, which means an estimated number of 2,000 sports injuries. The injury incidence calculated in our study is based on data collected from ski resort clinic, which means the local hospital will be confronting potentially more traumatic cases.

Injury patterns

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years), with 10.4% younger than 18 years old and 3.0% older than the age of 60. The mean age of skiers was older than snowboarders, which is consistent with other studies.[7,10] In china, winter vacation for teenage students lasts for about 4 weeks around Chinese New Year, which creates a peak of teenage visitors to Chongli in January and February. The results showed sports injury in teenagers concentrate in these two months, and took up nearly 11% of all injures. The incidence of ski injury was reported higher in teenagers than in adults.[11] Suezie K et al.[7] conducted a study where they listed the top 10 injuries in adult and children/adolescent skiers and snowboarders. They found the overall injury patterns were similar between adults and children. However, wrist injury and lower extremity fracture were more likely to be seen in young injured snowboarders. In young skiers, anterior cruciate ligament tear was not prevalent, while tibial fracture was the fifth common injuries in children and adolescent skiers.

No significant difference was shown in the sex profile between injured skiers and snowboarders. Previous studies found female skiers are more susceptible to lower extremity injury, especially knee injuries, with nearly 50% of injured females suffer from knee injury.[12] The present study found similar rate of female suffering from lower extremity injuries in skiing population; however, there was no significant difference in injured body part

between males and females in both sports groups. Paolo G et al.[13] found that men experienced more severe injuries than women, which may result from higher speed, body weight and trail difficulty in men.

Due to the small number of participants in other winter sports, such as cross-country, mountaineering, telemark and skiboarding, we divided the injured visitors from Wanlong Ski Resort into 2 categories: skiing and snowboarding. Snowboarding accounted for nearly 40% of the injured population in the latest season. Based on the previously published data, an increase of the percentage of snowboarders in total and injured winter sport population has been noticed.[7,14] Derived from skateboarding in 1970s, this young sport appeals to more young people and at the same time, reshapes the injury profile. In a study conducted in Big Sky area in United States, snowboarders took up 42.8% of injured visitors in the 2009-2010 season, while between 1995 and 2000 only 23.0% of injured people were snowboarders.[14] Many studies reported that snowboarders had significantly more injuries to the head, spine and upper extremity when compared with skiers, whereas skiers sustained significantly more lower extremity injures.[7,10,15] The present study revealed the same patterns, with higher rates of head, upper extremity injuries in snowboarders, and lower rates of lower extremity injuries. In a study comparing injury severity in different sports, the authors reported that the percentage of mild, moderate and severe injuries in skiing were 41%, 44% and 15% respectively, while the percentage in

snowboarding were 34%, 53% and 13%.[9] Maat SC et al. [15]reported that skiers were more seriously injured with Injury Severity Scale (ISS) higher than 9.

Beginners and medium level skiers (63.5%) and snowboarders (81.4%) made up the majority of injured visitors. When comparing the injured body part between different level groups, no significant difference was found in neither skiers nor snowboarders. In a study involving 19539 injured snowboarders in Japan, proportions of the trunk and multiple injuries were found to increase with higher skill level; the injury severity was also found to increase with skill level.[16] Another study found no relationship between skill level and injury severity in skiing and snowboarding population once unconscious patients (who cannot report their skill level) were ruled out.[13]

Over two thirds of the injuries did not involve others, which is lower than the reported rate of self-inflicted injury on Austrian ski slopes.[3] The difference are likely attributed to the higher density of skiers/snowboarders on the slope in China compared with other countries, which is implied by the fact that the rate of crash accident was extremely high on medium trails. Yet, no available studies provide conclusive evidence of the influence factors of self-inflicted and crash injury rate.[17] The cause of injury was also found to be related with the injured body part in both skiers and snowboarders. Head injury took up a significantly more portion in accident involving others. Sport-specific injuries, such as shoulder injury in snowboarding and knee injury in skiing,[7] were more frequent in accident not

involving others. These findings can be attributed to different injury mechanism prevalent in various traumatic setting, with non-contact injury often causing ligament and tendon sprains or tears, contact injury causing bony injury and concussion.[18]

Strategies to local hospital

From an epidemiological view, the present study provides strategies that can guide the restructure of local hospital and unload the burden in winter season. First, establish pediatric orthopedic department to cope with the pediatric patients who take up nearly 11% of the whole injury population, especially the surge during winter vacation in China. Second, establish department of neurosurgery and department of oral and maxillofacial surgery in order to deal with the head and face injury, which took up to 15% of all injuries. Third, rearrange the worktime schedule according to the time-related "tide" of winter sports injury to increase effectiveness with limited manpower. For example, change weekends into work days and set other rest days in winter season to cope with the traumatic cases in weekend which are twice as many as in weekdays. Fourth, build up communication and cooperation network with nearby ski resorts to allow access to critical patient's information in advance and guide prehospital care. Up to now, the local hospital in Chongli has reinforced its orthopedics and sports medicine department by seeking cooperation with superior hospitals in Beijing. An evidence-based

restructure of local hospital may increase the accessibility to health care for injured skiers and snowboarders in nearby ski resorts.

Several limitations exist in this study. First, the severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. Second, although medical providers in ski resort have collected injury cases as through as possible, there were still patients who went to local or superior hospitals directly, or did not receive any type of medical help for mild injuries. In this case, the incidence of injury may be underestimated. Currently, we are conducting a large-scale survey on the demography of Chinese winter sports participants, and a prospective research of winter sports injury in skiing population in China to fill the gap of epidemiological study of winter sports injury in China. The effectiveness of hospital restructure will be reported as well.

5. Patient and public involvement

It was not appropriate to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

6. Acknowledgement

The medical director of Wanlong Ski Resort, Zhang Jinwei, provided help in the collection of injury data.

7. Funding

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8. Conflicts of interest

The author states no conflicts of interest.

9. Author Contributions

Chen Nayun carried out the data analysis and drafted the manuscript. Yang Yuping carried out the design of patient information registration chart, and helped to draft the manuscript. Ao Yingfang conceived of the study, and participated in its design.

10. Data availability statement

The data in the present study is deidentified participant data which are available upon reasonable request. Please contact the first author for permission to reuse the original data. Email: albert_west@163.com

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373

374 Tables and Figures

375 Table 1. Details of injured skiers and snowboarders

	Skiers (n=453)	Snowboarders (n=294)	P value
Sex, n (%)			
Male	281 (63.3%)	184 (62.6%)	0.846
Female	163` (36.7%)	110 (37.4%)	
Age, y	35.1±14.5	29.0±8.9	<0.01*
Skill level, n (%)			
Beginner	110 (29.5%)	101 (37.5%)	<0.01*
Medium	127 (34.0%)	118 (43.9%)	
Advanced	85 (22.8%)	37 (13.8%)	
Expert	51 (13.7%)	13 (4.8%)	

376

377 Table 2. Cause of injury and slope difficulty

	Injury not involving others (n=486)	Injury involving others (n=226)	P value
Beginner trail	93	18	<0.01*
Medium trail	103	87	
Advanced trail	292	121	

Table 3. injured body part in skiers and snowboarders

	Skiers (n=417)	Snowboarders (n=265)	P value
Head and cervical	57 (13.7%)	36 (13.6%)	<0.01*
Torso	83 (19.9%)	63 (23.8%)	
Upper extremity	79 (18.9%)	125 (47.2%)	
Lower extremity	222 (53.2%)	50 (18.9%)	
Multipart	22 (5.3%)	9 (3.4%)	

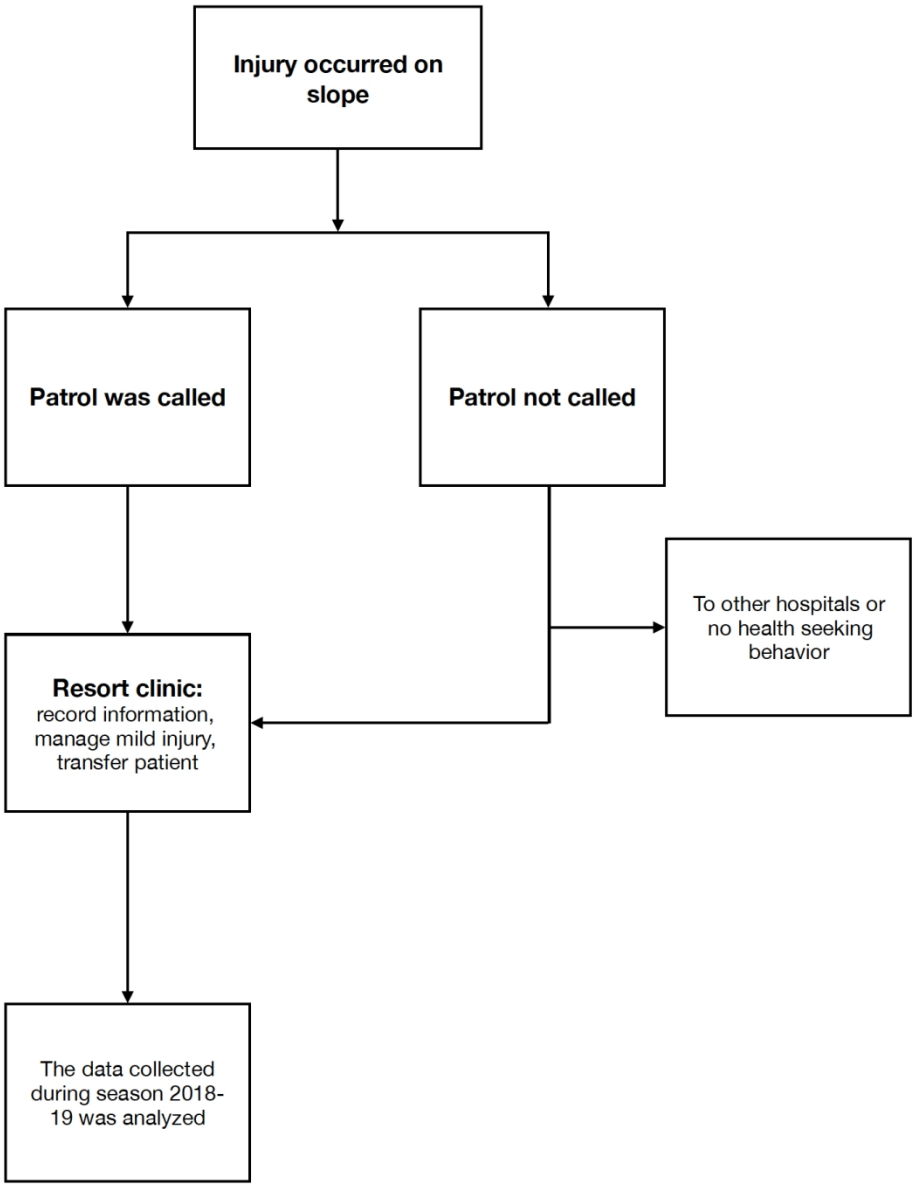
Table 4. The relationship between cause of injury and injured body part in skiers

	Injury not involving others (n=289)	Injury involving others (n=116)	P value
Head and cervical	21(7.3%)	31(26.7%)	<0.01
Torso	53(18.3%)	26(22.4%)	
Upper extremity	53(18.3%)	24(20.7%)	
Lower extremity	171(59.2%)	48(41.4%)	
Multipart injury	9(3.1%)	12(10.3%)	

Table 5. The relationship between cause of injury and injured body partin snowboarders

	Injury not involving others (n=197)	Injury involving others (n=63)	P value
Head and cervical	17(8.6%)	19(30.1%)	<0.01
Torso	39(19.8%)	22(34.9%)	
Upper extremity	107(54.3%)	16(25.4%)	
Lower extremity	37(18.8%)	12(19.0%)	
Multipart injury	3(1.5%)	6(9.5%)	

Figure 1. The flow chart on how the injury occurred in the ski resort was managed. If the patrol was called, the injured tourist will be sent to the resort clinic where further management was performed. If the patrol was called, the injured tourists may self-present to the resort clinic or go to other hospitals without seeing the clinic staff first, or even have no health-seeking behavior. The data in this study was collected during 2018-19 winter season.



The flow chart on how the injury occurred in the ski resort was managed. If the patrol was called, the injured tourist will be sent to the resort clinic where further management was performed. If the patrol was called, the injured tourists may self-present to the resort clinic or go to other hospitals without seeing the clinic staff first, or even have no health-seeking behavior. The data in this study was collected during 2018-19 winter season.

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Table 1. The relationship between sex and injured body part in skiers

	Male (n=260)	Female (n=158)	P value
Head and cervical	32(12.3%)	25(15.8%)	0.29
Torso	58(22.3%)	24(15.2%)	
Upper extremity	51(19.6%)	28(17.7%)	
Lower extremity	131(50.4%)	91(57.6%)	
Multipart injury	12(4.6%)	10(6.3%)	

Table 2. The relationship between sex and injured body part in snowboarders

	Male (n=158)	Female (n=107)	P value
Head and cervical	21(13.3%)	15(14.0%)	0.63
Torso	42(25.6%)	21(19.6%)	
Upper extremity	74(46.8%)	51(47.7%)	
Lower extremity	26(16.5%)	24(22.4%)	
Multipart injury	5(3.2%)	4(3.7%)	

Table 3. The relationship between age and injured body part in skiers

	Teenager (n=52)	Adult (n=329)	Elderly (n=22)	P value
Head and cervical	15(28.8%)	39(11.9%)	2(9.1%)	0.14
Torso	6(11.5%)	70(21.3%)	4(18.2%)	
Upper extremity	12(23.1%)	57(17.3%)	8(36.4%)	
Lower extremity	22(42.3%)	179(54.4%)	11(50%)	
Multipart injury	3(5.8%)	16(4.9%)	3(13.6%)	

Table 4. The relationship between age and injured body part in snowboarders

	Male (n=26)	Female (n=238)	Elderly (n=0)	P value
Head and cervical	6(23.1%)	30(12.6%)	0	0.21
Torso	4(15.4%)	59(25.2%)	0	
Upper extremity	15(57.7%)	109(45.8%)	0	
Lower extremity	2(7.7%)	48(20.2%)	0	
Multipart injury	1(3.8%)	8(3.4%)	0	

Table 5. The relationship between skill level and injured body part in skiers

	Beginner (n=106)	Medium (n=118)	Advanced (n=79)	Expert (n=49)	P value
Head and cervical	13(28.8%)	12(11.9%)	11(9.1%)	5(%)	0.19
Torso	18(11.5%)	27(21.3%)	16(18.2%)	10(%)	
Upper extremity	22(23.1%)	18(17.3%)	15(36.4%)	13(%)	
Lower extremity	54(42.3%)	164(54.4%)	48(50%)	24(%)	
Multipart injury	2(5.8%)	4(4.9%)	9(13.6%)	3(%)	

Table 6. The relationship between skill level and injured body part in snowboarders

	Beginner (n=93)	Medium (n=109)	Advance (n=36)	Expert (n=11)	P value
Head and cervical	15(23.1%)	11(12.6%)	5	1	0.32
Torso	20(15.4%)	27(25.2%)	10	2	
Upper extremity	46(57.7%)	51(45.8%)	14	7	
Lower extremity	14(7.7%)	26(20.2%)	8	8	

Multipart injury	2(3.8%)	6(3.4%)	1	0

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-8

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective study

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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective study

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Word Count：2848

Abstract

Objective: The aim of the study is to describe the injury patterns in recreational skiers and snowboarders in China, and to provide the primitive data to guide the restructure of regional health care facility to deal with the increasing number of participants in snow sports. The secondary goal is to compare injury patterns in different subgroups.

Design: Retrospective study

Methods: A retrospective study was performed in Wanlong Ski Resort in Chongli. The data of all injured skiers and snowboarders treated in the resort clinic during season 2018-2019 was collected. Patients information, including sex, age, equipment, ski level, injured body part was analyzed.

Results: A total of 753 sports injuries were recorded. The estimated incidence of injury was 1.98 per 1000 skier days. 453 cases (60.2%) were associated with skiing. The mean age of skiers was older than snowboarders (35.1±14.5 vs. 29.0±8.9, $p<0.01$). Injury not involving others took up 67.9% of all injuries. The most common injured body part in skiers was lower extremity injuries; while in snowboarders, it was upper extremity injuries. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders.

Conclusion: The incidence of skiing/snowboarding injury in China is similar to previous studies. The injury pattern differs according to different sports and cause of injury.

Key words: Sports injury, Skiing, Snowboarding

Strength and limitations of this study:

1. Since Beijing was selected to host the 2022 Winter Olympics, skiing and snowboarding population in China has risen rapidly. The present study is the first epidemiological study investigating the injury patterns in Chinese ski resort.

2. This study provided evidence for restructuring the local hospital in the host city of 2022 Winter Olympic Games.

3. Several limitations exist in this study. The severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. There were still patients who went to local or superior hospitals directly, or did not receive any type of medical help for mild injuries. In this case, the incidence of injury may be underestimated.

1. Introduction

Skiing and snowboarding are popular winter sports world-wide but carry a substantial risk of sports injuries, with reported incidence of 0.5-1.35 injuries per 1000 skier/snowboarder days in recreational skiers/snowboarders[1-3] and 6.9 injuries per 1000 runs (or 26.8 injuries per 100 athletes per season)[4] in professional alpine skiers in recent years. In the latest Winter Olympic Games in PyeongChang, 12% of the athletes incurred at least one injury, equaling 12.6 injuries per 100 athletes over the 17-day period[5].

Since Beijing was selected to host the 2022 Winter Olympics, skiing and snowboarding population in China has risen from 8 million in 2015 to 13.2 million in 2018 (industry annual report, 2019). The skiing population in China concentrates in developed areas; however, large-scale ski resorts in China are often located in areas remote from major cities. Undoubtfully, hospitals close to ski resorts have confronted an increasing number of injured skiers and snowboarders. It is important that regional facilities are equipped to ingest large number of patients and manage severe injuries.

The aim of the study is to describe the injury patterns in recreational skiers and snowboarders in China by investigating the largest ski resort in the host city of 2022 Winter Olympic Games, and to provide the primitive data to guide the restructure of the local hospital to deal with the increasing number of participants in snow sports. The secondary goal is to compare injury patterns in different subgroups.

2. Patients and Methods

The data of this retrospective study was collected from the resort clinic of Wanlong Ski Resort in Chongli during ski season 2018-2019. Wanlong Ski Resort is a destination ski resort in Northern China, which has various terrain and the largest number of annual visits. The resort clinic is staffed by a registered general practitioner and a nurse, and is responsible for the primary care of all injured visitors, whether self-present or sent by patrols; it is also responsible for treating mild injury, transferring patients to local hospital, carrying out basic life support for life-threatening injuries. The season of 2018-2019 in Wanlong Ski Resort lasted for 158 days, from 2018/11/1-2019/4/7. A total of 388606 visits (379503 skier days) were recorded.

Besides patient's name, sex and age, we also recorded equipment, skill level, the date and time of injury, the cause of injury, the slope difficulty and the injured body part. Equipment was classified into skis and snowboards. Special equipment, such as cross-country skis, skiboards, was rare in China and not seen in recorded injured people. According to self-reported years of participation in skiing and snowboarding, patients were classified as beginner (first season), medium (1-5 years), advanced (5-10 years) and expert (≥10 years). The date of injury was divided into weekdays and weekends/holidays according to the Chinese government holiday arrangement. The business hour of Wanlong Ski Resort is 8:00-16:00, so we split the time of injury into 4 periods with 2 hours each, morning (first 2 hours of business), noon,

afternoon and late afternoon (last 2 hours of business). According to the subjective description of injury scene, we summarized 2 types of causes of injury: not involving others, defined as falling or crashing without any body contact with others; and involving others, defined as crashing involving 2 or more people. The slope difficulty was categorized into beginner trail, medium trail and advanced trail according to the official data of slope inclination angle. Injured body parts were categorized into the following 4 anatomical body regions: (1) head/cervical, (2) torso, (3) upper extremity, and (4) lower extremity. Acromioclavicular joint injuries were classified as upper limb injury, while other clavicle injures were classified as torso injuries.[6] Injuries involving gluteal region were classified as torso injury. Whether patients have multi-part injuries was also recorded, while each injured body part was counted in one of the above groups. The relationship between injured body part and sex, age, equipment and cause of injury was further determined by subgroup analysis.

The present study is epidemiological and anonymous, therefore informed consent was not applicable. This study was approved by Peking University Third Hospital Medical Science Research Ethics Committee.

Statistical analysis

All statistical analysis was performed with SPSS (v 24.0; IBM Corp). Continuous variables were presented as mean and standard deviations, while categorical data were presented with frequency count and percentages. To do comparison between subgroups, Chi-squared test was used for categorical

variables and student t test was used for continuous variables. When there is missing data, the available case was analyzed to determine difference between groups. P<0.05 was considered to indicate statistical significance.

3. Results

During the study period, there were 388606 visits (379503 skier days) and 753 cases of injury recorded in Wanlong Ski Resort. The estimated incidence of injury was 1.98 per 1000 skier days.

Features of injury

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years). Pediatric patients under 15 years old took up 9.3%, while senior patients (over the age of 60) took up 3.0% of all injured population. The number of males was twice as females. Among these injuries, 453 cases (60.2%) were associated with skiing. Table 1 shows more detailed demographic and sport-related profiles of these injuries.

The season of 2018-2019 in Wanlong Ski Resort consisted of 107 weekdays and 51 weekends/holidays according to the Chinese government arrangement. The average daily number of injuries was 3.38 on weekdays and 7.65 on weekends/holidays. A peak of pediatric cases was noted in January and February (Figure 1). Within a day, the percentage of injury occurred in morning, noon, afternoon and late afternoon was 9.7%, 31.6%, 22.0% and 36.7% respectively.

Accidents not involving others took up 67.9% of all injuries. The most common injured body parts were upper and lower limbs, which made up 28.4% and 37.6% of all injuries respectively. Head and cervical injuries also took up a notable portion of injuries (13.1%).

Injury pattern in subgroups

The mean age of skiers was 35.1±14.5 years, whereas the mean age of snowboarders was 29.0±8.9 years ($p<0.01$). There was no significant difference in the sex profile between skiers and snowboarders.

The injured body parts showed different patterns between skiers and snowboarders. More than half of the patients injured while skiing sustained lower extremity injuries, while the most common injury in snowboarders was upper extremity injury. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders. Multipart injury took up 5.3% in skiers and 3.4% in snowboarders (Table 2). The cause of injury was also found to be related with the injured body parts in both skiers and snowboarders. Head injury took up a significantly more portion in accidents involving others. In skiers, lower extremity injury had the highest rate in both accidents involving others and accidents not involving others, while the rate was significantly higher in accidents not involving others (Table 3). In snowboarders, head, cervical and torso injury took up a greater portion in accidents involving others (Table 4). The correlation between age, sex, skill level and injured body parts was not significant. (Supplementary Tables 5-10)

4. Discussion

We found that the incidence of snow sports related injury of recreational skiing and snowboarding population in China's largest ski resort was 1.98 per 1000 skier days, which was comparable to reported injury incidence of 0.5-3.7 per 1000 skier days in European and North American countries in recent years.[1,7-9] According to the government report, the total number of visits in ski resorts in Chongli hit nearly 1 million in the 2018-19 ski season, which means an estimated number of 2,000 sports injuries per season if such finding is extrapolated to the whole region. Therefore, a better understanding of injury pattern in Chinese population will guide the reform of local health care facility and help dealing with the seasonal increase of sports injury.

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years), with 9.3% younger than 15 years old. In china, winter vacation for teenage students lasts for about 4 weeks around Chinese New Year, which creates a peak of teenage visitors to Chongli in January and February. We found that sports injury in teenagers concentrated in January and February, and took up nearly 15% of injuries occurred in these two months. The incidence of ski injury was reported higher in teenagers than in adults.[10] An increase of pediatric patients of snow sports injury will be seen in the future, as more young people participate in these activities.

Previous studies found female skiers are more susceptible to lower extremity injury, especially knee injuries, with nearly 50% of injured females suffer from knee injury.[11] The present study found similar rate of females suffering from lower extremity injuries in skiing population; however, there was no significant difference in injured body parts between males and females in both sports groups. Paolo G et al.[12] found that men experienced more severe injuries than women, which may result from higher speed, body weight and trail difficulty in men.

Snowboarding accounted for nearly 40% of the injured population in the latest season. Based on the previously published data, an increase of the percentage of snowboarders in total and injured winter sport population has been noticed.[7,13] Derived from skateboarding in 1970s, this young sport appeals to more young people and at the same time, reshapes the injury profile. In a study conducted in Big Sky area in United States, snowboarders took up 42.8% of injured visitors in the 2009-2010 season, while between 1995 and 2000 only 23.0% of injured people were snowboarders.[14] Many studies reported that snowboarders had significantly more injuries to the head, spine and upper extremity when compared with skiers, whereas skiers sustained significantly more lower extremity injures.[7,14,15] The present study revealed the same patterns, with higher rates of head, upper extremity injuries in snowboarders, and lower rates of lower extremity injuries. In a study comparing injury severity in different sports, the authors reported that the

percentage of mild, moderate and severe injuries in skiing were 41%, 44% and 15% respectively, while the percentage in snowboarding were 34%, 53% and 13%.[9] Maat SC et al. [15]reported that skiers were more seriously injured with Injury Severity Scale (ISS) higher than 9.

Beginners and medium level skiers (63.5%) and snowboarders (81.4%) made up the majority of injured visitors. In a study involving 19539 injured snowboarders in Japan, proportions of the trunk and multiple injuries were found to increase with higher skill level; the injury severity was also found to increase with skill level.[16] Another study found no relationship between skill level and injury severity in skiing and snowboarding population once unconscious patients (who cannot report their skill level) were ruled out.[13]

Over two thirds of the injuries did not involve others, which is lower than the reported rate of self-inflicted injury on Austrian ski slopes.[3] The difference are likely attributed to the higher density of skiers/snowboarders on the slope in China compared with other countries, which is implied by the fact that the rate of crash accident was extremely high on medium trails. (Supplementary Table11) Yet, no available studies provide conclusive evidence of the influence factors of self-inflicted and crash injury rate.[17] The cause of injury was also found to be related with the injured body parts in both skiers and snowboarders. Head injury took up a significantly more portion in accidents involving others. Sport-specific injuries, such as shoulder injury in snowboarding and knee injury in skiing,[7] were more

frequent in accidents not involving others. These findings can be attributed to different injury mechanism prevalent in various traumatic setting, with non-contact injury often causing ligament and tendon sprains or tears, contact injury causing bony injury and concussion.[18]

From an epidemiological view, the present study provides strategies that can guide the restructure of local hospital and unload the burden in winter season. First, establish pediatric orthopedic department to cope with the pediatric patients who take up nearly 10% of the whole injury population, especially the surge during winter vacation in China. Second, establish department of neurosurgery and department of oral and maxillofacial surgery in order to deal with the head and face injury, which took up to 13% of all injuries. Third, rearrange the worktime schedule according to the time-related "tide" of winter sports injury to increase effectiveness with limited manpower. For example, change weekends into work days and set other rest days in winter season to cope with the traumatic cases in weekend which are twice as many as in weekdays. Fourth, intensive care unit is crucial to manage severe injuries as the population of snowboarders, higher skill level and young participant grow bigger, because these populations are at higher risk of severe injuries according to previous studies. Fifth, build up communication and cooperation network with nearby ski resorts to allow access to critical patient's information in advance and guide prehospital care. Although the present study did not provide information about injury severity and number of

patients who need transfer and further treatment, up to 60% of injured skiers and snowboarders seen in resort clinic require transfer to hospital based on existing literature.[9] Up to now, the local hospital in Chongli has reinforced its orthopedics and sports medicine department by seeking cooperation with superior hospitals in Beijing. An evidence-based restructure of local hospital may increase the accessibility to health care for injured skiers and snowboarders in nearby ski resorts.

Several limitations exist in this study. First, the severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. Second, although medical providers in ski resort have collected injury cases as through as possible, there were still patients who went to local or superior hospitals directly, or did not receive any type of medical help for mild injuries. In this case, the incidence of injury may be underestimated. Additionally, the injury severity and number of patients who needed transfer was incomplete, so we were unable to estimate the burden of local hospital in skiing season. Currently, we are conducting a large-scale survey on the demography of Chinese winter sports participants, and a prospective research of winter sports injury in skiing population in China to fill the gap. The effectiveness of hospital restructure will be reported as well.

5. Patient and public involvement

It was not appropriate to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

6. Acknowledgement

The medical director of Wanlong Ski Resort, Zhang Jinwei, provided help in the collection of injury data.

7. Funding

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8. Conflicts of interest

The author states no conflicts of interest.

9. Author Contributions

Chen Nayun carried out the data analysis and drafted the manuscript. Yang Yuping carried out the design of patient information registration chart, and helped to draft the manuscript. Ao Yingfang conceived of the study, and participated in its design.

10. Data availability statement

The data in the present study is deidentified participant data which are available upon reasonable request. Please contact the first author for permission to reuse the original data. Email: albert_west@163.com

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Tables and Figures

Table 1. Demographic and sport-related information of injured population

	n (%)
Sex	
Male	475 (63.3%)
Female	278 (36.7%)
Age	
<15 years	68 (9.3%)
15-60 years	643 (87.7%)
>60 years	22 (3.0%)
Equipment	
Ski	453 (60.6%)
Snowboard	294 (39.4%)

Skill level	
Beginner	211 (29.5%)
Medium	246 (34.0%)
Advanced	122(22.8%)
Expert	64 (13.7%)
Slope difficulty	
Beginner trail	111(15.3%)
Medium trail	206 (26.5%)
Advanced trail	425 (58.1%)

Table 2. Details of injured skiers and snowboarders

	Skiers (n=453)	Snowboarders (n=294)	P value
Sex, n (%)			
Male	281 (63.3%)	184 (62.6%)	0.846
Female	163` (36.7%)	110 (37.4%)	
Age, n (%)			
<15 years	44 (10.3%)	22 (7.5%)	<0.01*
15-60 years	363 (84.6%)	270 (92.5%)	
>60 years	22 (5.1%)	0 (0%)	
Skill level, n (%)			

Beginner	110 (29.5%)	101 (37.5%)	<0.01*
Medium	127 (34.0%)	118 (43.9%)	
Advanced	85 (22.8%)	37 (13.8%)	
Expert	51 (13.7%)	13 (4.8%)	
Date of Injury, n (%)			
Weekdays	223 (50.2%)	134 (45.7%)	0.232
Weekends/Holidays	221 (49.8%)	159 (54.3%)	
Time of injury, n (%)			
Morning	44 (10.1%)	28 (9.9%)	0.466
Noon	137 (31.6%)	89 (31.3%)	
Afternoon	86 (19.8%)	69 (24.3%)	
Late afternoon	167 (38.5%)	98 (34.5%)	
Slope difficulty, n (%)			
Beginner trail	67 (15.3%)	42 (14.4%)	0.868
Medium trail	116 (26.5%)	82 (28.2%)	
Advanced trail	254 (58.1%)	167 (57.4%)	
Cause of injury, n (%)			
Involving others	153 (32.5%)	97 (30.6%)	0.680
Not involving others	291 (67.5%)	197 (69.4%)	
Injured body part, n (%)			
Head and cervical	57 (13.7%)	36 (13.6%)	<0.01*
Torso	83 (19.9%)	63 (23.8%)	

Upper extremity	79 (18.9%)	125 (47.2%)
Lower extremity	222 (53.2%)	50 (18.9%)
Multipart	22 (5.3%)	9 (3.4%)

Table 3. The relationship between cause of injury and injured body part in skiers

	Injury not involving others (n=291)	Injury involving others (n=126)	P value
Head and cervical	21(7.2%)	36(28.6%)	<0.01
Torso	54(18.6%)	29(23.0%)	
Upper extremity	53(18.2%)	26(20.6%)	
Lower extremity	172(59.1%)	50(49.7%)	
Multipart injury	9(3.1%)	13(10.3%)	

Table 4. The relationship between cause of injury and injured body part in snowboarders

	Injury not involving others (n=197)	Injury involving others (n=68)	P value

Head and cervical	17(8.6%)	19(27.9%)	<0.01
Torso	39(19.8%)	24(35.3%)	
Upper extremity	107(54.3%)	18(26.5%)	
Lower extremity	37(18.8%)	13(19.1%)	
Multipart injury	3(1.5%)	6(8.8%)	

Figure 1. Number of injury cases in differet age group during the season of 2018-2019.

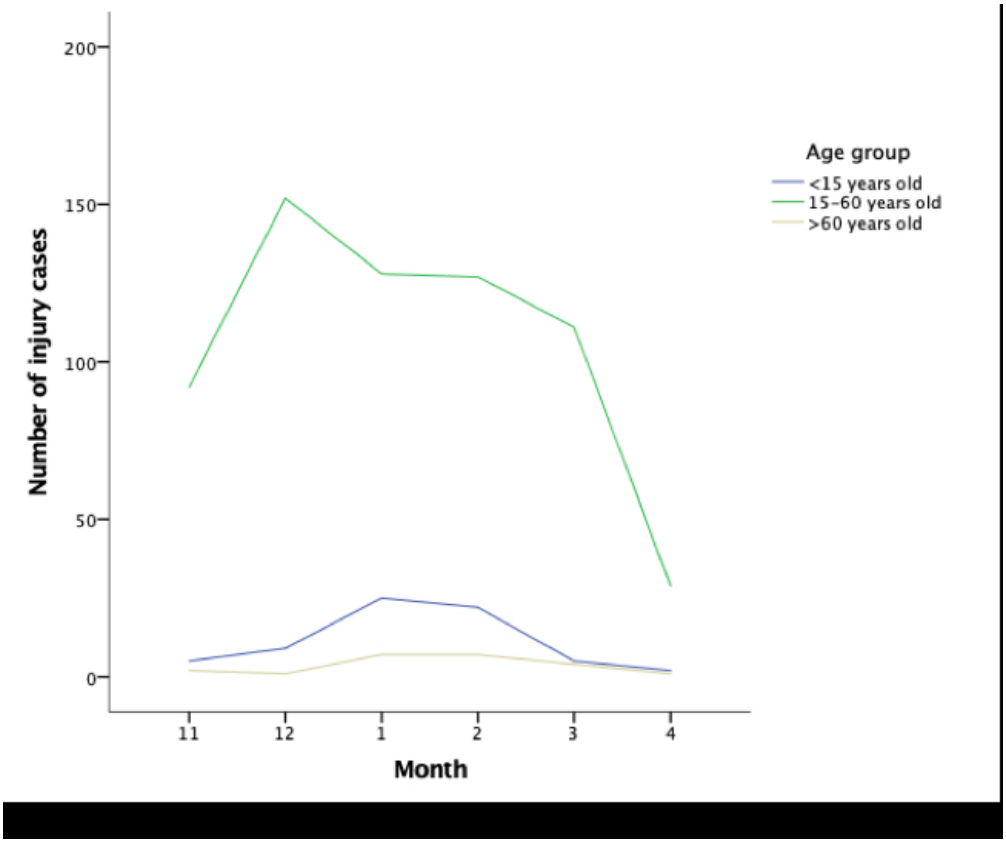

Figure 1. Number of injury cases in differet age group during the season of 2018-2019.

Table 5. The relationship between sex and injured body part in skiers

	Male (n=260)	Female (n=158)	P value
Head and cervical	32(12.3%)	25(15.8%)	0.29
Torso	58(22.3%)	24(15.2%)	
Upper extremity	51(19.6%)	28(17.7%)	
Lower extremity	131(50.4%)	91(57.6%)	
Multipart injury	12(4.6%)	10(6.3%)	

Table 6 The relationship between sex and injured body part in snowboarders

	Male (n=158)	Female (n=107)	P value
Head and cervical	21(13.3%)	15(14.0%)	0.63
Torso	42(25.6%)	21(19.6%)	
Upper extremity	74(46.8%)	51(47.7%)	
Lower extremity	26(16.5%)	24(22.4%)	
Multipart injury	5(3.2%)	4(3.7%)	

Table 7. The relationship between age and injured body part in skiers

	Teenager (n=52)	Adult (n=329)	Elderly (n=22)	P value
Head and cervical	15(28.8%)	39(11.9%)	2(9.1%)	0.14
Torso	6(11.5%)	70(21.3%)	4(18.2%)	
Upper extremity	12(23.1%)	57(17.3%)	8(36.4%)	
Lower extremity	22(42.3%)	179(54.4%)	11(50%)	
Multipart injury	3(5.8%)	16(4.9%)	3(13.6%)	

Table 8. The relationship between age and injured body part in snowboarders

	Teenager (n=26)	Adult (n=238)	Elderly (n=0)	P value
Head and cervical	6(23.1%)	30(12.6%)	0	0.21
Torso	4(15.4%)	59(25.2%)	0	
Upper extremity	15(57.7%)	109(45.8%)	0	
Lower extremity	2(7.7%)	48(20.2%)	0	
Multipart injury	1(3.8%)	8(3.4%)	0	

Table 9. The relationship between skill level and injured body part in skiers

	Beginner (n=106)	Medium (n=118)	Advanced (n=79)	Expert (n=49)	P value
Head and cervical	13(28.8%)	12(11.9%)	11(9.1%)	5(%)	0.19
Torso	18(11.5%)	27(21.3%)	16(18.2%)	10(%)	
Upper extremity	22(23.1%)	18(17.3%)	15(36.4%)	13(%)	
Lower extremity	54(42.3%)	164(54.4%)	48(50%)	24(%)	
Multipart injury	2(5.8%)	4(4.9%)	9(13.6%)	3(%)	

Table 10. The relationship between skill level and injured body part in snowboarders

	Beginner (n=93)	Medium (n=109)	Advance (n=36)	Expert (n=11)	P value
Head and cervical	15(23.1%)	11(12.6%)	5	1	0.32
Torso	20(15.4%)	27(25.2%)	10	2	
Upper extremity	46(57.7%)	51(45.8%)	14	7	
Lower extremity	14(7.7%)	26(20.2%)	8	8	

Multipart injury	2(3.8%)	6(3.4%)	1	0

Table11. Cause of injury and slope sifficulty

	Self-inflicted (n=486)	Crash (n=226)	P value
Beginner trail	93	18	<0.01*
Medium trail	103	87	
Advanced trail	292	121	

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-8

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8 NA NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective cross-section study

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Injury patterns in a large-scale ski resort in the host city of 2022 Winter Olympic Games: a retrospective cross-section study

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Abstract

Objective: The aim of the study is to describe the injury patterns in recreational skiers and snowboarders in China, and to provide primary data for reconstruction of regional health care facility to deal with the increasing number of participants in snow sports.

Design: Retrospective cross-section study

Methods: A retrospective study was performed in Wanlong Ski Resort in Chongli, China. The data of all injured skiers and snowboarders treated in the resort clinic during season 2018-2019 were collected. Patients information, including sex, age, equipment, skill level, injured body part were analyzed.

Results: A total of 753 sports injuries were recorded. The estimated incidence of injury was 1.98 per 1000 skier days. 453 cases (60.2%) were associated with skiing. The mean age of skiers was older than snowboarders (35.1±14.5 vs. 29.0±8.9, $p<0.01$). Injury not involving others took up 67.9% of all injuries. The most common injured body part in skiers was lower extremity, contrary to upper extremity in snowboarders. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders.

Conclusion: The incidence of skiing/snowboarding injury in China was similar to other countries. The injury pattern differed among different sports and cause of injury.

Key words: Sports injury, Skiing, Snowboarding

Strength and limitations of this study:

1. The present study is the first epidemiological study investigating the injury patterns in Chinese ski resort.

2. The severity of injury and accurate diagnosis were not recorded, and patients were not followed up for their prognosis.

3. The incidence of injury may be underestimated, due to the fact that patients might visit the local or tertiary hospital instead of the resort clinic, or did not receive any medical help for mild injuries.

1. Introduction

Skiing and snowboarding are popular winter sports world-wide but carry a substantial risk of sports injuries, with reported incidence of 0.5-1.35 injuries per 1000 skier/snowboarder days in recreational skiers/snowboarders[1-3] and 6.9 injuries per 1000 runs (or 26.8 injuries per 100 athletes per season)[4] in professional alpine skiers in recent years. In the latest Winter Olympic Games in PyeongChang, 12% of the athletes incurred at least one injury, equaling 12.6 injuries per 100 athletes over the 17-day period[5].

Since Beijing was selected to host the 2022 Winter Olympics, skiing and snowboarding population in China has risen from 8 million in 2015 to 13.2 million in 2018 (industry annual report, 2019). Large-scale ski resorts in China are often located in areas remote from major cities where medical capacity cries for improvement to ingest large number of winter sports injuries and manage severe injuries.

The aim of the study is to describe the injury patterns in recreational skiers and snowboarders in China by investigating the largest ski resort in the host city of 2022 Winter Olympic Games, and to provide primary data to guide the reconstruction of the local hospital to deal with the increasing number of participants in snow sports.

2. Patients and Methods

The data of this retrospective study was collected from the resort clinic of Wanlong Ski Resort in Chongli during ski season 2018-2019. Wanlong Ski

Resort is a destination ski resort in Northern China, which has various terrain and the largest number of annual visits. The resort clinic is staffed by a registered general practitioner and a nurse, and is responsible for the primary care of all injured visitors, whether self-present or sent by patrols; it is also responsible for treating mild injury, transferring patients to local hospital, carrying out basic life support for life-threatening injuries. The season of 2018-2019 in Wanlong Ski Resort lasted for 158 days, from 2018/11/1-2019/4/7. A total of 388606 visits (379503 skier days) were recorded.

Besides patient's information of sex and age, we also recorded equipment, skill level, the date and time of injury, the cause of injury, the slope difficulty and the injured body part. Equipment was classified into skis and snowboards. Special equipment, such as cross-country skis, skiboards, was rare in China and not seen in recorded injured people. According to self-reported years of participation in skiing and snowboarding, patients were classified as beginner (first season), medium (1-5 years), advanced (5-10 years) and expert (≥10 years). The date of injury was divided into weekdays and weekends/holidays according to the Chinese government holiday arrangement. The business hour of Wanlong Ski Resort is 8:00-16:00, so we split the time of injury into 4 periods with 2 hours each, morning (first 2 hours of business), noon, afternoon and late afternoon (last 2 hours of business). According to the subjective description of injury scene, we summarized 2 types of causes of injury: not involving others, defined as falling or crashing

without any body contact with others; and involving others, defined as crashing involving 2 or more people. The slope difficulty was categorized into beginner trail, medium trail and advanced trail according to the official data of slope inclination angle. Injured body parts were categorized into the following 4 anatomical body regions: (1) head/cervical, (2) torso, (3) upper extremity, and (4) lower extremity. Acromioclavicular joint injuries were classified as upper limb injury, while other clavicle injures were classified as torso injuries.[6] Injuries involving gluteal region were classified as torso injury. Whether patients have multi-part injuries was also recorded, while each injured body part was counted in one of the above groups. The relationship between injured body part and sex, age, equipment and cause of injury was further determined by subgroup analysis.

This study was approved by Peking University Third Hospital Medical Science Research Ethics Committee. Informed consent was waived considering that the study was epidemiological and anonymous.

Statistical analysis

All statistical analysis was performed with SPSS (v 24.0; IBM Corp). Continuous variables were presented as mean and standard deviations, while categorical data were presented with frequency count and percentages. To do comparison between subgroups, Chi-squared test was used for categorical variables and student t test was used for continuous variables. When there is

missing data, the available case was analyzed to determine difference between groups. P<0.05 was considered to indicate statistical significance.

3. Results

During the study period, there were 388, 606 visits (379, 503 skier days) and 753 cases of injury recorded in Wanlong Ski Resort. The estimated incidence of injury was 1.98 per 1000 skier days.

Features of injury

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years). Pediatric patients under 15 years old took up 9.3%, while senior patients (over the age of 60) took up 3.0% of all injured population. The number of males was twice as females. Among these injuries, 453 cases (60.2%) were associated with skiing. Table 1 shows more detailed demographic and sport-related profiles of these injuries.

The season of 2018-2019 in Wanlong Ski Resort consisted of 107 weekdays and 51 weekends/holidays according to the Chinese government arrangement. The average daily number of injuries was 3.38 on weekdays and 7.65 on weekends/holidays. A peak of pediatric cases was noted in January and February (Figure 1). Within a day, the percentage of injury occurred in morning, noon, afternoon and late afternoon was 9.7%, 31.6%, 22.0% and 36.7% respectively.

Accidents not involving other skiers took up 67.9% of all injuries. The most common injured body parts were upper (28.4%) and lower limbs (37.6%), followed by head and cervical injuries (13.1%).

Injury pattern in subgroups

The mean age of skiers was 35.1±14.5 years, whereas the mean age of snowboarders was 29.0±8.9 years ($p<0.01$). There was no significant difference in the sex profile between skiers and snowboarders.

The injured body parts showed different patterns between skiers and snowboarders. More than half of the skier patients sustained lower extremity injuries, while the most common injury in snowboarders was upper extremity injury. Head and cervical injury was identified in 13.7% of skiers and 13.6% of snowboarders. Multipart injury took up 5.3% in skiers and 3.4% in snowboarders (Table 2). The cause of injury was also found to be related with the injured body parts in both skiers and snowboarders. Head injury took up a significantly higher rate in accidents involving others. In skiers, lower extremity injury was most common no matter whether the accidents involved others or not. However, the rate of lower extremity was significantly higher in accidents not involving others (Table 3). In snowboarders, head, cervical and torso injury took up a greater portion in accidents involving others (Table 4). The correlation between age, sex, skill level and injured body parts was not significant. (Supplementary Tables 1-6)

4. Discussion

We found that the incidence of sports injury of Chinese recreational skiing and snowboarding population was 1.98 per 1000 skier days, which was comparable to reported incidence of 0.5-3.7 per 1000 skier days in European and North American countries in recent years.[1,7-9] According to the government report, the total number of visits in ski resorts in Chongli hit nearly 1 million in the 2018-19 ski season, which means an estimated number of 2,000 sports injuries in one season if such finding is extrapolated to the whole region. Therefore, a better understanding of injury pattern in Chinese population will guide the reform of local health care facility to deal with the increasing number of participants in snow sports.

The mean age of injured visitors was 32.5±12.9 years (range 3-73 years). 9.3% of the injured population were younger than 15 years old. In china, winter vacation for students last for about 4 weeks around Chinese New Year. We found that sports injury in teenagers peaked in January and February, and took up nearly 15% of all injuries occurred in these two months. The incidence of ski injury was reported higher in teenagers than in adults.[10] As more young people participate in these activities, an increase of pediatric patients of snow sports injury will be seen in the future.

Previous studies found female skiers are more susceptible to lower extremity injury, especially knee injuries, with nearly 50% of injured females suffer from knee injury.[11] The present study found lower extremity was the

most common injured body part in female skiers. However, there was no significant difference in injured body parts between males and females in both skiers and snowboarders. Paolo G et al.[12] found that men experienced more severe injuries than women, which may result from higher speed, body weight and trail difficulty in men.

Snowboarders accounted for nearly 40% of the injured population in the latest season. Based on the previously published data, an increase of the percentage of snowboarders in total and injured winter sport population has been noticed.[7,13] This young sport appeals to more young people and at the same time, reshapes the injury profile. In a study conducted in Big Sky area in United States, snowboarders took up 42.8% of injured visitors in the 2009-2010 season, while between 1995 and 2000 only 23.0% of injured people were snowboarders.[14] Many studies reported that snowboarders had significantly more injuries to the head, spine and upper extremity when compared with skiers, whereas skiers sustained significantly more lower extremity injures.[7,14,15] The present study revealed the same patterns, with higher rates of head, upper extremity injuries in snowboarders, and lower rates of lower extremity injuries. In a study comparing injury severity in different sports, the authors reported that the percentage of mild, moderate and severe injuries in skiing were 41%, 44% and 15% respectively, while the percentage in snowboarding were 34%, 53% and 13%.[9] Maat SC et al.

[15]reported that skiers were more seriously injured with Injury Severity Scale (ISS) higher than 9.

Beginners and medium level skiers (63.5%) and snowboarders (81.4%) made up the majority of injured visitors. In a study involving 19, 539 injured snowboarders in Japan, proportions of the trunk and multiple injuries were found to increase with higher skill level; the injury severity was also found to increase with skill level.[16] Another study found no relationship between skill level and injury severity in skiing and snowboarding population once unconscious patients (who cannot report their skill level) were ruled out.[13]

In our study, the rate of injures not involving others was 67.9%, which is lower than the reported rate on Austrian ski slopes.[3] The difference are likely attributed to the higher density of skiers/snowboarders on the slope in China, which is implied by the fact that the rate of crash accident was extremely high on medium trails (See Supplementary Table 7). Yet, no available studies provide conclusive evidence of the influence factors of self-inflicted and crash injury rate.[17]

The cause of injury was also found to be related with the injured body parts in both skiers and snowboarders. Head injury took up a significantly more portion in accidents involving others. Sport-specific injuries, such as shoulder injury in snowboarding and knee injury in skiing,[7] were more frequent in accidents not involving others. These findings can be attributed

to different injury mechanism, with non-contact injury often causing ligament and tendon tear, contact injury causing bony injury and concussion.[18]

From an epidemiological view, the present study provides strategies that can guide the restructure of local hospital and unload the burden in winter season. First, to establish pediatric orthopedic department to cope with the pediatric patients who take up nearly 10% of the whole injury population, especially the surge during winter vacation in China. Second, to establish department of neurosurgery and department of oral and maxillofacial surgery to deal with the head and face injury, which took up to 13% of all injuries. Third, to rearrange the worktime schedule according to the time-related “tide” of winter sports injury to increase effectiveness with limited manpower. For example, change weekends into work days and set other rest days in winter season to cope with the traumatic cases in weekend which are twice as many as in weekdays. Fourth, intensive care unit is crucial to manage severe injuries as the population at higher risk of severe injuries, including snowboarders, higher skill level and young participant, are growing bigger. Fifth, to build up communication and cooperation network with nearby ski resorts to allow access to critical patient’s information in advance and guide prehospital care. Although the present study did not provide information about injury severity and number of patients who need transfer and further treatment, up to 60% of injured skiers and snowboarders seen in resort clinic require transfer to hospital based on existing literature.[9] Up to now, the local

hospital in Chongli has reinforced its orthopedics and sports medicine department by seeking cooperation with superior hospitals in Beijing. An evidence-based restructure of local hospital may increase the accessibility to health care for injured skiers and snowboarders in nearby ski resorts.

Several limitations exist in this study. First, the severity of injury and accurate diagnosis were not recorded, patients were not followed up for their prognosis. Second, although medical providers in ski resort have collected injury cases as through as possible, there were still patients who went to local or superior hospitals directly, or did not receive any type of medical help for mild injuries. In this case, the incidence of injury may be underestimated. Additionally, the injury severity and number of patients who needed transfer was incomplete, so we were unable to estimate the burden of local hospital in skiing season. Currently, we are conducting a large-scale survey on the demography of Chinese winter sports participants, and a prospective research of winter sports injury in skiing population in China to fill the gap. The effectiveness of hospital restructure will be reported as well.

5. Patient and public involvement

It was not appropriate to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

6. Acknowledgement

The medical director of Wanlong Ski Resort, Zhang Jinwei, provided help in the collection of injury data.

7. Funding

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8. Conflicts of interest

The author states no conflicts of interest.

9. Author Contributions

Chen Nayun designed the study, carried out the data analysis and drafted the manuscript. Yang Yuping carried out the design of patient information registration chart, and helped to draft the manuscript. Jiang Yanfang helped to connect with relevant staffs in Wanlong Ski Resort and revise the manuscript. Ao Yingfang conceived of the study, and participated in its design.

10. Data availability statement

The data in the present study is deidentified participant data which are available upon reasonable request. Please contact the first author for permission to reuse the original data. Email: albert_west@163.com

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Tables and Figures

Table 1. Demographic and sport-related information of injured population

	n (%)
Sex	
Male	475 (63.3%)
Female	278 (36.7%)
Age	
<15 years	68 (9.3%)
15-60 years	643 (87.7%)
>60 years	22 (3.0%)
Equipment	
Ski	453 (60.6%)
Snowboard	294 (39.4%)
Skill level	
Beginner	211 (29.5%)

Medium	246 (34.0%)
Advanced	122(22.8%)
Expert	64 (13.7%)
Slope difficulty	
Beginner trail	111(15.3%)
Medium trail	206 (26.5%)
Advanced trail	425 (58.1%)

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356 Table 2. Details of injured skiers and snowboarders

	Skiers (n=453)	Snowboarders (n=294)	P value
Sex, n (%)			
Male	281 (63.3%)	184 (62.6%)	0.846
Female	163` (36.7%)	110 (37.4%)	
Age, n (%)			
<15 years	44 (10.3%)	22 (7.5%)	<0.01*
15-60 years	363 (84.6%)	270 (92.5%)	
>60 years	22 (5.1%)	0 (0%)	
Skill level, n (%)			
Beginner	110 (29.5%)	101 (37.5%)	<0.01*
Medium	127 (34.0%)	118 (43.9%)	

Advanced	85 (22.8%)	37 (13.8%)	
Expert	51 (13.7%)	13 (4.8%)	
Date of Injury, n (%)			
Weekdays	223 (50.2%)	134 (45.7%)	0.232
Weekends/Holidays	221 (49.8%)	159 (54.3%)	
Time of injury, n (%)			
Morning	44 (10.1%)	28 (9.9%)	0.466
Noon	137 (31.6%)	89 (31.3%)	
Afternoon	86 (19.8%)	69 (24.3%)	
Late afternoon	167 (38.5%)	98 (34.5%)	
Slope difficulty, n (%)			
Beginner trail	67 (15.3%)	42 (14.4%)	0.868
Medium trail	116 (26.5%)	82 (28.2%)	
Advanced trail	254 (58.1%)	167 (57.4%)	
Cause of injury, n (%)			
Involving others	153 (32.5%)	97 (30.6%)	0.680
Not involving others	291 (67.5%)	197 (69.4%)	
Injured body part, n (%)			
Head and cervical	57 (13.7%)	36 (13.6%)	<0.01*
Torso	83 (19.9%)	63 (23.8%)	
Upper extremity	79 (18.9%)	125 (47.2%)	
Lower extremity	222 (53.2%)	50 (18.9%)	

Multipart	22 (5.3%)	9 (3.4%)

Table 3. The relationship between cause of injury and injured body part in skiers

	Injury not involving others (n=291)	Injury involving others (n=126)	P value
Head and cervical	21(7.2%)	36(28.6%)	<0.01
Torso	54(18.6%)	29(23.0%)	
Upper extremity	53(18.2%)	26(20.6%)	
Lower extremity	172(59.1%)	50(49.7%)	
Multipart injury	9(3.1%)	13(10.3%)	

Table 4. The relationship between cause of injury and injured body part in snowboarders

	Injury not involving others (n=197)	Injury involving others (n=68)	P value
Head and cervical	17(8.6%)	19(27.9%)	<0.01
Torso	39(19.8%)	24(35.3%)	

Upper extremity	107(54.3%)	18(26.5%)
Lower extremity	37(18.8%)	13(19.1%)
Multipart injury	3(1.5%)	6(8.8%)

Figure 1. Number of injury cases in differet age group during the season of 2018-2019.

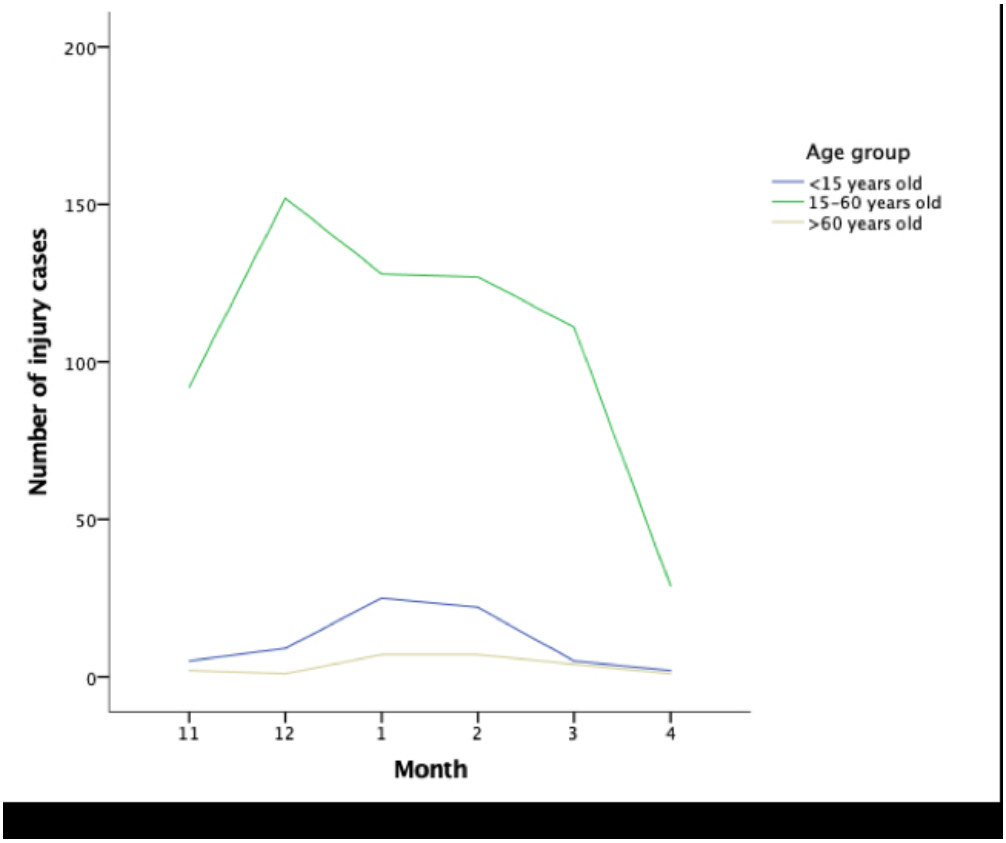

Figure 1. Number of injury cases in differet age group during the season of 2018-2019.

Table 1. The relationship between sex and injured body part in skiers

	Male (n=260)	Female (n=158)	P value
Head and cervical	32(12.3%)	25(15.8%)	0.29
Torso	58(22.3%)	24(15.2%)	
Upper extremity	51(19.6%)	28(17.7%)	
Lower extremity	131(50.4%)	91(57.6%)	
Multipart injury	12(4.6%)	10(6.3%)	

Table 2. The relationship between sex and injured body part in snowboarders

	Male (n=158)	Female (n=107)	P value
Head and cervical	21(13.3%)	15(14.0%)	0.63
Torso	42(25.6%)	21(19.6%)	
Upper extremity	74(46.8%)	51(47.7%)	
Lower extremity	26(16.5%)	24(22.4%)	
Multipart injury	5(3.2%)	4(3.7%)	

Table 3. The relationship between age and injured body part in skiers

	Teenager (n=52)	Adult (n=329)	Elderly (n=22)	P value
Head and cervical	15(28.8%)	39(11.9%)	2(9.1%)	0.14
Torso	6(11.5%)	70(21.3%)	4(18.2%)	
Upper extremity	12(23.1%)	57(17.3%)	8(36.4%)	
Lower extremity	22(42.3%)	179(54.4%)	11(50%)	
Multipart injury	3(5.8%)	16(4.9%)	3(13.6%)	

Table 4. The relationship between age and injured body part in snowboarders

	Teenager (n=26)	Adult (n=238)	Elderly (n=0)	P value
Head and cervical	6(23.1%)	30(12.6%)	0	0.21
Torso	4(15.4%)	59(25.2%)	0	
Upper extremity	15(57.7%)	109(45.8%)	0	
Lower extremity	2(7.7%)	48(20.2%)	0	
Multipart injury	1(3.8%)	8(3.4%)	0	

Table 5. The relationship between skill level and injured body part in skiers

	Beginner (n=106)	Medium (n=118)	Advanced (n=79)	Expert (n=49)	P value
Head and cervical	13(28.8%)	12(11.9%)	11(9.1%)	5(%)	0.19
Torso	18(11.5%)	27(21.3%)	16(18.2%)	10(%)	
Upper extremity	22(23.1%)	18(17.3%)	15(36.4%)	13(%)	
Lower extremity	54(42.3%)	164(54.4%)	48(50%)	24(%)	
Multipart injury	2(5.8%)	4(4.9%)	9(13.6%)	3(%)	

Table 6. The relationship between skill level and injured body part in snowboarders

	Beginner (n=93)	Medium (n=109)	Advance (n=36)	Expert (n=11)	P value
Head and cervical	15(23.1%)	11(12.6%)	5	1	0.32
Torso	20(15.4%)	27(25.2%)	10	2	
Upper extremity	46(57.7%)	51(45.8%)	14	7	
Lower extremity	14(7.7%)	26(20.2%)	8	8	

Multipart injury	2(3.8%)	6(3.4%)	1	0

Table 7. Cause of injury and slope difficulty

	Self-inflicted (n=486)	Crash (n=226)	P value
Beginner trail	93	18	<0.01*
Medium trail	103	87	
Advanced trail	292	121	

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	NA
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-8

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8 NA NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.