Upper Limb Traumatic Accidents among French Paratroopers. A Review of 266 Accidents which Occurred at the Paratrooper School between 2000 and 2007

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Abstract

Objective: To analyse 289 upper limb injuries and compare the rate and severity of these injuries resulting from Static Line (SL) and Free-Fall (FF) military jumps. Methods. This study included 266 paratroopers with 289 upper limb injuries which occurred between January 2000 and June 2007. We studied their parachuting experiences, ages, types of parachute, diagnoses, types of jumps, use of extra equipment, whether they did day or night jumps, and the time they spent on sick leave and the convalescent time when jumping was not authorized. Results. The upper limb injury rate for SL was higher than that for FF jumps (1.19 vs 0.34 per 1,000 jumps). However the relative risk of osteoarticular injuries was greater for FF than for SL jumps. The shoulders constituted the main location of the injuries and landing caused most of the injuries. The periods spent on sick leave and convalescent periods when jumping was not authorized were longer following an injury caused by FF military jumps. Conclusion. Although the injury rate was greater for SL than for FF jumps, FF jumps presented a more significant risk factor of severe injuries.

Keywords: Free fall jump. Parachuting injuries. Upper extremity. Static line.

Résumé

ACCIDENTS TRAUMATIQUES DU MEMBRE SUPÉRIEUR CHEZ LES PARACHUTISTES MILITAIRES FRANÇAIS. UNE REVUE DE 266 ACCIDENTS SUR L'ECOLE DES TROUPES AÉROPORTÉES DE 2000 À 2007.

Objectif : analyser 289 blessures du membre supérieur et comparer le taux et la sévérité de ces blessures entre les sauts en ouverture automatique (OA) et en ouverture retardée (OR). Méthode : cette étude porte sur 266 parachutistes ayant eu 289 blessures sur la période janvier 2000 à juin 2007. Nous avons étudié l'expérience des parachutistes, leur âge, le type de parachute, le diagnostic, le type de saut, le nycthémère, l'utilisation d'une gaine, la durée des arrêts de travail et d'inaptitude TAP. Résultats : le taux de blessure au membre supérieur en OA a été plus élevé qu'en OR (1,19 contre 0,34 pour 1 000 sauts). Cependant en OR, le risque relatif de blessures ostéo-articulaires est plus grand qu'en OA. L'épaule est la principale localisation de ces blessures et l'atterrissage est la plus fréquente des circonstances. Les durées d'arrêts de travail et des inaptitudes TAP ont été plus longues en OR qu'en OA. Conclusions : bien que le taux de blessures soit plus élevé en OA qu'en OR, ces derniers sont un facteur de risque significatif de blessures sévères.

Mots-clés : Blessures en parachute. Membre supérieur. Sauts en ouverture retardée. Voile hémisphérique.

Introduction

Military parachuting has been used to drop troops into remote and hazardous areas since World War II. Military static line parachuting is a method by which large numbers of troops can be effectively dropped into otherwise inaccessible battlefields. Unlike civilian skydivers who jump for fun, military free fall jumpers use their equipment simply as a means to reach the objective of their missions (recon or extraction). The technical difficulties are greater and previous parachuting experience is required. Military parachuting is more dangerous than any other military activity (1) thus it can be used as a marker to identify significant additional risks

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to the health of soldiers. Military parachuting is 20 times more likely to be the cause of an injury than other military activities. Thus parachuting injuries have often been studied. Although the risks are maximal in war time, accidents occur in training jumps as well (2).

The equipment used in military parachuting has advanced considerably since its first widespread use in World War II (3). In France, two types of parachutes are presently used: canopy parachutes with a static line (TAP 696-26) and square parachutes for free fall jumps (ARZ G9 and BT80). Canopy parachutes are opened by static lines attached to the aircraft strong points. As parachutists fall to the limit of their static lines, the inner bags containing the parachutes are pulled away, releasing the parachutes (4). Parachutists land at a speed of 6 m/s. Round parachutes are non-steerable, as opposed to rectangular parachutes which can be steered with hand toggles. In free falls, parachutists open their square parachutes and land at a considerably slow speed (as opposed to landing with canopy parachutes).

In the South West of France, in 2005 (2), the injury rate was 1.38 per 1,000 training jumps and static line jumps were 3.4 times more risky than free fall jumps.

Although upper limb injuries have been described as the second or third most frequent location for parachuting injuries (4-9), we have found only one study in which they are recorded precisely (10), because research generally focuses on lower limb injuries. Several articles described more severe injuries such as traumatic rupture of biceps brachii (11-16) or amputation (17).

The purpose of this study is to describe upper limb injuries which occurred during parachuting accidents and to compare the injuries which occurred during "Static Line" (SL) and "Free-Fall" (FF) military jumps.

Materials and methods

Usual management of injured personnel in the Paratrooper School zone

The population studied consisted in military personnel who were learning to jump or training in drop zones around the Paratrooper School in Pau. This school was selected because it is the only school in France with a drop zone which can accommodate more parachutists than any other military drop zone. (2) During training jumps, a first aid station is located near the main landing area and is operated by a military general practitioner and two people from the paramedical staff of the school medical centre. They take care of the injured paratroopers in the drop zone, and evacuate them to the medical centre or a civilian hospital. They can be helped by an emergency team if necessary. Each paratrooper is examined by the military medical team. Any parachuting injury, even minor, is systematically recorded immediately after the injury on standardized medical forms as well as on the paratroopers' military medical files. The practitioners complete the files with the injured persons and add complementary examinations as needed.

Study design

We retrospectively analysed the reports from January 2000 to June 2007 and extracted information about upper limb injuries. Information about overall injuries was available only between January 2000 and December 2006 and data on all the jumps (night or day) between January 2002 and December 2006. The parachutists included in our study came from the Paratrooper School and other battalions nearby who also jumped on the site of Pau. Only the subjects whose injuries occurred between leaving the aircraft and straight after landing were included.

Data collected from the medical forms included parachuting experiences, ages, types of parachute (SL or FF), diagnoses (injury location and type), types of jump (during basic courses or training exercises), circumstances, day or night jumps, extra equipment, time spent on sick leave and convalescent periods when jumping was not authorized. Jumping experience was categorized into three groups in accordance with Lacombe's proposition (7). Experience was defined as the number of previous jumps. The first group included novice parachutists who had done between 1 to 50 jumps, the second included experienced parachutists (51 to 200 jumps) and the third, expert parachutists (more than 200 jumps). Injuries were classified into four categories according to clinical diagnoses (18): (1) contusion injuries defined as bruises, contusions, strains and superficial wounds; (2) sprain injuries defined as sprains and muscular lacerations; (3) dislocations (including tendon rupture) and (4) fractures.

Extra equipment is equipment on independent parachutes called a wedge which is released just before landing. (19)

Statistical Analysis

For the sake of statistical analysis the upper limbs were divided in two parts: the shoulders and arms constitute the proximal part, and the elbows, forearms, wrists and hands in the distal part. Osteoarticular injuries also included dislocations, fractures and soft tissues injuries contusions and sprains.

The Exact Kruskal-Wallis test and the Chi-Square test were used to determine the relationships between the variables. The analysis considered a p-value < 0.05 as significant. EpiInfo® software was used for this analysis.

Results

Parachuting accidents and distribution of injuries

From January 2000 to December 2006, 293,236 jumps (190,229 SL parachute jumps *versus* 103,007 FF jumps) were recorded; 1,847 injuries resulted from SL *versus* 140 from FF jumps. The overall injury rate was 9.7 per 1,000 jumps for SL versus 1.36 per 1,000 jumps for FF. So the relative risk (RR) to be wounded during a SL jump versus a FF jump was 7.14 with a 95% Confidence Interval (CI) of 6.02 to 8.45 ($p<0.05$). No death was recorded.

During this period, the lower limbs constituted the main location of SL injuries (1039 injuries or 56.25%) followed by the spine (414) and the upper limbs (226 or 12.25%). There were 168 other locations. Regarding FF injuries, the lower limbs were also the main location (62 injuries, 44.29%), followed by the upper limbs (35 injuries, 25%), the spine (29) and 14 other locations. Data presented in Figure 1 illustrates this distribution. The upper limb injury rate for paratroopers doing Static Line jumps (1.19 injuries per 1,000 jumps) was significantly higher than those concerning Free Fall jumps (0.34 injuries per 1,000 jumps) with a significant relative risk of 3.5 (CI=2.45-4.99).

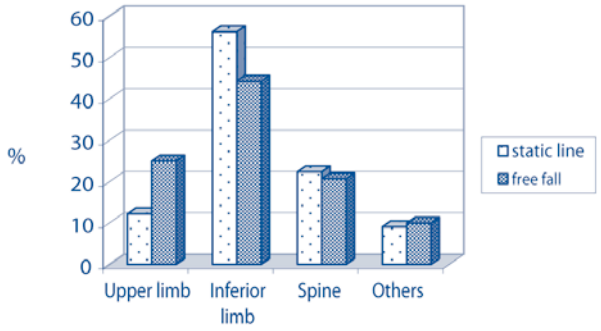


Figure 1. Repartition of all parachuting injuries between static line and free fall jumps.

Upper limb study

During the period studied (January 2000- June 2007), 266 accidents were recorded (233 SL vs. 33 FF) which resulted in 289 injuries (252 vs. 37). Therefore, the relative risk (RR) to incur an upper limb injury during a SL jump versus a FF jump was 3.69 with a 95% Confidence Interval of 2.61 to 5.21 ($p<0.05$).

Population

Static line (SL) paratroopers had a mean age of 25.9 (range, 18-49) versus 34.3 (range, 19-54) for free fall (FF) parachutists ($p<0.05$). One hundred and fifty seven parachutists were novices (out of whom 4 were FF jumpers), 43 experienced jumpers (5 FF) and 16 experts (10 FF). Experience was not recorded for 50 paratroopers who consequently were excluded from experience calculations but remained in unrelated calculations throughout this study. Figure 2 shows the parachuting experiences of injured military parachutists in each category: static line and free fall jumps. For a novice, the relative risk of injury between SL and FF was 1.31 (CI=1.12-1.52) $p<0.005$.

Different types of jumps were recorded: regarding SL, basic training courses caused 95 accidents and 105 injuries, with an injury rate of 0.07 per 100 jumps versus 0.119 per 100 for the other types of jumps. Therefore, jumpers involved in basic courses were injured significantly less often than more experienced jumpers (RR= 0.18, CI: 0.14- 0.23). With regard to FF, basic courses caused only one accident, high level jumps

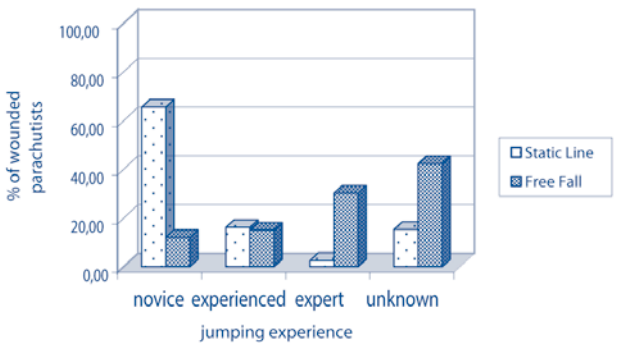


Figure 2. Parachuting experience of injured military parachutists in each category: static line and free fall jumps.

caused 10 accidents, training exercises 11, other types of jumps 11, but the repartition of the types of jumps was unknown, consequently injury rates could not be calculated.

Clinical characteristics of injuries

Table I shows the distribution of the 289 injuries according to their clinical diagnoses. The most common injuries were contusions (73.8% for SL vs 37.8% for FF).

Tableau I. Summary of injury rates according to severity of injury.

		Static line jumps		Free fall jumps		Total	
Severity of injury		No of injury	%	No of injury	%	No of injury	%
Moderate injuries	Contusions	186	73.8	14	37.8	200	69.2
	Sprains	22	8.7	11	29.7	33	11.4
Severe injuries	Dislocations	32	12.7	9	24.3	4	14.2
	Fractures	12	4.8	3	8.2	15	5.2
Total		252	100	37	100	289	100

Concerning FF, 29.7% of the injuries were sprains and 24.3% were dislocations. We counted 12 fractures resulting from SL and 3 from FF. Concerning SL, 208 injuries affected soft tissues versus 25 for FF, so the relative risk was 1.14 (CI=0.98-1.31) $p<0.05$. Twelve FF injuries were osteoarticular injuries versus 44 for SL. The relative risk of osteoarticular injuries for FF versus SL jumps was 1.86 (32.4 vs. 17.5 %) with a 95% CI of 1.09 to 3.18 ($p<0.05$). Contusions were mainly located on the shoulders for SL (37.4%) and for FF (47%). Sprains were mainly located on the wrists for both SL (50%) and FF (45.5%), followed by the elbows for SL (27.3%) and the shoulders for FF (27.3%). Dislocations were mainly located on the shoulders for both SL (84.4%) and FF (88.9%). Fractures were mainly located on the wrists for SL (33%) as opposed to FF resulting in fractures on the shoulders, the elbows and the hands.

Concerning the proximal part of the upper limbs, the risk of osteoarticular injuries was significantly higher for FF than for SL (RR=0.02, CI=1.16-3.50). The difference was not significant for the distal part of the upper limbs.

The shoulders constituted the main location of all the injuries resulting from SL (41.7%) and FF jumps (51.4%), followed by the elbows for SL (17.5%) and the arms for SL (14.7%) whereas the wrists came second for FF (21.6%) and the hands third (10.8%) (Table II). The significant relative risk of being injured on the proximal part of the upper limbs for FF versus SL jumps was 1.39 with a 95% CI from 1.23 to 1.56. There was no difference between the injury locations on the distal part of the upper limbs for SL and FF jumps.

Tableau II. Upper limb injury locations according to anatomical diagnoses.

		Static line jumps		Free fall jumps		Total	
Upper limb location		No of injuries	%	No of injuries	%	No of injuries	%
Proximal parts	Shoulder	105	41.7	19	51.3	124	42.9
	Arm	37	14.7	3	8.1	40	13.8
Distal parts	Elbow	44	17.5	2	5.4	46	15.9
	Forearm	6	2.4	1	2.7	7	2.4
	Wrist	29	11.5	8	21.6	37	12.8
	Hand	31	12.3	4	10.8	35	12.1
Total		252	100	37	100	289	100

Accident circumstances

Concerning SL jumps, 69.1% of the accidents took place while landing, 21.4% while leaving the aircrafts and 3% as the parachutes opened. Concerning FF, 57.6% of the accidents took place while landing, 21.2% as the parachutes opened and 9.1% while leaving the aircrafts. Most of the injuries occurred while landing ($p<0.05$) (Table III).

For SL jumps, the injuries which occurred while leaving the aircrafts were due to the entanglement of the static lines around the parachutists' arms for half of the known incidents (21/53) resulting in arm and shoulder locations, 47.4 and 42.1% respectively. These injuries were mainly contusions (62.4%) but 21% were dislocations. Seven accidents were caused by an impact on the aircraft door, causing injuries on the elbows (42.9%) and the shoulders (28.6%), but these injuries were limited to contusions (85.7%) and sprains (14.3%).

For FF jumps, 5 forms were detailed concerning the opening of the parachute: 4 accidents were due to the opening impact and caused 3 shoulder dislocations and 1 shoulder contusion.

Among the landing accidents, the shoulders constituted the most common location of injuries for both SL and FF jumps followed by the elbows for SL and the wrists for FF but there was no significant difference.

Tableau III. Mechanisms of parachute jumps.

	Static line		Free fall		Total	
Mechanisms	No of accidents	%	No of accidents	%	No of accidents	%
Aircraft exit	50	21.4	3	9.1	53	19.9
Parachute opening	7	3.0	7	21.2	14	5.3
Descent	3	1.3	0	0.0	3	1.1
Landing	161	69.1	19	57.6	180	67.7
Unknown	12	5.2	4	1.7	16	6.0
Total	233	100	33	100	266	100

Other variables

The injury rate for SL jumps was 1.24 per 1,000 jumps during the day versus 1.25 per 1,000 jumps at night with a relative risk of 1 (CI=0.63-1.58) deemed not significant. For FF, this rate was 0.33 per 1,000 during the day and 0.87 per 1,000 at night with a relative risk of 0.38 (CI=0.09-1.62) deemed not significant

The criteria "day versus night" (similar to the combat equipment criteria) induced no significant differences regarding the incidence rates, the types or locations of the injuries.

Time spent on sick leave and convalescent time when jumping was not authorized

Regarding the 233 SL accidents affecting the upper limbs, the mean time of sick leave was 7.69 days (range, 0-60) but 56.2% of the accidents had no consequences (no sick leave). For FF jumps (33 accidents), the mean time was 12.94 days (range, 0-120), and 42.2% did not have any consequence. Table IV shows comparisons of times of sick leave for static line versus free fall jumps. The relative risk of a sick leave of at least 30 days between FF and SL jumps was 1.19 with a 95%CI from 0.95 to 1.47 with a p-value = 0.032. The relative risk of a sick leave of less than 5 days between SL and FF was 1.13 (95%CI = 1.01-1.25) with a p-value = 0.016.

Tableau IV. Summary of time of sick leave.

	Static line		Free fall		Total	
Sick leave	No of accident	%	No of accident	%	No of accident	%
0-5 days	156	67.0	15	45.5	171	64.3
6-29 days	56	24.0	11	33.3	67	25.2
≥30 days	21	9.0	7	21.2	28	10.5
Total	233	100	33	100	266	100

Regarding the time injured paratroopers were not authorized to jump, the 233 SL jumps resulted in a mean time of 20 days (range, 0-365) as opposed to 66 days

(range, 0-1,000) in the case of the 33 FF jumps. This difference is significant. Table V summarizes the injury rates according to the time when jumping was not authorized. Only 34.3% of SL accidents had no consequence on the authorization to jump versus 24.2% of FF. The significant relative risk to be forbidden to jump for more than 30 days was higher for FF than for SL, (RR = 1.15, CI=1.02-1.30, p<0.005). Out of all the parachutists, two are permanently unable to jump: one because of a rupture of the supra-spinatus in a FF landing and the second because of an anterior scapulo-humeral dislocation in an aircraft FF exit which led to permanent shoulder instability.

Tableau V. Summary of convalescent time when jumping is not authorized.

	Static line		Free fall		Total	
Medical restriction	No of accidents	%	No of accidents	%	No of accidents	%
< 30 days	172	73.8	17	51.5	189	71.0
≥30 days	61	26.2	16	48.5	77	29.0
Total	233	100	33	100	266	100

Discussion

Parachuting accidents

The overall injury rate of 9.71 per 1,000 jumps for SL and 1.36 per 1,000 jumps for FF observed in this study is low. In other studies, the injury rate is 4.51 (20) to 89.1 (5) per 1,000 jumps for SL and 0.113 (2) to 11.3 (18) per thousand jumps for FF parachuting. We have shown that SL jumps are significantly more dangerous than FF jumps in terms of overall accidents and upper limb injuries.

The location of the injuries described here is similar to that described in other studies published in the literature. For SL, lower limbs come first and upper limbs third 2% of injuries (21) to 7.6% (20). Leger *et al.* (5) described a high percentage of upper limb injuries (14.61%) but lower limb injuries remained the most important. For FF, lower limbs also come first but upper limbs come second (5% of injuries (18) to 23.42% (6)).

Comparing injury rates between published studies is difficult mainly because the parameters of each study are different: there are different parachutes (22, 23), different landing positions and different drop zones. It is also important to note that all quoted studies took place in peacetime, not during war operations.

Upper limb injuries

Even if medical cards were filled prospectively, the limitations of this study include the fact that it was a retrospective study, which implies that some data was missing. We had to choose a classification for the types of injuries and locations among many studies and suggested classifications. So, we chose a simple classification, which could be criticized.

The authors were fortunate to have the opportunity to study parachuting injuries at the Paratrooper School, because it is the only school which teaches the French basic training course and because of the high number of jumps performed each year. This amount of data lends itself nicely to our evaluation. Since the Paratrooper School is a teaching institution, extrapolating these data to a paratrooper battalion would not be appropriate. However, it is interesting to note that a military study written in 2007 (2) claims that the Paratrooper School has the lowest rate of parachuting injuries of all other paratrooper battalions. Because it is a school, the mean age of the parachutists is younger than in other studies. The older age observed among FF parachutists can be explained by the fact that they must first train to be SL parachutists. Another likely explanation is that military parachutists who learn to jump are naturally young (19, 24).

Beginner paratroopers' upper limbs are significantly more likely to be wounded during SL jumps than during FF jumps, and during SL, there are fewer upper limb injuries during basic courses than during other types of jumps.

Similarly, in the literature, novice jumpers have a higher rate of injuries for SL (22) but a lower rate for FF (6) than expert jumpers. Those results are in keeping with data on injury rates in basic courses versus training exercises. Regarding SL, jumpers following basic courses are less likely to be injured than jumpers following training exercises (19, 24, and 25). Regarding FF, Ekeland (18) concluded that paratroopers following training exercises had a lower rate of injuries than those following basic courses (4.5 versus 19.7 per 1,000 jumps).

Regarding SL, it is interesting to note that the basic course jumps did not present a risk for upper limb injuries because of a better physical preparation and a better mental concentration for the jumps. The jumping conditions are better too (large intervals between jumpers, better weather conditions). (24). When jumping takes a lower priority than the mission, novice parachutists focus more on their missions and less on their jumps. This can cause careless mistakes. Regarding FF, expert parachutists are more often wounded than novice jumpers because the conditions of the jumps are more difficult and they tend to strive for an outstanding performance and take more risks. (6)

The upper limb injury rate was 1.19 per thousand jumps for SL versus 0.34 for FF jumps. In a literature review, we found a SL injury rate of 1.6 per thousand jumps in 1993 (10), and another of 1.36 per thousand jumps in 1990 (26) but that included SL and FF jumps. The injury location rate on the upper limbs was similar to that in Hay's study for SL (25) and in Lacombe's for FF jumps (6). However, the comparisons between our data and the ones presented in those studies have to be interpreted with caution because they use different criteria.

According to Tripon (10), the shoulders constitute the most common location for SL injury as opposed to the wrists in the case of FF jumpers. However, Tripon's conclusions were based on injuries treated in a hospital. Likewise, Lacombe (6) reported the same findings and based his study on injuries leading to more than two months when jumping was not authorized. Tripon and

Lacombe's studies did not include light injuries. In the daily practice of a general practitioner, these conclusions are not considered relevant. In this study, proximal part (shoulder and arm) injuries were significantly more frequent for FF than for SL jumps and the shoulders constituted the main location for both SL and FF jumps. Contusions were more common for SL than for FF jumps. Conversely, osteoarticular injuries were significantly more common for FF than for SL jumps. These conclusions could be explained with a better understanding of the injury circumstances.

The landing process was most frequently responsible for the injuries (9, 8, 22- 25). This explains the shoulder injuries: landing after SL jumps, requires a parachute landing fall (4, 19, 25) which exposes the shoulders while the arms are tucked in. The parachute landing falls combine impact, collapse and roll of the body: paratroopers must grip the suspension lines while their elbows are held tight against their chests, and their hands outstretched in front of their shoulders. While landing, their hips first touch the ground then their shoulders and finally their backs. Whereas parachutists land standing on their feet after FF jumps. Landing in an upper limb position, with extension and retropulsion and hands held at the level of the pelvis, exposes the shoulders and wrists if the parachutists are behind or thrown off balance laterally. Parachute reactions also expose the upper limbs although these must be near the body for protection. If the elbows are not protected during landing, they may hit the ground causing a transmission of impact to the shoulder girdle. (13)

Leaving the aircrafts, opening the parachutes, and the static lines are other known causes of injuries. Static lines can be trapped in a gap between the parachutists and their outstretched arms. This can lead to injuries of the upper arms or shoulders (23).

According to Glorioso (8), the difference in shoulder injuries can be explained mainly by the use of the upper limbs in flaring the canopy for landing. During this part of the jump, the arms are extended and thus exposed to greater risks in a fall or tumble injury; in static line jumping, the arms are tucked in, in the landing position.

Upper limb injuries are significantly more severe for FF than for SL jumps resulting in a longer length of time away from work (mean of 12.94 days versus 7.69) and a longer convalescent time when jumping is not authorized (mean of 66 days versus 20). However, those times are shorter than those described by Journaux (9): a mean of 96.28 days of sick leave and 209.82 days when jumping was not authorized. Of all the parachuting injuries upper limb injuries are not the most severe.

The other studied variables (day or night, with or without combat equipment) make no significant difference probably due to the low numbers of injuries, thus making significant statistical comparisons impossible. However, night jumps appeared to result in more injuries than day jumps in most investigations (21, 24, 27). This study tends to show that this difference concerned upper limb injuries. Likewise, various studies highlighted the increased risk of injuries when jumping with combat equipment. (8, 19, 23, 25)

Only a few variables from existing medical records could be used. Some variables that may have some influence on the incidence and types of injuries were not included: the number of jumps during the day of the injury (6, 27), previous damage on upper limbs (24), weather conditions (8, 9, 19, 22-24, 27) and drop zones (21, 24, 25).

Conclusion

In conclusion, free fall jumps present a risk factor for osteoarticular injuries on the upper limbs with a time of sick leave and a convalescent time when jumping is not authorized longer than for static line jumps. Whereas the injury rate is less important for FF than for SL jump.

The United States Army has developed an over-the-boot ankle brace (PAB), known as the parachutist ankle brace, resulting in a decrease in the overall injury rate (16.5 to 13.5 per 1,000 descents) (20). Could a similar device adapted for the wrist be used? This seems feasible for SL jumps but parachutists would then be unable to use their weapons if needed or to get into action quickly. Regarding FF, the use of a wrist brace is impossible because wrists must be free to steer the parachute.

The best method for upper limb injury prevention remains the physical preparation and the repetition of security rules before each jump. The French Army is testing a new parachute, easier to steer than canopy parachutes and less technical than square parachutes. This new parachute may be an effective tool to further minimize injuries to French parachutists.

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