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Descriptive epidemiological study of fatal incidents and injury mechanisms among civilian sport parachutists in Norway from 1963 to 2008

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Abstract: Introduction. Even though worldwide sports parachuting results in up to 100 deaths annually, very low number of scientific studies is dedicated to this sport activity.

Methods. Descriptive epidemiological method was used describing reports from 32 fatalities and 14 post-mortem reports. Operator performance was analysed by two independent professional instructors from Special Operation Forces of the Norwegian Army.

Results. The fatality rate was 2.2 per 100,000 jumps. The most frequent injury mechanism is ground deceleration leading to severe lesions and injuries of CNS. No fatalities due to use of high performance parachutes or high speed landing pattern were found.

Discussion. The general risk of parachuting is low, but higher than in Scandinavia. Student training there is also safer than the international level. Three fatalities occurred when using a functioning automatic activation device, one was a result of malfunction of such device. The fraction of fatalities associated with longer survival has increased. Failure in executing emergency procedures is the dominant cause of fatalities. 40 % of fatalities could have been avoided by use of safety devices.

Conclusions. The risk level associated with parachuting in Norway was lower than the international average. The majority of the fatalities are due to personal failure. The previous high risk of drowning is reduced. Lives can be saved by improving ground training and using the most recent and modern equipment. There seems to be an increased benefit of emergency medicine service when rescuing parachutists.

Key Words: skydiving, parachuting fatalities, fatal sport accidents, epidemiology, risk, safety.

The aim of the study is to describe the epidemiology of fatal incidents in Norwegian civilian sport parachuting from 1963 to 2008 to create a basis for prevention of further incidents. The Norwegian Air Sports Federation investigates these to identify their principal cause and thereafter take the necessary measures of prevention. One of the experienced instructors expressed the thought authors share: "I recognised the origin of many of the safety regulations when reading the fatality reports". The first civilian Norwegian parachute students were trained in 1964 [1].

Despite that, no systematic review of parachuting fatalities has been done until now. Authors' study can offer a more systematic view on risk and injury mechanism to improve the basis for preventive actions.

MATERIALS AND METHODS

The investigation reports including all known parachuting fatalities in Norway in the period of 1963-2008 were reviewed and covered 32 cases altogether. Data describing these events as well as demography of

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the civilian parachuting population were provided by Norwegian Air Sports Federation (NLF) and Aircraft Investigation Board Norway. To determine cause of death, injuries sustained and possible influence of drugs and alcohol, forensic autopsy records were reviewed.

A descriptive epidemiological method was chosen to analyse human, equipment and environmental factors and compare the results of the study to demographical and jump data. Methodology and structure of analysis is taken from a Swedish study of Westman and Björnstig done in 2005 [2, 3].

RESULTS

1. Epidemiology of the parachuting fatal accidents in Norway during 1963-2008 period.

During the 46 year period of the study, 32 fatalities were analysed, yielding an incidence of 0.7 fatalities per year. The maximum fatalities per year were found in 1980 and 1992 with three deaths each year. The annual number of active parachutists has increased from 149 in 1964 to 3,849 in 1996, giving a mean annual fatality rate of 43 per year when referred to 100,000 jumpers. In the first ten year period of the study the fatality rate was 56.5 per 100,000 jumpers. This was 4.5 times higher than the last five year period, 2004-2008, where the fatality rate was only 12.4 fatalities per 100,000 jumpers per year. Table 1 shows epidemiology of fatal parachuting accidents during 1963-2008 period with case-fatalities rate (CF) referred to 100,000.

Table 1. Incidence of parachuting fatalities in Norway 1963-2008

	Fatalities	Jumps	Fatalities per 100,000 jumps
1963-1973	2	30,524	6.6
1974-1983	10	193,168	5.2
1984-1993	9	403,087	2.2
1994-2003	9	517,453	1,7
2004-2008	2	291,652	0.7
TOTAL	32	1,435,884	2.2

During the period 2004-2008, with lowest CF, the rate of fatal incidents was 9 times lower than in the first period of the study 1963-73.

2. Age and gender.

Mean age of fatally injured parachutists was 29.4 years (range 17 – 58, median 25.6). Six deceased (19%) were women with mean age 28.0 years (range 18-39, median 25.0). One female and four men (total 15.6 %) were younger than 21 years (Fig. 1).

Six of the fatalities (18.8 %) were associated with failure to deploy main parachute. Four parachutists also failed to deploy their reserve parachute manually after failure to deploy main parachute. This gave a fraction of 33.3 % of female fatalities and 15.4 % of male fatalities following failure to manually deploy either parachute.

3.1. Death mechanisms up to the technical point of view.

Five primary mechanisms of death were identified: a) ground deceleration (26 cases), b) drowning (3 cases), c) sudden cardiac arrest, d) impact in aircraft and e) acute hypobaric hypoxia (1 case in each of the last three).

Ground deceleration deaths (26) can be divided into deceleration from impact speed of terminal velocity (8 cases), sub-terminal velocity (15 cases) and canopy speed (3 cases). Terminal velocity for a human being in free fall without any parachute to reduce speed has a range from 200 km/h to 500 km/h, while lower speeds are more probable.

Sub-terminal velocity is any vertical speed below terminal velocity, but higher than one would expect when the jumper is suspended under an operational parachute (higher 25 km/h) and is obtained when the original speed is reduced by malfunctioned parachute equipment. Canopy speed is defined as any vertical speed that can be obtained under an operable parachute [4].

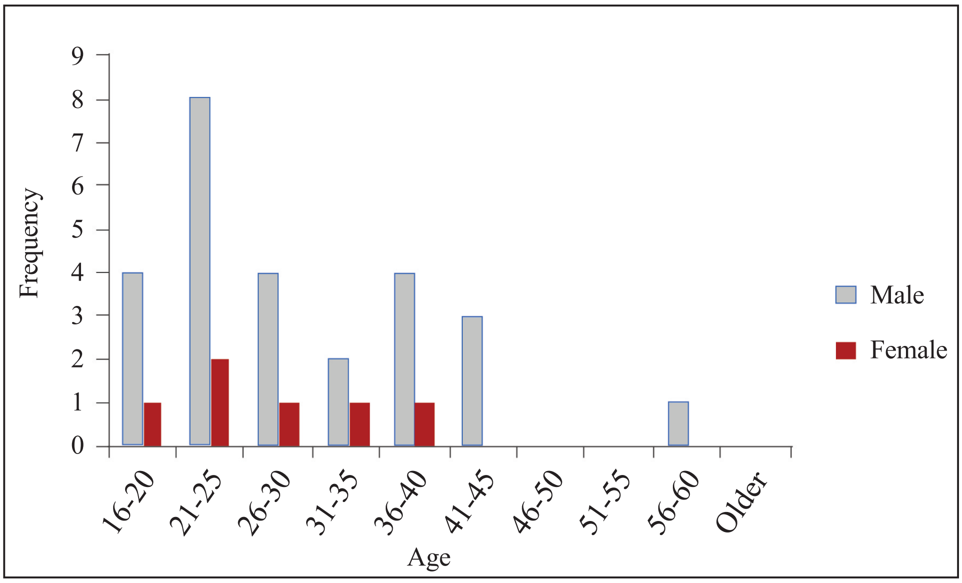

Figure 1. Age and gender distribution of 32 deaths 1963-2008 (male n=26, female n=6)

Table 2. Survival time and place of death in 26 fatalities after ground deceleration

Deceleration speed	Survival time	Place of death
Terminal	0 min (8)	Drop zone (8)
Sub-terminal	Range: [0 min -25 h] Mean: 1 h 58 min Mode: 0 min (8) Median: 0 min	Drop zone (11) Transport (3) Hospital (1)
Canopy speed	20 min (1) 4h 15min (1) 1y 2m 18d (1)	Drop zone (1) Hospital (2)

Table 2 compares time of survival after ground deceleration in different impact speed, which understandably implicates the place of death.

When correlating deaths due to deceleration injuries to experience level, authors study shows that students caused fatal accident in 10/32 cases altogether, while they mostly died after ground impact in sub-terminal velocity. Experienced jumpers died in other 21 accidents while one third of these fatalities were a result of the fall from height in terminal velocity.

3.2. Cause of death, injuries sustained and toxicology examined in forensic autopsies.

The primary cause of death could be identified in 14 all 32 fatalities (44 %). Cause of death was injuries to CNS in five cases (36 %) as well as thoracic organ injuries, drowning in three cases (21 %) and poly trauma in one case (7 %). Table 3 describes more accurately the autopsy findings and final diagnoses.

Table 3. Cause of death in 14 fatalities among civilian sport parachutists, Norway 1963-2008

Cause of death		Fatalities
CNS injuries	Rupture of medulla oblongata	2
	Decapitation	1
	Cerebral injury after skull base fracture	1
	Acute cerebral hypoxia	*1*
Thoracic injuries	*Aortic rupture*	*2*
	Multiple chest trauma	*1*
	Commotio cordis	*1*
	Pulmonary lesions	*1*
Drowning		*3*
Poly trauma		*1*
		14

From the available 14 autopsy reports, all the injuries in addition to the one recorded as primary cause of death, were documented in the forensic autopsy protocols and are listed in Table 4.

Toxicology analysis post-mortem was performed in 13 cases. One was positive for tetrahydrocannabinol (THC) at a blood concentration of 0.010 µmol/L. None of the tests were positive for ethanol. Six of the 13 analysis were extended analysis, including ethanol, barbiturates, BZD, THC, opiates and cocaine/amphetamine from blood, urine and vitreous humour with negative results.

4. Technical equipment analysis.

Of the 32 accidents studied, 9 parachutists (28 %) were equipped with round main and reserve parachute. None of these used an automatic activation device (ADD). Twelve of the deceased jumpers (38 %), had square main parachute and round reserve parachute, 7 of them had an AAD. In the last 11 (34 %) accidents the jumpers had square both main and reserve parachute with an operable AAD in 7 cases. The last configuration of equipment is standard today. Nowadays, the use of an AAD has become mandatory for the least experienced jumpers and even the most of the experienced jumpers increase their safety using it. Round canopies are no more used in civilian parachuting in Norway today.

No accidents expressly due to structural malfunction of equipment or harness rupture/ disintegration were found. However, 3 accidents (9 %), were related to a low degree of mechanical equipment failure. One was due to a badly manufactured reserve ripcord disintegrating when being used, resulting in no reserve activation. One was due to misfire of an aero-mechanical AAD following entanglement of the two parachutes. The last one was a parachutist impacting in terminal velocity after the lead seal of the reserve container blocked reserve parachute opening.

Two parachutists had no use for their main parachute, as one who later died from acute hypoxia did not exit the airplane, and the other one was killed while leaving the airplane. Six parachutists (19 %), did no appropriate attempt to activate their main parachute or did not succeed in throwing their pilot chute into the airstream/ pulling their activation ripcord. Such a failure is called as "no activation" and is often a human factor error [5].

31 % of all fatalities happened after the parachutist was suspended under an operable main parachute, defined by its capability to protect the parachutists from landing injuries. Three of these drowned after unintentionally landing in water. Another two had entanglement between main and reserve parachute. Two parachutists disconnected their main without any obvious malfunction.

44 % of the deceased parachutists experienced a malfunctioning main parachute. Primary malfunction is defined as any malfunction that could not be attributed to action of a jumper during the freefall.

Table 4. Injuries sustained for 14 parachuting fatalities, Norway 1963-2008

		Terminal (n=3)	Sub-terminal (n=6)	Other (n=5)	
Orthopaedic injuries	Lower limb	66 %	33 %	-	
	Upper limb	33 %	17 %	-	
	Pelvic ring	66 %	33 %	-	
	Thoracic cage	66 %	67 %	-	Excl. thoracic vertebrae
	Cervical spine	33 %	17 %	20 %	
	Thoracic spine	33 %	17 %	-	
	Lumbar spine	-	17 %	-	
Abdominal organs	Spleen	66 %	50 %	-	
	Liver	66 %	67 %	-	
	Pancreas	-	-	-	
	Kidney	-	50 %	-	
	Bladder	-	17 %	-	
Thoracic organs	Heart	100 %	50 %	-	Incl. pericardium
	Aorta	100 %	50 %	-	
	Diaphragm	-	17 %	-	
	Lungs	100 %	83 %	60 %	Incl. pulm. vessels, pleura, hemo- or pneumothorax
Skull	Base	66 %	33 %	20 %	
	Calvarium	-	-	20 %	
	Facial skeleton	66 %	17 %	20 %	Incl. mandible
CNS	Cerebrum	33 %	33 %	20 %	
	Cerebellum	33 %	17 %	20 %	
	Meninges	-	33 %	-	Incl. epi- and subdural hematoma
	Medulla .obl.	66 %	-	20 %	
	Spinal cord	-	-	-	

Secondary malfunction of the main parachute is defined as any malfunction resulting from sub-optimal action by the parachutist after leaving the airplane. Four out of five students experiencing secondary malfunctions did so as a result of instability during or prior to main parachute activation, resulting in a less than favourable body position at time of activation.

Three accidents (9 %), followed a reserve parachute malfunction. One of these could also be classified as a gear failure, and is mentioned above as an incidence where lead seal blocked reserve container opening. The second accident was due to a packing error of the jumper himself in combination with missing mandatory modification of the reserve parachute.

The third fatality was due to a secondary reserve malfunction after the student initiated reserve deployment at inappropriate time.

An AAD is viewed as a life-saving, last minute safety device. However, there are 3 fatalities (9 %), where the parachutists died in spite of correctly mounted AAD which was properly functioning and activated the reserve as it was designed to do. One was due to entanglement following a student's late activation of main parachute. One was caused by release from a malfunctioned main parachute by an experienced jumper where the jumper did not pick up high enough vertical speed in sufficient altitude to let the AAD-activated reserve parachute save his life.

The last accident was due to a pilot chute hesitation, a situation where reserve activation is halted by a pilot chute resting in the air turbulence trailing behind the free falling parachutist.

DISCUSSION

Today civilian sport parachuting activities are reported by 118 nations in all six continents [6]. There are only two known systematic analysis of CF in civilian parachuting: by Westman and Björnstig from Sweden and Hart and Griffith's analyses done in USA [7, 8]. The most reliable source for establishing an international CF is the annual Safety Report from the Safety and Training Committee of the International Parachuting Commission (IPC) [9, 10].

Case fatality reports from Scandinavian countries from 1963-2009 show the maximal annual fatality rate of 26 accidents in 1965. Since then, the amount of accidents has decreased and even has become zero in the mid-80s. This may be a benefit of several major changes in design of parachute equipment in that period, in particular transition from round to square ram-air canopies and introduction of „piggyback" harnesses and containers [11]. It's not reasonable to generally conclude that the risk of parachuting is not increasing year by year. Although the 2004-2009 annual risk level reached only 0.32 fatalities per 100,000 jumps in Finland, Norway and Sweden, annual risk level of 40 reporting countries in 2009 is 0.88 fatalities per 100,000 jumps which is more than 2.5 times higher. However, Scandinavian countries have had a significant reduction in risk year by year [7-10].

Thirteen fatalities (41%), could be expected to have ended more favourably if all jumpers had been equipped with AAD. It is found that 4 of the fatalities could have yielded a better outcome of using either AAD or reserve static line (RSL). It is important to note that 9 of the fatalities occurred when using equipment that was not designed for RSL. AADs of multiple designs and manufacturers have been available during the whole studied time period.

In 17 out of 32 fatalities the jumper executed their emergency procedure wrong, too low or not at all. In all these 17 fatalities there was a potential for improving the outcome by carrying out the emergency procedure correctly at a sufficient altitude. For students, eight out of 11 (72 %), were in the same situation. This reveals a demand for more and/or better recurrence training on emergency procedures.

Taking into consideration that one might observe a raised awareness on refreshing emergency procedure skills during the spring, following the low activity season, due to harsh winter climate in Norway, it might be a possible explanation of the peak in experienced jumper fatalities in August and September that this awareness is declining during the summer.

When counting the newest 10 fatalities, occurring from 1997 to 2006, 50 % would have had an increased potential for surviving with properly executed emergency procedures in high enough altitude.

The 3 fatalities from drowning involved two parachutists using a life jacket/flotation device. There was one possible life jacket failure and one fatality where the manually operated life jacket was not activated. The drowning happened in the period from 1976 to 1980, all with round main parachutes, which are no more used today.

The use of helmet is mandatory in Norway offering a variety of designs, ranging from leather hats to open face/integrated hard shell helmets. Analysis of data from 14 port-mortem reports gave no evidence of lower level of injuries with certain types of helmets. Injuries of CNS, skull and facial skeleton were always concluded as being fatal.

CONCLUSIONS

The risk level associated with parachuting in Norway from 1963 to 2008 was lower than the international average, but somewhat higher than comparable risk in Sweden. The majority of the fatalities are due to personal failure. The previous high risk of drowning has been reduced, and is now on a minimum. Almost half of the fatalities involves main parachute malfunction, and there is a life-saving potential in improving ground training for emergency procedures. Student training in Norway appears to be associated with a very low level of risk, compared to international data and studies from other countries.

There seems to be a future life-saving potential in meeting a predicted increased demand for emergency medicine services and of course, using recommended original equipment when parachuting.

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