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Indian Journal of Aerospace Medicine

Short Communication

Snow Survival Training of Astronauts: Through the eyes of a Flight Surgeon

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Received : 29 November 2021
Accepted : 11 November 2022
Published : 01 June 2023

DOI
10.25259/IJASM_31_2021

Quick Response Code:

ABSTRACT

Manned space flight missions always harbor within themselves the possibility of an off-nominal re-entry and landing. The crew has to be prepared to deal with such an eventuality. Hence, survival training post-landing forms an integral part of the pre-flight preparation of an astronaut. The survival training is aimed at enhancing the ability of the crew to take rational decisions and actions during extreme situations after an emergency escape from a spacecraft, till the arrival of the search and rescue team. The training enables the crew to acquire the skills required in the event of an off-nominal landing (or splashdown). This paper deals with the snow survival training for astronaut candidates conducted by a foreign Astronaut Training Centre. The Snow Survival Training program consists of theoretical lectures, practical demonstrations in the field, and 48 h of snow survival in real environmental conditions. With the advent of the Human Spaceflight Programme, the lessons learnt in the snow survival training would be helpful in conducting extreme weather training for Indian Astronauts as well as serve as a welcome addition to the existing training pattern of Jungle and Snow Survival courses for aircrew in India.

Keywords: Snow survival, Astronaut training, Flight surgeon

INTRODUCTION

On April 12, 1961, Yuri Gagarin became the first human to venture into space. However, it took the space faring fraternity another 4 years to realize the importance of snow survival training for astronauts. On March 19, 1965, failures in the navigation system lead Voskhod-2 to overshoot the landing zone by 386 km, resulting in a long delay in wilderness recovery. The crew had to spend 3 days in the dense frozen taiga where the temperature plunged to –30°C at night. The cosmonauts' bulky spacesuits were wet, and their survival kit had no winter clothes as Voskhod-2 was planned for a splashdown. To protect themselves from adverse weather conditions, they built fire from the woods, and when darkness descended on the taiga, they took shelter in their crew module using their parachutes as blankets.[1,2] The lessons learnt from this incident resulted in the introduction of snow survival training in the curriculum of mission preparedness of Cosmonaut/Astronaut trainees.

On October 16, 1976, the Soyuz-23 mission was terminated early due to a failure in the docking system. The crew module landed in blizzard conditions in a frozen lake at night. The search and rescue team could recover the crew 9 h after the touchdown.[3,4] This incident further reinforced the importance of snow survival training for the astronauts.

Survival training is aimed at teaching the astronauts how to protect themselves against forces of nature by effective use of survival equipment in their crew module, emergency clothing, and the

available natural resources at the landing site.[5] It also teaches them the actions to be taken to prevent and treat diseases or injuries caused by adverse post-flight factors.

The components of a survival training curriculum involve both theoretical knowledge as well as hands on experience in the form of field exercises. Participation in field exercises in difficult and isolated environments (e.g., woods, mountains, winter, water survival training, isolation, and confinement training) gives astronauts the chance to experience their reactions to real and challenging situations where a single mistake may result in serious consequences. These field exercises offer astronauts the opportunity to develop self-awareness of the challenging aspects of these environments, learn new coping skills, and confirm the usefulness of previously learnt coping techniques. The stand-out features across these activities include remoteness, physical hardships, self- and team awareness, reliance on technical training and specialized gear, careful attention to operational procedures and hazards, meticulous rationing of food, water, and maintenance of hygiene.[6]

The advent of India's maiden Human Spaceflight Programme has necessitated the importance of survival training for our astronaut candidates on various aspects of the off-nominal mission. This paper deliberates on the first person narrative of the author who had the opportunity to witness the snow survival training conducted by a foreign Astronaut Training Centre.

SNOW SURVIVAL TRAINING

The snow survival training program consisted of theoretical lectures, practical demonstrations in the field, and 48 h of snow survival experience in real environmental conditions. For ease of understanding, the curriculum is discussed in three phases, namely, the pre-training phase, training phase, and post-training phase.

Pre-snow survival training phase

It commenced 1 week before the snow survival training. It was primarily dedicated toward preparation for snow survival and consisted of the following:

(a) **Familiarization with Sokol spacesuit:** The candidates were given basic theoretical details about the Sokol suit and practical experience in donning and doffing of Sokol suit, as they were required to perform it during snow survival.

(b) **Familiarization with Soyuz MS manned transport system:** Introductory class was conducted on Soyuz 1:1 scale simulator. Candidates were familiarized with the design and layout of the habitable area, descent module, and operation of the hatch of Soyuz descent module.

(c) **Familiarization of survival kit:** The "Portable Survival Kit" (PSK) Figure 1 located in the crew module of Soyuz spacecraft is designed for 3 days of crew life support at the site of emergency landing. The PSK comprises the following:

i. Emergency radio and light signaling devices, camping gear, water, food items, first-aid kit, and stowed in three orange bundles.
ii. Personal floatation devices (three sets) and
iii. Thermal suits (three sets).

Figure 1: Components of portable survival kit (Image courtesy: Google).

Detailed classes on the contents and their usage during snow survival were conducted.

(d) **Formation of team:** The candidates were split into batches to undergo snow survival training for 48 h. Each batch comprised two astronaut candidates and one survival training instructor as the Mission Commander.

(e) **Medical and psychological evaluation of team members:** Before being subjected to field training in snow survival, the candidates were evaluated by the physician and psychologist. The evaluation involved weight measurement, general physical examination, monitoring of temperature, pulse rate and BP, and psychological evaluation.

(f) **Medical aspects of survival in the event of emergency landing in the wood in winter time:** In this class, candidates were explained about the components of the first aid box of the Survival kit, their usage, and various steps to be taken during certain medical conditions such as generalized overcooling, frostbite, common cold, carbon monoxide (CO) intoxication, snow blindness, and fracture/trauma.

(g) **Changing in Soyuz MS descent module:** Candidates were made to practice changing from Sokol suit to survival suits within the confined space of Soyuz descent module. It was a simulation to actions of changing into survival suit post-landing in snow before coming out of the capsule.

(h) **Crew actions in the event of emergency landing in the wood in winter time.** Candidates were taught

how to build temporary shelters (Lean-on and Tepee), making of smoke signal, lighting of signal flare, and build stretcher with the available materials such as parachute and thermal suit for the purpose of casualty evacuation.

Snow survival training phase

The training was conducted in a mixed coniferous-deciduous forest (called "woods") within the confines of the training facility. The time period chosen was during the winter season (January–February) when the temperature varies from −14°C to +4°C. The main objective of the survival training was to learn various methods of survival which could be incorporated into real-life situations. The events consisted of the following:

(a) Before the initiation of snow survival, a safety briefing was conducted for all the crewmembers including the survival training instructor. The salient points covered in the safety briefing were:
   i. Do not hasten
   ii. Do not exert and take rest in between activities
   iii. Ingress into capsule with helmet half open
   iv. Egress from capsule with legs first
   v. Do not be a hero, rather survive as a team
   vi. Remove the mouthpiece from water-can before putting it near fire
   vii. Do not touch water-can with bare hands
   viii. Direction of machete should be away from self and crew members while cutting trees and logs
   ix. Activity of cutting logs not to be undertaken during dark hours
   x. Do not make shelter under a dead or leaning tree
   xi. Do not walk over a fallen tree, instead walk around it
   xii. Dry your clothes before going to bed especially feet covers
   xiii. Divide shift for night watch
   xiv. Individual keeping night watch is responsible for the fire as well as safety of other crewmates
   xv. Crew to give radio call for 10 min on each astronomical hour. The following are to be reported during each call "Mayday, Mayday, Mayday; Call sign, Call sign, Call sign; Emergency landing of Soyuz, Location coordinates, Health status of the crew," the call is to be repeated after a gap of 02 min for a total 3 times during the first 10 min of each astronomical hour
   xvi. As plenty of snow is readily available to make water, drinking water is replenished in the water-can of survival kit when needed and the crew is advised not to drink the water after melting snow.

(b) Following this, the crew members had their lunch and got their body weight recorded. Then, they changed into their Sokol suit and were positioned inside the crew module in the woods. Inside the capsule, they had to change into their flight suit and thermal suit, collect the Survival kit, egress from the capsule, and survive in the snow for 48 h. After leaving the crew module, they chose a suitable site to build a shelter, to protect themselves from the wind and cold.

(c) They had to build a "Lean-on" shelter on Day 1 and a "Tepee" shelter on Day 2. On Day 2, the crew were assigned to create a smoke signal and light signal flare to be spotted by the SAR helicopter. On Day 3, the assignment was a simulated medical emergency, during which the crew were instructed to evacuate an injured member in a makeshift stretcher after providing necessary first aid. The training concluded with a simulated recovery by the SAR team at the rendezvous point.

(d) Monitoring during snow survival: At regular intervals (i.e., 0900 h and 1800 h), the crew were visited by a team comprising of instructors, flight surgeon, and psychologist. The flight surgeon performed a physical examination (to rule out any cold injury to the extremities) and checks the temperature, pulse rate, blood oxygen saturation (SpO_2), and blood carbon monoxide saturation (SpCO) of the crew members using a finger pulse oximeter. As reported by the flight surgeon, SpO_2 and vital parameters of the crew recorded during training were all within normal limits. SpCO values were nominal (near 0%). The psychologist enquires regarding their general well-being and sleep.

(e) For safety purposes, a 24 h observation post was maintained, at a distance well enough from the woods to preserve the crew's autonomy, but to respond immediately in case of any emergency. The observers monitored the training team visually as well through RT communications from the post. A flight surgeon was also stationed at that post with an emergency medical kit.

Post-snow survival training phase

On completion of the snow survival, the crew was evaluated by the doctors and psychologist. The evaluation involved general physical examination, monitoring of temperature, pulse rate and BP, and psychological evaluation. Post-training weight recording was also done and the crew members were detected to have lost 2 kg of body weight during 48 h of field training. This was followed by a debriefing session for the participants. No training was scheduled for the candidates for the week succeeding the snow survival training.

DISCUSSION

Survival of an individual in an emergency situation depends largely on the psychophysiological traits of the individual, such as determination and will to survive, presence of

mind, ability to cope with an unfavorable situation, physical strength, and endurance. The foundation of conducting survival training for astronauts is based on the premise that they would retain their fitness post-landing and survive under extreme physical and geographic conditions, by making use of the available natural resources. Thus, the objective of a survival training curriculum is to provide the requisite theoretical knowledge and practical skills to overcome such emergencies. Furthermore, the astronauts are psychologically prepared so as to evaluate the situations effectively, take rational decisions, and act accordingly.[5]

It is imperative to ensure that the conditions in which the survival training is carried out must resemble actual conditions as much as possible. Survival training in diverse terrain and climates is essential not only for training purposes, but also for the assessment of personality traits, psychological qualities, interpersonal relationships, and group dynamics between crewmembers detailed for a mission. This approach would make the astronaut trainees to appreciate that they could preserve their physical well-being and psychological stability through the use of knowledge and survival skills. It is also vital to identify the critical areas for human survival and ensure safe outcome of the training protocol.[5]

The snow survival training described in the paper is comprehensive with didactic lectures, practical demonstrations, and real-time field experience. The training imparted to the spaceflight crews has successfully prepared them with survival skills in the event of an off-nominal landing in challenging snowy terrain under adverse weather conditions. In a study published in 2021, it was brought out that 50 International Space Station crews had participated in snow survival training between 2011 and 2019. The crewmembers included cosmonauts and astronauts from Roscosmos, NASA, ESA, CSA, and JAXA, as well as spaceflight participants.[7]

Medical check-up and psychological evaluation of the team members before field training ensures readiness of the crew. Monitoring of the crew members at regular intervals as well as from the outpost is an effective practice to tackle any emergency during field training. In 2012, flight surgeons from NASA had proposed the practice of measurement of HR, blood SpO2, and blood SpCO of the crew, and this had been routinely performed since then.[7]

Medical issues associated with snow survival training include skin injury (namely, first and second-degree burns of the fingers, first-degree frostbite, contact dermatitis, lacerations, abrasions, and chaffing), eye injury (namely, allergic/toxic conjunctivitis, foreign bodies in the eyes, and superficial keratitis), and mucosal injury (namely, rhinitis and pharyngitis).[7] Management of the medical events was covered during the pre-training phase and none of the crew members reported any medical issue. Although a loss of body weight (average 2 kg) was observed post-training, it is a common finding as reported by Kireev *et al*. This is attributed to multiple factors such as weather conditions, physical activity, water and food consumption regimens, and cold induced diuresis.[7]

In India, survival training is provided to aircrew in the form of Jungle and Snow Survival Course (JSSC). It is a 4-week course which involves didactic lectures, trekking, and endurance run on week 1, followed by snow survival training, jungle survival training, and desert survival training on week 2, 3, and 4, respectively. Discussion of JSSC in details is beyond the scope of this paper. However, one important distinguishing feature is that the aim of JSSC is to teach a fighter pilot to survive independently, avoid being detected if in an enemy territory, whereas, as an astronaut, one needs to survive the adversities as a team and make all efforts to be detected by the SAR team at the earliest. In addition, psychological evaluation and monitoring of JSSC trainees do not form a part of the training curriculum.

LESSONS LEARNT

1. Role of psychologist: The psychologist is an integral part of training in the form of their evaluation and monitoring before, during, and after completion of snow survival training of astronauts
2. Medical evaluation: Evaluation of trainees/candidates before and after completion of survival training is essential. During the course of winter survival training, emphasis was laid on monitoring of vital parameters and detection of cold injury to extremities. The flight surgeon plays an important role in this regard
3. SpCO monitoring: In addition to monitoring of SpO_2, it is also vital to monitor the SpCO of the crew members during survival training. As they spend their night in close proximity of wood-fire in confined shelters, with possibly poor ventilation, there are concerns of carbon monoxide toxicity
4. Operational: The concept of giving RT call for 10 min on each astronomical hour (instead of reporting hourly post landing) is vital for SAR procedure as it is operationally pertinent for the SAR team to monitor the RT call during an astronomical hour
5. Training: Hands on training of astronaut candidates on the actions to be taken during survival scenarios as well as correct utilization of contents of their survival pack ensures successful outcome of the training
6. Rest and recuperation: It plays an important role after exposure to extreme weather survival training. Hence, no training was scheduled for the candidates for the week succeeding the snow survival training.

CONCLUSION

The snow survival training described in this paper has stood the test of time and has achieved its aim of providing comprehensive training to the astronaut candidates. With the advent of India's Human Spaceflight program, the horizons have widened further beyond into the space. The lessons learnt in the snow survival training at the foreign Astronaut Training Centre would be helpful in conducting extreme weather training of Indian Astronaut designates as well as serve as a welcome addition to the existing training pattern of JSSC.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Sannigrahi P, Mishra S, Sharma V, Prusty PP, Chandrawanshi S. Snow Survival Training of Astronauts: Through the eyes of a Flight Surgeon. Indian J Aerosp Med 2022;66:94-8.