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Military parachuting injuries: a literature review

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This article is a literature review of the aspects of military parachuting related to occupational medicine and focuses on 'conventional' military static line parachuting using a round parachute. The analysis of injuries resulting from military parachuting provide an excellent example of military occupational medicine practice. The techniques of military parachuting are described in order to illustrate the potential mechanisms of injury, and a number of 'classical' parachuting injuries are described. Finally some recommendations are made for the recording of parachute injuries which would assist in the international comparison of injury rates and anatomical distribution.

Key words: Military; occupational health; parachuting.

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INTRODUCTION

The development of military parachuting techniques which have allowed large numbers of soldiers to be delivered to the battlefield by air provides an example of how physicians have been closely involved with a workforce operating in a hazardous environment. This relationship has led to the definition of a health and safety policy; the creation of medical standards for employees; refinement of workplace equipment and procedures; the provision of a medical service; the measurement of performance with effective audit and the publication of numerous academic papers. The medical support of military parachuting is an excellent example of the practice of military occupational medicine.

This review focuses on 'conventional' military static line parachuting using a round parachute. It excludes the use of square parachutes which, for military use, is almost invariably the province of small teams of specialist soldiers. The over-riding requirement in military parachuting is to have a system which enables soldiers to jump from an aircraft and land on the ground in a fit state to fight. The parachute system should enable the aircraft to fly as low as possible to enable it to avoid radar and anti-aircraft weapons systems. The soldiers should exit the aircraft as fast as possible to minimize the time the aircraft spends over the dropping zone (DZ) and also to reduce the dispersal of soldiers across the DZ. The design of the parachute should allow the soldier to parachute with sufficient personal equipment to be effective and it should be released as soon as possible after arrival on the ground so that the soldier can get into action quickly. Such an operation would be likely to be conducted at night.

The technique of military parachuting

The principles of operation of the military parachute have remained essentially unchanged since the 1940s but several modifications have improved its performance and safety record. The military parachute is contained in a bag on the back of the soldier. The soldier almost invariably will have a reserve parachute attached to his front. If military equipment is carried, it is usually attached below the reserve parachute.

The parachute is opened by a 'static' line attached to a strong point on the aircraft. Parachutists exit from the side door of the aircraft, either singly and in rapid succession or from alternate sides of the aircraft in rapid succession. As the parachutist falls the static line pulls the parachute and rigging lines from the bag until the system has completely deployed. At this point the breaking strain of the tie holding the static line to the parachute is exceeded, the static line breaks off and the parachutist falls free as shown in Figure 1. If the parachutist is carrying equipment this is often lowered on the end of a rope during descent so that the parachutist hits the ground unencumbered. The landing force varies between types of parachute but is usually equivalent to jumping off a

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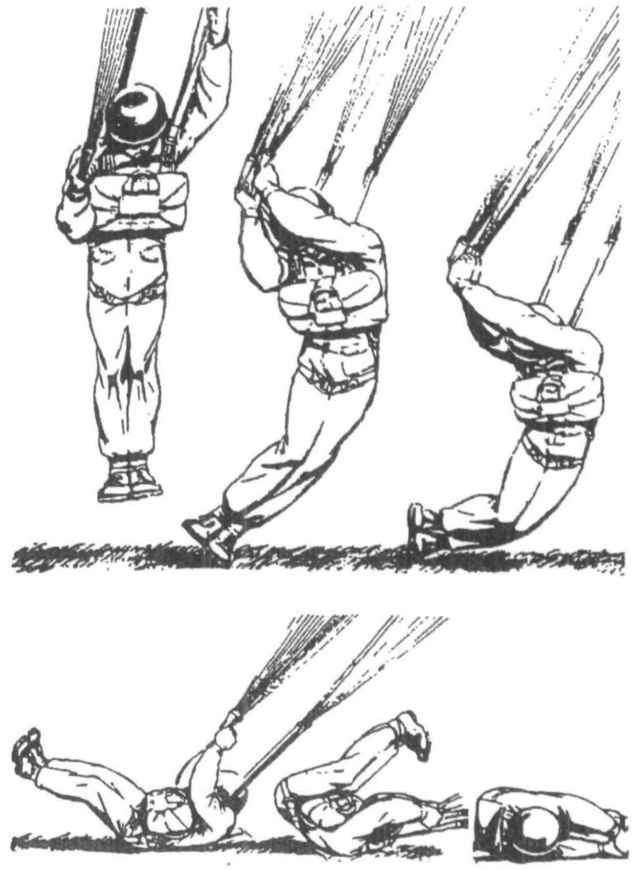
Figure 1. A military parachutist.

Figure 2. The parachute landing roll.



9–12 foot wall. The kinetic energy is dissipated by a landing roll.

During the early days of parachute training the Germans and the Americans taught a forward landing roll. Trainees landed with feet apart and conducted a forward roll across an outstretched arm. The German parachute harness was attached at a single point at the centre of the upper back and consequently the parachutist landed in a forward facing position making this type of landing roll the only option. The US harness was similar to the British harness with the rigging lines merging onto risers which attached to the parachute harness on the top of each shoulder. Thus the parachutist descended in an upright position. The British developed an alternative landing roll in which the parachutist landed with the feet and knees together and conducted a sideways roll successively onto outer side of the leg, thigh, buttocks, across the back and onto the opposite shoulder. This technique caused significantly fewer injuries than the first forward landing roll and was adopted by the US Army in June 1943.[1] The parachute landing fall (PLF) is shown in Figure 2.

It is possible for the wind to catch the parachute after landing and drag the parachutist along the ground, thus causing injury. In order to prevent this the parachute is collapsed as quickly as possible, either by pulling on the rigging lines which causes air to spill from the canopy, or releasing a riser from the harness using a specially designed release catch. Once this is done the parachutist removes the harness and is ready for action.

Training and selecting military parachutists

The military parachutist is regarded as part of an elite element in all the armed forces. Appointment to the role is usually the result of a selection process that tests physical fitness and mental determination. The rationale behind this has more to do with the nature of airborne operations than the requirement for high standards of physical fitness for parachuting *per se*. Once a soldier has qualified as a military parachutist in the British airborne forces the basic fitness standards are no different from the remainder of the British Army. There is international variation in the military physical standards required for parachuting and in many countries women are allowed to parachute if they achieve the physical standards required.

The training for military parachutists is considerably longer than that required for civilian parachutists. This is because the practical skills required are substantially greater, eventually leading to the ability to conduct a massed parachute assault at night. This training has the desired effect of imprinting the biomechanical skills involved so that the basic drills become automatic. This principally applies to conditioning the response of exiting the aeroplane on the 'Green light' or command 'Go' and the proper execution of the PLF.

PARACHUTING INJURY RATES

The aim of this review was to produce a 'benchmark' for parachuting injury rates from a review of the medical literature. A systematic search was made of the medical literature using *Medline* to search *Index Medicus* back to 1963 for reports of medical aspects of parachuting. The Mesh terms used were 'parachuting' and 'aviation'. *Index Medicus* was also hand-searched for reports dating from 1940–63. The *Journal of the Royal Army Medical Corps* and *Military Medicine* were hand-searched for papers published prior to 1963. Only English language publications were obtained because there was no facility for translation. The reference list for each paper was also checked to obtain further reports.

Each paper was reviewed to obtain injury rates. Papers were included in the analysis if there was a clear case definition, a clear description of the setting and the rate denominator was based on parachute descents. Studies were excluded if it was clear that not all parachute injuries were included (*e.g.*, studies based on positive x-ray findings) or if the denominator was based on time (*e.g.*, annual incidence) rather than descents.

Table 1 shows all reported rates of injury for military parachuting per thousand descents. Rates for single parachute programmes were excluded because these reports may cover extreme casualty rates. All reports chosen show a mean of injury rates measured over at least a 6 month period. The summary statistics exclude the US and UK reports from the Second World War because both report rates approximately ten times greater than all subsequent reports.

Table 2 shows a summary of the reported injury rates for civilian parachuting. Unfortunately, only three reports could be found. It should be noted that a substantial proportion of civilian parachuting included freefall parachuting in which the parachutist deploys his own parachute. This affects the injury pattern, obviating static line injuries but creating the risk of injury during the freefall period. A study by Ellitsgaard[17] reported five injuries occurring during freefall of which four were fatalities.

There are many factors reported that affect the casualty rates for individual parachute programmes, a number of which are listed in Table 3. The association between ground wind speed and casualty rates was realized very early on in the development of military parachuting. Early British experience suggested a marked increase in casualty rates at wind speeds greater than 15 mph (13 knots),[3] and a more recent analysis[11] suggested a cut-off point at 9 knots. A Belgian report suggested a cut-off point at 12.75 knots.[9] It is clear that casualty rates increase with increasing windspeed and thus many military forces have a windspeed threshold for parachuting. The height and weight of the parachutist also has an effect on injury rates. Several studies have shown that the mean weight of casualties amongst military parachutists is greater than the mean weight of the military parachuting population as a whole.[9,11,13] The evidence for an association of risk of injury with increasing height is less clear with an English study demonstrating a linear correlation[11] but a Belgian study failing to show any relationship.[9]

ANATOMICAL DISTRIBUTION OF PARACHUTING INJURIES

There is a well-recognized constellation of injuries associated with a fall from a height, which reflects the distribution of kinetic energy along the body. Table 4 is a summary of the anatomical distribution of injuries reported from military parachuting. It is not appropriate to summarize the anatomical distribution by taking a mean of the reported injury rate for each region because of the variation in reporting criteria and diagnostic categories used by different authors. However, it can be seen that most injuries occur to the ankle with a progressively lower proportion affecting the leg, back, arm, shoulder and chest. Closed head injuries represent a significant proportion of injuries, which reflects the vulnerability of the brain to impact.

The mechanisms of parachuting injuries

Parachute injuries can occur at any time between leaving the aircraft and completing the removal of the harness. These are best grouped as problems with exit, descent and landing. Bizarre incidents, such as a reserve parachute opening within the aircraft, will be excluded from this discussion.

The static line is usually attached to a cable running the length of the aircraft. This enables the parachutist's static line to move down the aircraft with him until it is in line with the door as he exits. Initial parachute exit training required the parachutist to grasp both sides of the door. This created a gap between the parachutist and his outstretched arms in which, occasionally, the static line became trapped. This could lead to injury to the upper arm or shoulder.[23] The exit procedure used by UK forces has always emphasized a tight exit with the hands clasped onto the equipment. The US airborne forces adopted this technique in March 1994 by holding onto the reserve which has led to a substantial reduction in this mechanism of injury for their airborne forces.

Parachutists are taught to look up and make a positive 'drive' out of the door on exit, thereby ensuring a good position. If the parachute fails to deploy properly after exiting the aircraft, parachutists are trained to operate their reserve. If the parachutist exits in an uncontrolled manner he may tumble or twist which can lead to problems with the deployment of the parachute or rigging lines. In severe cases this can cause entanglement which may affect the deployment of the main parachute or the parachutist's ability to take up a safe landing position. If he falls with his legs above his head then his legs can be caught as the rigging lines deploy — an accident which

Table 1A. Reported injury rates for military parachuting (injuries per thousand descents)

Ref	Publication year	Country	Year of study	Crude rates (per thousand descents)		Day jumps from balloon, without equipment		Day jumps from balloon, with equipment		Day jumps from aircraft, without equipment		Day jumps from aircraft, with equipment		Night jumps from aircraft, with equipment		Injury classification	Remarks
				No of jumps	Injury rate	No of jumps	Injury rate	No of jumps	Injury rate	No of jumps	Injury rate	No of jumps	Injury rate	No of jumps	Injury rate		
2	1941	USA	Aug 1940–Aug 1941	4490	24												PLF was by fwd roll
3	1946	UK	Jan–Nov 1944	20777	21	810	11					17831	19	2136	14	Injury = receipt of medical treatment on DZ	6th AB Div
			Apr 1942–Jan 1943	10696	37	1493	24					9203	41				1st AB Div
4	1946	UK	Jan 1944–Jun 1945	66408	2.6					13272	1.7	779	2.7			n/k	
5	1951	USA	1946	21004	6.5												
			1947	39662	7.6												
			1948	32848	6.4												
			1949	80706	4.2												
6	1965	USA	1946	21004	6.5											not given	
			1947	39662	7.6												
			1948	32848	6.4												
			1949	80706	4.2												
			1956	61649	4.5												
			1957	89325	2.1												
			1958	97785	4.3												
			1959	107127	4.7												
			1960	95281	3.4												
			1961	101226	2.4												
			1962	83412	2.3												
			1962	95099	0.9												
			1963	115518	1.4												
7	1960	USA	1956	61649	4.5											Injury = incident causing time lost from duty	
			1957	89325	2.1												
			1958	97785	4.3												
			1959	107127	4.7												
8	1975	Israel		83718	6.26								4.62		11.25	Injury = receipt of medical treatment on DZ	
9	1985	Belgium	1974–1983	201977	5	34332	0.17	21150	0.33	21215	0.52	23423	0.85	9948	0.7	Injury = fracture, first shoulder dislocation, admission < 1 day	672 type of parachute
						37525	1.41			21073	1.9						665 type of parachute
10	1989	UK	n/k	51828	4											Injury = seen at A+E	Parachute training
11	1991	UK	1983–86	34236	11.1	7120	0.13			1353	1.5	23740	15.3	2116	1.37	Injury = event requiring treatment on DZ	
12	1992	Australia	Mar 1987–Dec 1988	8886	7.1					5687	3.3	3199	13.7			Injury = requiring evacuation from DZ, restriction of duties or admission	
13	1995	Malaysia	n/k	9514	3.8											Injury = moderate/severe	
14	1996	USA	n/k	7948	22							3211	14	4358	27	Injury = any restriction of duty	US Rangers
15	1997	USA	1993	138132	7.1											Injury = ER consultation	82nd AB Div
			1994	107115	8.9												82nd AB Div
			1995	133888	7.5											82nd AB Div	
16	1998	Israel	n/k	43542	8.9											Injury = incident preventing jumps for at least 2 days	Parachute training

Table 1B. Summary statistics (excluding references 4 & 5)

Crude rates		Day jumps from balloon, without equipment	Day jumps from balloon, with equipment	Day jumps from aircraft, without equipment	Day jumps from aircraft, with equipment	Night jumps from aircraft, with equipment
No of jumps	*Injury rate*	*Injury rate*	*Injury rate*	*Injury rate*	*Injury rate*	*Injury rate*
Total	2437940	78977	21150	62600	54352	16422
Mean rate	5.61	0.57	0.33	1.78	8.53	10.08
Max	22.00	1.41	0.33	3.30	15.30	27.00
Min	0.90	0.13	0.33	0.52	0.85	0.70
SD	3.78	0.73		1.00	6.49	12.27
95%CI	6.77	0.79		2.09	10.52	13.84
5%CI	4.90	0.49		1.56	7.42	8.62

Table 2A. Reported injury rates for civilian parachuting (injuries per thousand descents)

Ref	*Publication year*	*Country*	*Year of study*	*Crude rates*		*Day jumps from balloon, without equipment*	*Day jumps from balloon, with equipment*	*Day jumps from aircraft, without equipment*		*Day jumps from aircraft, with equipment*	*Night jumps from aircraft, with equipment*	*Injury classification*	*Remarks*
17	1987	Denmark	1979–83	110000	6.7			110000	6.7			Injury = requirement for medical treatment	Civilian
18	1986	UK	1984	19356	2.7			19356	2.7			Injuries seen at A+E dept	Civilian
19	1988	Netherlands	1981–85	47278	3.7			47278	3.7				

Table 2B. Summary statistics

Total	176634
Mean rate	4.3
Max	6.7
Min	2.7
SD	2.08
95%CI	5.00
5%CI	2.84

Table 3. Associations with parachuting injuries

Factor	*Effect on injury rate*
Windspeed	Increasing windspeed increase rate
Multiple parachutists leaving aircraft	Increase
Night descent	Increase
Carriage of equipment	Increase
Nature of dropping zone	Hard, uneven or hazards increase rate
Balloon descents	Decrease relative to aircraft
Design of parachute	Decreased with modern parachutes
Height and weight of parachutist	Increase
Inexperience of parachutist	Increase

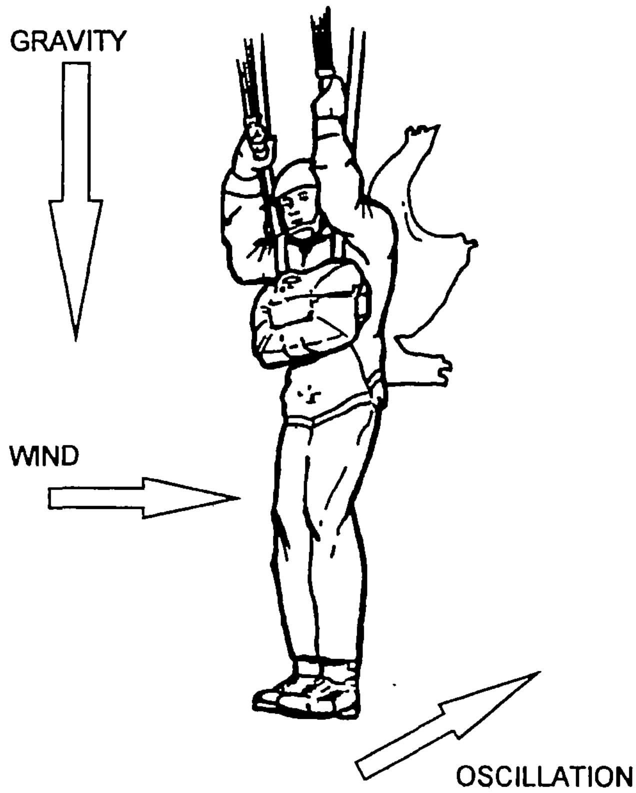
has been shown to be associated with damage to the collateral ligaments of the knee.[24]

The principal hazard during the descent phase is other parachutists. It is possible to steer military parachutes a little by pulling on the risers on the left or right and allowing some air to spill out. This is sufficient to manoeuvre the parachute. Collisions with other parachutists can cause entanglements with consequent risk to the canopy. If a parachutist drifts over the top of another parachutist's canopy a phenomenon know as an 'air steal' can occur. In this case the bottom canopy 'steals' air from the top canopy which collapses. The top parachutist then free-falls until he is on the bottom at which point his canopy catches air which in turn steals air from the other canopy. Clearly if this happens close to the ground one of the parachutists can land without the support of a fully deployed canopy.

It is impact with the ground that causes the majority of military parachuting injuries. In preparation for landing, the parachutist is trained to adopt a relaxed position. The chin is placed on the chest and the hands clasp the lift webs with the elbows tightly tucked in. The legs are held forwards with the knees slightly bent and the toes lifted so that the feet land flat on the ground.

When the parachutist hits the ground he is subjected to a number of forces as shown in Figure 3. These are the downward force from gravity, sideways force from wind, sideways force from oscillation and possibly a rotational force if he is spinning. The downward force is dependent on the parachute design and load. Factors that affect this are limits to the weight and volume of parachute material that the parachutist can carry, the maximum design load for a parachutist and his equipment and the maximum descent speed consistent with landing safely. The sideways force from the wind is a crucial factor that determines injury rate which has already been discussed. Oscillation of the parachute was a significant problem with the early, semicircular design of parachute. This was reduced by removing a circle of material from the apex of the parachute so that air could vent from the top and was not forced out from the edge of the parachute in a uneven fashion. A mesh skirt was developed during the 1950s[5] which is attached to the periphery of the parachute to even the flow of air from

Figure 3. Diagram of forces on landing.



the edge. Modern circular military parachutes are parabolic in shape rather than semicircular which further reduces oscillation.[12] The parachutist is taught to steer into the wind during the last phase of descent in order to reduce the lateral velocity to a minimum. Spinning is usually the result of the untwisting of twisted rigging lines and is not normally a significant problem.

The feet should be the first point of contact with the ground. If the toes are pointed the landing force is transmitted through the metatarsals (which may fracture) to the articular surface of the tibia, possibly causing the posterior lip to fracture.[25] If the landing is made with the feet apart, one foot is likely to strike the ground before the other. When a paratrooper attempts a PLF, the ankle furthest from the direction of the PLF is subjected to an eversion force which may lead to a fracture of the ankle. If there is substantial sideways drift, even if the feet are held tightly together, there is likely to be considerable force acting on the ankle closest to the direction of the PLF which causes marked supination. This may cause damage to the ankle ligament complex, fracture of the tibia or fracture of the tibia and fibula.[26] Strain of the superior tibio-fibular joint or fracture of the upper third of the fibula have been reported as classical parachute injuries, but are not often seen.[1] Likewise, isolated knee injuries do not seem to be a common result of poor landings.[24]

Severe landings due to parachute mishaps may cause fractures of the femur or pelvis but the force required for this is so great that it is unlikely that the unfortunate parachutist could have influenced the outcome. Landing backwards can cause the parachutist to 'sit down' thus

Table 4. Regional distribution of parachuting injuries (as percent of total reports)

Site of injury	*Reference*												
	5	*8*	*14*	*15*	*15 Military*	*15*	*20*	*21*	*12*	*16*	*18*	*19 Civilian*	*22*
Head and Neck	6.4	0.0	4.0	19.4	17.8	16.4	14.2	3.6	12.0	7.0	2.8	3.3	4.9
Closed head injury	5.2		4	19.3			12.9	3.6	12.0		2.3		4.9
Closed HI with LOC					8.7	7.9							
Closed HI without LOC					9.1	8.5							
Facial contusion	0.3						0.4						
Skull/facial fracture	0.3			0.1	0	0	1.0				0.6		
Mandible fracture	0.5												
Nose fracture	0.1												
Neck injury	1.4	0.0	2.0	5.9	9.4	8.8	0.0	0.0	0.0		0.0		2.4
Neck contusion	0.3												
Neck strain	1.1		2	5.9	9.4	8.8							2.4
Shoulder	5.3	0.0	0.0	1.1	1.1	1.1	11.5	3.4	14.5		1.7	2.3	2.4
Shoulder injury	0.3												
Shoulder contusion	1.3												2.4
Shoulder sprain	0.6						1.9						
Shoulder fracture							0.4						
Shoulder fracture–dislocation							4.8						
Shoulder dislocation	2.5			1.1	1.1	1.1	3.8	1.3	12.8	0.7	1.7		
Acromioclavicular dislocation	0.2							0.8	1.7				
Fracture clavicle	0.1						0.6	1.2					
Fracture scapula	0.4							0.2					
Arm	1.6	2.5	2.0	1.8	1.1	1.9	5.0	4.0	0.0		13.6	7.6	4.8
Arm contusion	0.3							0.1			1.1		2.4
Strain/sprain				1.2	0.7	1.7							
Upper extremity fracture/dislocation			2.5	2									
Humerus fracture	0.7			0.5	0.1	0	4.0	1.3			1.1		
Elbow sprain	0.2												
Forearm fracture				0.1	0.2	0					0.6		
Ulna fracture	0.1							0.2					2.4
Radius fracture	0.1						0.8	0.9					
Hand and wrist fracture				0	0.1	0.2	0.2	1.5		0.7	10.2		
Wrist dislocation								0.2			0.6		
Finger dislocation	0.2												
Chest and abdomen	4.2	0.4	3.0	0.5	0.3	0.3	0.8	1.3	0.0		1.7	3.3	2.4
Chest or abdominal wall injury			3										
Chest contusion	0.6												
Sternum fracture	0.1												
Rib fracture	1.3							0.3					
Abdomen contusion	0.3												
Groin contusion	0.3												
Pelvic fracture	1.6	0.4		0.5	0.3	0.3	0.8	0.7			1.7		2.4
Separation of symphysis pubis								0.3					
Back	40.1	16.4	16.0	12.5	15.5	16.0	15.2	5.8	13.7		12.5	9.3	7.3
Back injury											1.7		
Back contusion	13.2						3.8				2.3		
Buttock contusion	2.2												
Back strain		11.2	14	9.5	12.4	12.9	3.3				0.6		
Lumbrosacral sprain	12.7												
Sacro-iliac sprain	1.7												
Back fracture	10.0	3.2	1	3	3.1	3.1	8.1	5.8	13.7		8.0	7.3	
Back fracture-dislocation	0.3												
Contusion or fracture of coccyx		2	1										
Leg	38.0	47.4	57.0	26.3	26.9	27.8	50.0	81.0	50.4		60.2	64.5	68.2
Leg strain				5.9	4.7	4.1							
Contusion of leg	3.6	1.1									2.8		
Contusion of thigh		1	7										
Hip contusion	1.3												
Hip sprain	0.6												
Hip dislocation	0.2							0.0					
Femur fracture	2.7	1.1		0.5	0.6	0.5	1.7	1.2			1.1		4.9
Knee contusion	1.0		11								0.6		
Knee sprain	4.9	4.7	3	3.3	1.7	2.4	6.3				2.3		4.9
Tear of collateral knee ligament		1						3.1			1.7		
Knee meniscus injury			2										
Knee dislocation	0.2										0.6		2.4
Patella fracture	0.2							0.4					
Tibia fracture	3.1			0.5	1.5	0.7	3.5	1.6	6.0	4.0	5.7		
Fibula fracture	4.5		4	2	3.5	4.7		2.6		4.0			
Tibia-fibular fracture		1.6	2	1.1	1.6	1.5		4.1					15
Fibula dislocation								0.3					
Ankle sprain	7.5	17.8	12	8.7	9.1	10.2	9.0			25.0	11.9		2.4
Contusion of ankle		4.8	1							7.3			
Ankle fracture	5.5	13		1	1.3	0.7	22.9	48.5	44.4	0.1			27
Ankle fracture dislocation											25.0		9.8
Navicular fracture	0.1												
Foot injury											2.3		
Foot contusion			13										
Foot sprain	1.2	0.7		1.5	0.6	1.7	1.9						
Foot fracture	1.5	0.6	2	1.8	2.3	1.3	4.6	18.9			5.1		2.4
Foot dislocation								0.3			1.1		
Other	3.0	33.3	17.0	32.3	27.3	27.2	0.0	0.5	9.4		5.7		4.8
Other (diagnostic category)	3.0		17	1.6	2.5	1.7		0.5	9.4	6.0	5.7	1.6	
Contusions				22.8	19.8	19.1				35.2		8.0	
Abrasions/lacerations/contusions		33.3		5.2	3.6	4.8							2.4
Static line injury				1.8	1.4	1.3							
Nerve injury				0.8	0	0.3							2.4
Heat injury				0.1	0	0							
Total number of injuries	1,012	723	579	734	1,106	1,169	520	3,015	109	388	176	301	41

Table 5. Classic parachuting injuries

Injury	*Mechanism*	*Reference*
Concussion	Allowing head to whip back during the PLF, especially in a backward landing	3, 27
Fracture–dislocation of shoulder	Landing without tucking elbows in tightly	10
Traumatic rupture of biceps brachii	Entrapment of the static line with an arm on exiting the aircraft	23
Partial or complete dislocation of acromio-clavicular joint	Landing on the point of the shoulder	25
Strain of the superior tibio-fibular joint or fracture in upper third of fibula	Sideways strain on the leg which 'springs' the fibula head laterally	1
Compression fracture of vertebrae	Backwards landing with incomplete absorption of fall through PLF	21
Collateral knee ligament injuries	Excessive abduction of lower leg by somersaulting against rigging lines	24
Fracture of posterior lip of tibia	Landing with the toes pointed down	25

transmitting the force directly through the coccyx and lumbar spine which can cause compression-type fractures.[21] If the force is transmitted further, the head can be jerked backwards leading to 'whiplash' injuries of the neck or indeed a closed head injury if the helmet strikes the ground hard.[5,27]

If the parachutist has performed a good PLF, the landing forces will be transmitted across the back as he rolls over. If his elbows are not protected whilst this is happening the point of the elbow may strike the ground causing transmission of impact to the shoulder girdle. This may cause a humerus fracture, shoulder dislocation, acromio-clavicular joint dislocation or a fractured clavicle.[8,25] Finally the parachutist will complete the PLF and come to rest!

A number of 'classical' parachuting injuries have been reported. These are listed in Table 5. The mechanism of each type of injury has been discussed above. It should be noted that most of these are a reflection of a heavier-than-normal landing or poor parachuting skills.

DISCUSSION

The large number of medical papers written on military parachuting shows the close relationship that has developed between military doctors and military parachutists. This is largely because these military doctors are often trained parachutists themselves and thus have absorbed some of the culture associated with military airborne forces.

The results are skewed by the injury reports from the Second World War period of 1941–45[2,3] when both the British and the Americans reported injury rates ten times greater than subsequent reports. These reports were excluded from the summary statistics in Table 1 because they reflect parachute design and procedures which have been substantially modified since then. The comparison between reports of injury rates shows that the crude mean injury rate for military parachuting is 5.61 injuries per thousand descents [standard deviation (SD) = 3.78; 95% confidence interval (CI) = 6.77–4.90]. This compares to a mean for civilian parachuting of 4.37 (SD = 2.08; CI = 5.0–2.84). The difference between these means is 1.25 injuries per thousand descents. However, the heterogeneity of the types of military static line parachute programmes complicates interpretation of this difference. The military parachute programme which most closely equates to civilian parachuting is 'day jumps from aircraft without equipment'. The aggregated injury rate for this type of descent is 1.78 injuries per thousand descents (SD = 1.0; CI = 2.09–1.56) which compares favourably with civilian injury rates. Additional factors that increase the risk of injury in military parachuting relative to civilian parachuting include: the carriage of heavy equipment, pre-descent stress on prolonged turbulent aircraft flights, massed drops from multiple aircraft and night descents.

The principal source of bias between all the reports is the variation in the definition of an 'injury'. These definitions vary from any casualty requiring treatment to only casualties receiving attention at an Accident and Emergency department. Clearly this variation is attributable to the setting in which the authors work, but it does also limit the value of a comparison between reports.

This review has identified a number of factors that contribute to the injury rate for a particular military parachute programme. Table 1 shows the reported variation in injury rates between descent by day or night and with and without equipment. The rate of injury increases as would be expected, with balloon descents having the lowest injury rate and night jumps from aircraft with equipment the highest rate. It is not possible to make detailed comparisons between individual parachute programmes because of the wide variation in the effects of the various factors on single programmes.

Table 5 lists other variables that are associated with parachute injuries. Although these have been identified it is not possible to quantify the effects of many of them. The effect of windspeed is well known and is routinely used as a limiting factor for parachuting. Although night descents, multiple parachutists leaving the aircraft and the carriage of equipment are known to increase the injury rate, these factors are fundamental to the operational capabilities of parachute forces and thus cannot be avoided. Equally the choice of dropping zone is restricted to the availability of land for military training. Many forces use specially selected areas for basic parachute training[8,10,14] which are flat and free of hazards but it is often necessary to use less suitable dropping zones for military manoeuvre training.

These casualty rates have been used to guide the planning of emergency medical services for military parachuting. A predicted rate based on the numbers parachuting and time of descent (day or night) can be used to determine the number of medical personnel and evacuation vehicles required to ensure suitable provision for any parachutist who becomes injured. A knowledge of the anatomical distribution of injury also assists in determining the type of emergency equipment required such as spinal boards, cervical collars and traction splintage. It also ensures that medical personnel are aware of particular patterns of injury and can examine casualties appropriately. These principles can be extended for operational planning to determine the appropriate number of medical personnel and equipment required to support a parachute operation and also the number of parachutists required to ensure that sufficient are available to undertake the operational task after landing.

A review such as this may lead a non-military reader to consider that military parachuting is excessively dangerous. However, no attempt has been made to compare the risk of military parachuting with other military activities. There are a number of military activities which are carefully monitored (*e.g.*, flying and diving). The overall risk to an individual associated with being a military parachutist can only be assessed by a comparison of injury rates and patterns between soldiers who are military parachutists and soldiers who are not.

There is a clear benefit from maintaining this standard of medical surveillance of military parachuting and indeed the increasing constraints of health and safety legislation in many countries makes this surveillance mandatory. It is suggested that there would be great advantages to international authors conforming to an agreed data set to allow better comparisons. This could significantly assist in creating an international 'benchmark' standard. The definition of injury should be based on the potential effect on military operations for which there would be two criteria: (1) unfit to continue the military mission (which would inevitably exclude some minor injuries) and (2) admission to hospital. The second category is more relevant for injury surveillance because these injuries are most likely to have an effect on the soldier's long-term medical fitness.

The description of the anatomical distribution of injury could also be standardized, possibly using the categories in Table 4. The injury to each region could be described as a contusion, sprain, fracture, dislocation or fracture dislocation with additional categories for specific injuries, *e.g.,* closed head injury with or without loss of consciousness. This would also improve international comparisons.

CONCLUSIONS

This paper has reviewed the reports of military parachuting injuries in the medical literature. It is likely that individual armies retain other data but this is not available in the public domain. Overall it can be seen that there is a measurable risk associated with military parachuting.

The injury rates reported in this paper are indications of average expectations. It has to be anticipated that there will be variations in the injury rate for individual parachute programmes which will reflect chance. Furthermore it is important to remember the operational requirement that justifies the existence of airborne forces which is the ability to deploy a body of soldiers by parachute at night with all their fighting equipment. These are the most hazardous combination of circumstances which, although not practised excessively, must be included in training in order to ensure that the soldiers are as prepared as possible for this type of operation.

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