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ORIGINAL ARTICLE

Spinopelvic dissociation in patients suffering injuries from airborne sports

Henrik C. Bäcker[1,2] · Chia H. Wu[2] · J. T. Vosseller[2] · Aristomenis K. Exadaktylos[3] · Lorin Benneker[1] · Fabian Krause[1] · Sven Hoppe[1] · Christoph E. Albers[1]

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Abstract

Background Spinopelvic dissociation which is also called U-type or referred to H-type sacral fractures with a transverse fracture line is an infrequent injury that results mainly from high-energy accidents. This results in an osseous dissociation of the upper central segment of the sacrum and the entire spine from the lower sacral segments.

The purpose was to investigate the incidence of spinopelvic fracture in general among airborne injuries.

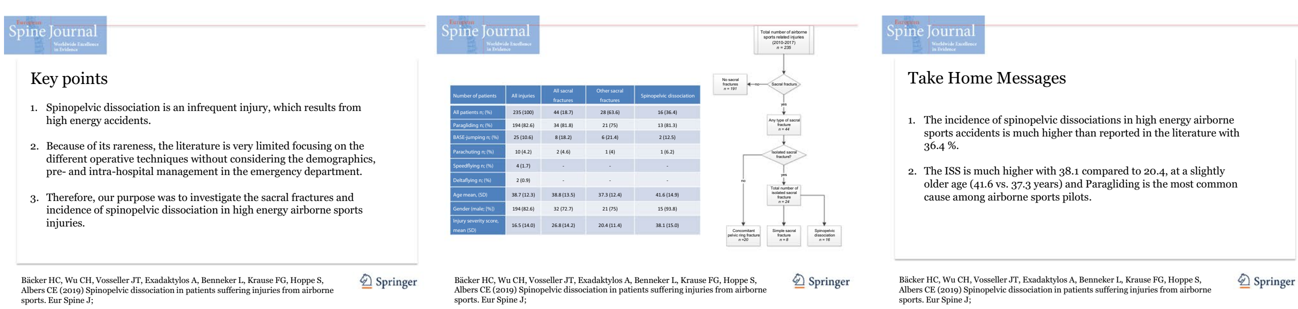
Patients and methods Using our electronic patient records, we retrospectively investigated all sacral fractures related to airborne sports between 2010 and 2017. All injuries were classified according to the Roy-Camille, Denis, AOSpine and the Tile classification system.

Results During the period of interest, 44 patients (18.7%) were admitted with sacral fractures after accidents obtained from airborne sports, including 16 spinopelvic dissociations (36.4%). The majority of these injuries were obtained from paragliding (75.0%), followed by BASE jumping (21.4%) and parachuting (4%). The mean injury severity score (ISS) in the spinopelvic dissociation group was significantly higher compared with other sacral fracture group (38.1 vs. 20.0; $p < 0.001$). Six lambda-type, four T-type, four H-type and two U-type injuries were identified. In total, four patients (25%) were found to have neurological impairment. For treatment, 87.5% of patients underwent subsequent surgical stabilization.

Conclusion Airborne sports have high potential for serious, life-threatening injuries with a high incidence of spinopelvic dissociation. In the literature, the prevalence of spinopelvic dissociation in sacral fractures is described to be between 3 and 5%. In our series, the prevalence is 36.4%. It is important to identify the potential injuries promptly for the further treatment.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Trauma · Sacral fractures · Paragliding · Lumbopelvic · Spinopelvic · Highly traumatic injuries

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Introduction

Spinopelvic dissociation is a rare injury resulting from high-energy trauma with severe concomitant injuries. When it was first described, it was originally termed 'suicidal jumper's fracture' by Roy-Camille et al. [1] and was later renamed spinopelvic dissociation according to Bents et al. [2, 3]. The fracture pattern is typically U-, lambda- or T-shaped with a transverse fracture at the S1/S2 disk space or S2 vertebral body, extending into bilateral vertical sacral fracture lines. This results in an osseous dissociation of the upper central segment of the sacrum and entire spine from the lower sacral segments [4]. Along with type C fractures according to the AOSpine classification, the type B4 is also unstable and shall be categorized as spinopelvic injury [5]. Due to the proximity, this injury is accompanied with a high risk of neurological deficit in the range of 94–100% [6, 7] as well as soft tissue injuries such as a Morel-Lavallee lesion [8]. Conservative treatment has been reported to lead to unsatisfactory results with persistent neurological deficit and permanent disability [4, 9]. Surgical lumbopelvic stabilization after reduction in the sacral fractures and decompression of the neurological structures is the treatment of choice [10, 11].

The most common classifications used in clinical practice are the Roy-Camille and Denis classifications. The topographical relation of Denis zone III and the horizontal fractures can be further described as "U," "H," "T" and "Y" shape (Fig. 1) [3, 12]. As flexion or extension changes pelvic incidence, posttraumatic difference between pelvic incidence and lumbar lordosis may affect the global sagittal alignment of the spine if not properly reduced [2].

Because of Switzerland's landscape and a well-established air-rescue system, airborne sports-related injuries (ISS equal to or greater than 16) are typically transported by helicopter to the nearest trauma center. An interdisciplinary primary survey is performed by emergency physician, anesthesiologists, orthopedic surgeons, trauma surgeons, neurosurgeons, as well as thoracic and abdominal surgeons. In accordance with Advanced Traumatic Life Support (ATLS), the evaluation includes a whole-body low-dose x-ray and computed tomography [13].

The aim of this epidemiological study was to determine (1) the proportion and demographics of sacral fractures and spinopelvic dissociations obtained from airborne sport accidents admitted to our level 1 trauma center; (2) the fracture pattern, neurological impairment, subsequent treatment and concomitant injuries of spinopelvic dissociation.

Patients and methods

We performed a retrospective study including all patients suffering injuries from airborne sports accidents admitted to our level 1 trauma center between February 2010 and May 2017. The catchment area includes approximately 1.5 million people living in a 10,000-km^2 area for selected patients such as with spinopelvic dissociation [14]. All emergency charts are saved in the interdisciplinary emergency department database. We reviewed the hospital records of the interdisciplinary emergency department for airborne sports-related injuries.

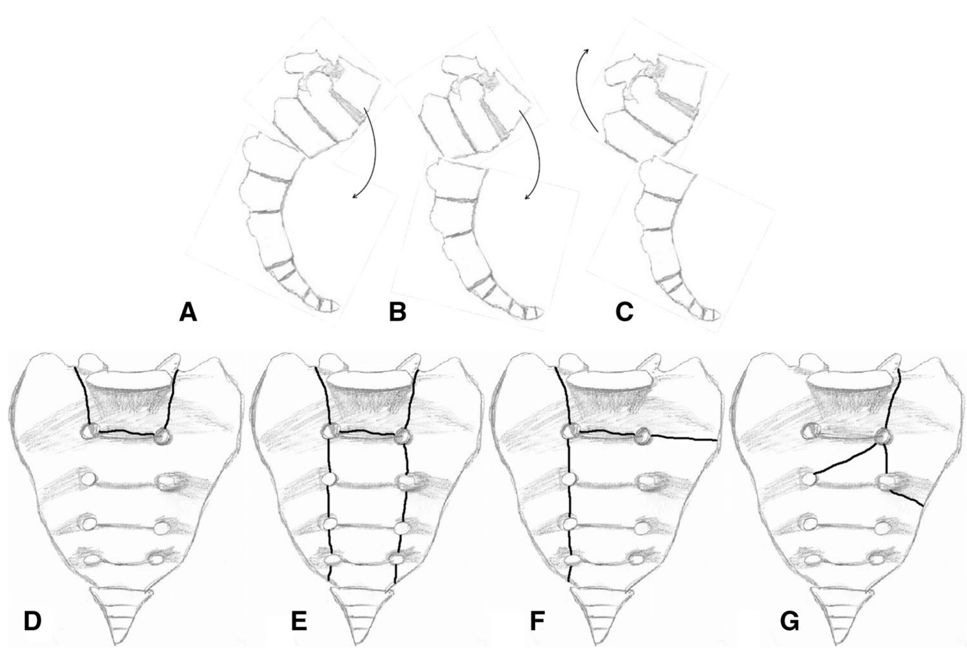

Fig. 1 **a–c** Roy-Camille classification on lateral sacral views: type I, flexion fracture, type II, flexion with posterior displacement, and type III, extension with anterior displacement. Additionally, low transverse sacral fracture (TSF), not shown; variety of sacral fractures, **d–g** H type, U type, lambda type, T type

Inclusion criteria were defined as all patients older than 18 years suffering from an acute traumatic accident. The ethical consent was granted by the Swiss ethical committee.

The database provides information about the demographics, type of airborne sports performed (i.e., paragliding, skydiving, delta flying, speed flying and BASE jumping), onset and severity of neurological deficit, concomitant injuries, injury severity score and radiographic imaging. All radiographs, neurological status (ASIA score) and injury severity scores were evaluated and compared with the chart by one of the authors. Radiographic imaging for injury assessment and fracture classification included computed tomography scans, low-dose X-rays (LODOX) in poly-traumatized patients as well as plain x-rays in less severely injured patients. Based on the imaging, the injuries were classified based on Roy-Camille, Denis, AOSpine and Tile classifications. Additionally, all surgery reports were reviewed to gain further information about the type of surgery performed.

For statistical analysis, we used SPSS, Microsoft Excel spreadsheet and Origin Lab to perform the ANOVA *T*-test. To detect statistical significance, we used a linear regression model with the standardized coefficient and p-value. All data are presented as absolute numbers and in percentages.

Results

Proportion of sacral fractures and spinopelvic dissociation in airborne injuries

Between February 2010 and May 2017, 235 patients suffering from airborne accidents were admitted to the emergency department at a mean age of 38.7 years (SD 12.3; range 18–74 years), with predominance in male (194; 82.6%). Unfortunately, two of the 235 patients died upon admission due to pulseless electrical activity (overall mortality rate 0.9%, $n = 2/235$). One death was due to hypovolemic shock from severe pelvic injury, liver laceration and hemothorax and the other one due to traumatic brain injury. In these patients, no further radiographic examinations were performed because of the required resuscitation. Therefore, it is not possible to state whether a spinopelvic dissociation was present or not. Forty-seven patients were identified with sacral injuries in total, and three patients were excluded, as no fracture was identified (bony contusion in two cases and gluteal hematoma in one patient). In the remaining 44 patients (18.7%), 16 cases suffered from spinopelvic dissociation (36.4%) and 28 patients from other sacral fractures (63.6%). There was predominance in male ($n = 32/44$; 81.8%), and the mean age was 38.8 years (SD 13.5) (Fig. 2). All patient demographics are illustrated in Table 1.

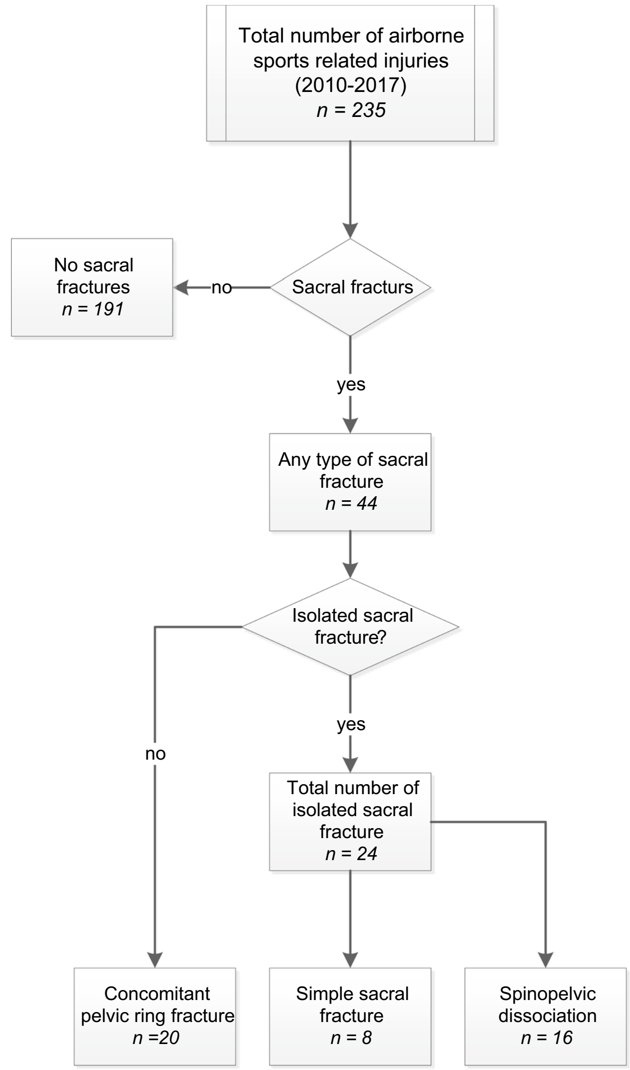

Fig. 2 Inclusion criteria of patients with sacropelvic injuries

Spinopelvic dissociation

Of the 16 spinopelvic dissociations, four were H type, three T type, two U type and two lambda type. The remaining five cases showed a spinopelvic dissociation without correlation to one of these fracture patterns. The right side was affected in nine cases. In five patients, both sides were affected. In the remaining two patients, left side only was affected. Twenty-five percent of patients ($n = 4$) presented with neurological deficit, and three suffered from incomplete paraplegia or cauda equina syndrome (type B according to ASIA and N3 according to the AOSpine classification). These same patients also had severe spine injuries, and one was diagnosed with a traumatized lumbar plexus (type C). Most patients underwent surgery ($n = 14$, 87.5%), and only two patients were treated non-operatively (12.5%)—one of them had no concomitant or combined pelvic fractures injuries,

Table 1 Proportion of sacral fractures and spinopelvic dissociation among airborne sports, percentages expressed in brackets

Number of patients	All injuries	All sacral fractures	Other sacral fractures	Spinopelvic dissociation
All patients *n*, (%)	235 (100)	44 (18.7)	28 (63.6)	16 (36.4)
Paragliding *n*, (%)	194 (82.6)	34 (81.8)	21 (75)	13 (81.3)
BASE jumping *n*, (%)	25 (10.6)	8 (18.2)	6 (21.4)	2 (12.5)
Parachuting *n*, (%)	10 (4.2)	2 (4.6)	1 (4)	1 (6.2)
Speed flying *n*, (%)	4 (1.7)	–	–	–
Delta flying *n*, (%)	2 (0.9)	–	–	–
Age mean (SD)	38.7 (12.3)	38.8 (13.5)	37.3 (12.4)	41.6 (14.9)
Gender (male, [%])	194 (82.6)	32 (72.7)	21 (75)	15 (93.8)
Injury severity score, mean (SD)	16.5 (14.0)	26.8 (14.2)	20.4 (11.4)	38.1 (15.0)

whereas the other one had a non-displaced, stable spinopelvic dissociation injury. In 37.5% of the patients, triangular spinopelvic stabilization (four bilateral, two unilateral) was performed, and 43.8% (seven patients) had percutaneous iliosacral screw fixation and one patient had dorsal plate osteosynthesis. For those that underwent triangular spinopelvic stabilization, the mean ISS was 46.3 (SD 14.7).

When looking for concomitant injuries, the most common one was spine injuries in 12 cases (75.0%). The most common fractures were located in the thoracolumbar spine with 65.9% ($n=29/44$) with seven fractures of L1 (15.9%). The second most common were injuries of the thorax found in 50.0% of the patients including three lacerations of the aortic arch, one traumatic dissection of the RIVA as well as intra-abdominal bleedings in 37.5% cases ($n=6/16$). Upper-extremity injuries were found in 31.3% of the patients ($n=5/16$), while lower-extremity injuries were found in 25.0% ($n=4/16$), including one Morel-Lavallee lesion. Head and face injuries were found in 18.75% of cases ($n=3/16$). All individual patients are listed in Table 2.

Other sacral fractures: sacropelvic ($n=20$) and isolated sacral fracture groups ($n=8$)

The Roy-Camille, Denis and AOSpine classifications of all sacral fractures other than spinopelvic dissociations are illustrated in Table 3. A majority of those patients were treated conservatively ($n=20/28$ patients, 71.4%). In three cases, a single anterior pelvic fixation (10.7%) was performed without fixation of the sacrum. Five patients were treated with iliosacral screw fixation (17.9%) including one combined anteroposterior osteosynthesis (Table 4). The most common concomitant injuries were spine fractures with 65.9% ($n=29/44$). All concomitant injuries for spinopelvic dissociation and sacral fractures are summarized in Table 5.

Comparison between spinopelvic dissociation and other sacral fractures

When performing linear regression statistical analysis, we found that age and gender were equally distributed. The injury severity score for the spinopelvic dissociation was significantly higher when compared to the sacropelvic fractures with a standardized coefficient of 0.463 ($p=0.001$). In terms of concomitant injuries, patients with spinopelvic dissociation had a significantly higher prevalence of spine fractures with a standardized coefficient of 0.329 (75.0% in the spinopelvic dissociation group versus 65.9% in the other sacral fracture group, $p=0.03$), whereas all other concomitant injuries were equally distributed without any further significances.

Discussion

In the current study, 235 patients were identified with airborne sports-related injuries between 2010 and 2017. Of them, 18.7% of patients were found to have sacral fractures ($n=44/235$). It is striking that our study found that 36.4% ($n=16/44$) of sacral-pelvic injuries sustained spinopelvic dissociations. These patients had a significantly higher prevalence of concomitant spinal injuries ($p=0.03$) and showed a mean injury severity score of 38.1 compared with an ISS of 16.5 in all 235 patients. Twenty-five percent of patients suffered from neurological impairment, while 87.5% ($n=14/16$) went for surgical treatment.

Airborne sports are associated with severe injuries including a high mortality for BASE jumping and paragliding with a reported fatality of one per 2,317 jumps and 45 per 100,000 jumps, respectively [15, 16]. Airborne sports are particularly dangerous during takeoffs and landings. In skydiving, the incidence of injury is 48 per 100,000 jumps [17]. The thoracolumbar spine, pelvis and lumbopelvic junction are most commonly affected by severe injuries sustained from airborne

Table 2 Characteristics of 16 patients with spinopelvic dissociation

Patient	Age	Gender	Type of airborne sports	ISS	Sacral fracture classification			Fracture pattern	Pelvic ring fracture (AOSpine classification)	Neurological deficit (AOSpine classification)	Treatment[a]	Concomitant injuries[b]
					Denis	Roy-Camille	AOSpine					
1	59	M	Paragliding	45	3	2	C3	H type	C1		4, 5	1, 2, 6
2	50	M	Paragliding	34	2	Low TSF	C1	T type	C1	3	2, 5	1, 2, 4, 5
3	20	F	Parachuting	50	2	1	B4 right	L type	C1	3	4	1, 6
4	37	M	Paragliding	35	2	Low TSF	C3	n.a	C2		2, 4	1, 2, 5
5	50	M	Paragliding	50	3	2	C1	U type	C2		2, 4	1, 5
6	30	M	BASE jumping	26	2	1	C3	H type	C1		2, 6	1
7	36	M	Paragliding	30	3	Low TSF	B4 left	L type	C1		2, 4	1, 5
8	61	M	Paragliding	26	2	Low TSF	B4 right	n.a	C1		2, 5	1
9	45	M	Paragliding	13	3	2	C1	T type			1	1
10	38	M	Paragliding	34	3	2	C1	H type			1	1, 3, 5
11	27	M	BASE jumping	66	3	Low TSF	B4 left	n.a	C1	3	2, 3, 5	1, 3, 4, 5, 6
12	71	M	Paragliding	50	2	Low TSF	C2	T type	C2	2	2, 4	1, 3
13	43	M	Paragliding	50	3	1	C3	H type	C2		2, 4, 5	2, 6
14	19	M	Paragliding	57	2	2	C3	U type			5	2, 3, 4, 5, 6
15	29	M	Paragliding	18	3	Low TSF	C1	n.a	C1		2, 4	5, 6
16	50	M	Paragliding	25	2	1	B4 right	n.a	C2		2, 4	

ISS injury severity score, *TSF* transverse sacral fracture

[a]Treatment: 1 conservatively, 2 osteosynthesis of the anterior pelvic ring, 3 decompression, 4 iliosacral screw, 5 triangular lumbopelvic osteosynthesis

[b]Concomitant injuries: 1 spine, 2 upper extremity, 3 lower extremity, 4 head and face, 5 thoracic trauma, 6 intra-abdominal trauma

Table 3 Fracture classifications

	Number of patients (*n*)	Roy-Camille				Denis			AO			Fracture pattern				Neurology (ASIA score)
		Low TSF	0	1	2	1	2	3	A	B	C	T	λ	U	H	
Spinopelvic dissociation	16	7	–	4	5	–	8	8	–	5	11	3	2	2	4	3B, 1C
Sacropelvic fractures	20	9	5	5	1	–	–	–	2	18	–	1	4	–	–	
Sacral fractures	8	3	2	1	2	4	–	–	6	2	–	1	–	–	–	

Table 4 Treatment modality per group

	Conservative	Anterior fixation		Posterior fixation		Decompression
			Combined anterior/posterior fixation	SI screw	Triangular fixation	
Spinopelvic dissociation	2		11	7	6	1
Sacropelvic fractures	12	3	1	4		
Sacral fractures	8					

For spinopelvic dissociation, posterior fixation was performed in 13 cases, one decompression and two conservative treatments. Anterior fixation occurred in 11 cases where posterior fixation was performed

SI sacroiliac screw, *TF* triangular fixation

Table 5 All concomitant injuries

	ISS	Number	Spine	Extremity	Pelvis	Abdomen	Thorax	Head/face
Spinopelvic dissociation	38.1	16	12	11	14	6	8	3
Other Sacral fractures	20.0	28	17	16	19	4	9	3
Total	26.8	44	29	27	33	10	17	6

ISS mean injury severity score

sports [12]. Overall, sacral transverse fracture is reported to range between 3 and 5% of all sacral fractures in the general trauma population [18]. U-shaped fractures are more infrequent, occurring at a rate of 2.9% of all patients suffering from pelvic ring fractures [19]. Our study reports a higher proportion of spinopelvic dissociation injuries among all sacral fractures. One explanation for this finding may be the nature of airborne sports-related high-energy trauma, involving significant spinal axial loading. As initially described by Roy-Camille, the most frequent cause for sacral fractures is falls from heights in up to 40% [1] of cases. A previous study by Hasler et al. reported a 21-fold increased risk of sustaining spinopelvic dissociation injuries in airborne sports-related accidents as compared to the general trauma population [12].

Sacral fractures are generally caused by multi-directional forces acting on the lumbopelvic junction. As a result, a combination fracture pattern is quite common [20, 21]. The main parameter that determines this type of injury is the position of the lumbar spine at the time of axial impact [1]. Simultaneous kyphosis of the lumbar spine leads to anteriorly directed force vectors, which results in a flexion-type spinopelvic dissociation injuries (Roy-Camille types 1 and 2). In contrast, extension-type injuries (Roy-Camille type 3) occur when the lumbar spine is lordotic during impact [1]. Interestingly, we did not observe any extension-type fracture in patients who suffered from spinopelvic dissociation. Only one patient (1.9%) in our cohort of sacral and pelvic injuries was identified to be without spinopelvic instability. Similar to our findings, Roy-Camille reported a predominance in flexion-type injuries after suicide attempts (76.9%; [1]), whereas another study found equal distribution of flexion- and extension-type spinopelvic injuries sustained from airborne sports [12].

Neurological injury in spinopelvic dissociation is closely related to the initial degree of displacement of the transverse sacral fracture [9]. Neurological injuries vary from nerve root compression, contusion, traction to laceration. Although previous studies reported up to 100% incidence of neurological deficits in spinopelvic dissociations [20, 22–26], there were only four patients (25%) in our cohort presenting with neurological dysfunction. One of them had concomitant burst fractures of the thoracolumbar spine, causing the observed neurological deficits. One patient (case 12) suffered from additional traumatic injury of the lumbar plexus. Based on the literature, the role and timing of surgical decompression of the neurological structures in patients suffering from spinopelvic dissociation remain a matter of debate. Evidence related to improved clinical outcome and neurological recovery is lacking [9, 10].

Surgical treatment of spinopelvic dissociation ranges from non-operative treatment to percutaneous iliosacral screw fixation, posterior tension band, bridge plating or triangular spinopelvic fixation [27]. Biomechanical tests under cyclic loading have shown that the displacement of triangular spinopelvic fixation is significantly less than the iliosacral screw fixation [11, 28]. In the current study, majority of patients with spinopelvic dissociation were treated operatively (87.5%). In most cases, sacroiliac screw fixation was performed in 44% of cases, followed by triangular spinopelvic fixation in 38% (Table 4). Low degree of fracture displacement was the reason cited for not performing lumbopelvic fixation in seven patients. A recent study by Chou et al. reported a series of 18 consecutive patients with spinopelvic dissociation [27]. In their study, all patients underwent surgical treatment. Of them, 16 patients had lumbopelvic fixation and two iliosacral screw fixation. The authors proposed a surgical treatment algorithm depending on the type and displacement of spinopelvic dissociation injuries [27].

As a result of the high-energy trauma mechanism, spinopelvic dissociation typically presents in the setting of polytrauma. In the current study, increased ISS was observed in patients suffering from spinopelvic dissociation (ISS 38.1 in patients with spinopelvic injury vs. ISS 16.5 in all patients). Lindahl et al. reported a median ISS of 27 in 36 patients with spinopelvic dissociation injuries. Comparing the ISS of patients in the current study, we found an ISS of 38.1 in the spinopelvic dissociation group and an ISS of 20.0 in the group including all sacral fractures ($p < 0.01$). The most common concomitant injuries identified in all patients with sacral fractures were fractures of the thoracolumbar spine at 65.9% ($n = 29/44$; Table 5). These findings were supported by a previous study assessing airborne sports-related injuries [12]. The authors reported an overall ISS of 8, of which patients with spinopelvic dissociation had a median ISS of 18.5. Moreover, the authors found thoracolumbar spine injuries to be the most frequent injuries in patients suffering from airborne sports-related accidents [12]. Similarly, Gauler et al. reported the highest prevalence of spinal fractures sustained from paragliding accidents located in the thoracolumbar region [29]. In contrast to our findings, there were no spinopelvic dissociations in their patient series.

This study is limited by its retrospective study design. In addition, we did not report the mid- to long-term clinical, functional or radiographic follow-up after surgery. This is meant to be an epidemiological study reporting the frequency of sacral injuries and spinopelvic dissociation in a highly specific patient population that is not directly comparable to the general trauma population. Due to the relatively rare nature of these injuries, small numbers negatively impacted the statistical power of the study. Furthermore, the regression coefficients indicating an association between ISS, spinal fractures and spinopelvic dissociations are relatively low. Lastly, because we performed the study at a level 1 trauma center, our study may be skewed because minor sacral fractures from airborne sports-related injuries may have already been managed in smaller community hospitals.

Conclusion

Airborne sports-related injuries are common in the Swiss Alps and have a high potential for sacral fractures with or without concomitant pelvic ring disruption or spinopelvic injuries. In total, 18.7% of patients presented with sacral injuries, of whom 36.4% were identified with spinopelvic dissociation. This is a significantly higher prevalence compared to the literature. The injury severity score was significantly higher in the spinopelvic group with 38.1 compared to the overall ISS of 16.5. Neurological deficits were seen in 25% and concomitant spine injuries occurred significantly more in this cohort ($p = 0.03$). Therefore, it is important to make emergency physicians and trauma surgeons aware, in order to treat these injuries promptly and appropriately.

Compliance with ethical standards

Conflict of interest None of the authors received any financial support that might pose a conflict of interest in connection with the submitted article.

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Affiliations

Henrik C. Bäcker[1,2] · Chia H. Wu[2] · J. T. Vosseller[2] · Aristomenis K. Exadaktylos[3] · Lorin Benneker[1] · Fabian Krause[1] · Sven Hoppe[1] · Christoph E. Albers[1]

✉ Henrik C. Bäcker
henrik.baecker@sports-med.org

Chia H. Wu
cw3112@cumc.columbia.edu

J. T. Vosseller
jtv2111@cumc.columbia.edu

Aristomenis K. Exadaktylos
Aristomenis.Exadaktylos@insel.ch

Lorin Benneker
lorin.benneker@insel.ch

Fabian Krause
fabian.krause@insel.ch

Sven Hoppe
sven.hoppe@insel.ch

Christoph E. Albers
christoph.albers@insel.ch

1 Department of Orthopaedic Surgery and Traumatology, University Hospital Bern, Freiburgstrasse, 3010 Bern, Switzerland

2 Department of Orthopaedic Hand, Trauma and Microvascular Surgery, Columbia University Medical Center, New York 10032, USA

3 Department of Emergency Medicine, University Hospital Bern, Freiburgstrasse, 3010 Bern, Switzerland