Evaluation of a Concept for a Military Expedition Performance Environment

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ABSTRACT

To evaluate four factors essential in the preparation of high-altitude expeditions and of the performance during these expeditions, the Manaslu 2016 Medical Team, as part of the medical team of the Royal Netherlands Marine Corps (RNLMC), developed the Military Expedition Performance Environment (MEPE) concept. The scope of this concept is intended to cover (1) selection of a team, (2) medical planning and support, (3) competencies in the field (team work and human factors), and (4) and chain of command.

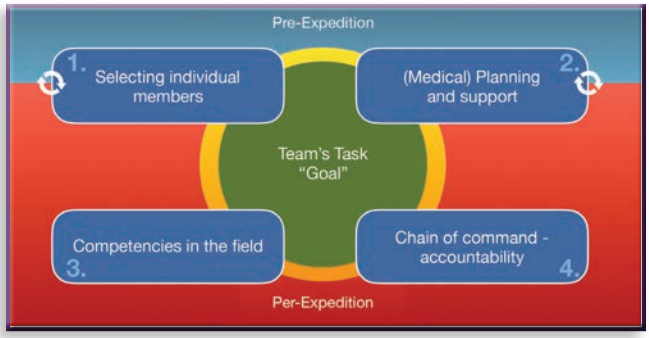
KEYWORDS: *Manaslu 2016 Medical Team; Royal Netherlands Marine Corps (RNLMC); Military Expedition Performance Environment (MEPE); teams; planning, medical; chain of command*

Introduction

"The chief work of the surgeon of a polar expedition is done before the ship leaves England" is a quotation from Alexander Macklin, surgeon on two of Ernest Shackleton's expeditions.[1] This quotation still stands today and applies to commercial and military expeditions. Medical preparedness to reach the summit of an 8,000m-high peak is one example. To evaluate four factors essential in the preparation of high-altitude expeditions and of the performance during these expeditions, the Manaslu 2016 Medical Team, as part of the medical team of the RNLMC, developed the MEPE concept. The scope of this concept is intended to cover (1) selection of a team, (2) medical planning and support, (3) competencies in the field (team work and human factors), and (4) and chain of command (i.e., accountability; Figure 1).

Military medicine introduced numerous practical adaptations to existing medical practices and started innovations in modern trauma care. An important finding in the study of Shlim et al.[2] is that a high mortality rate for altitude sickness, due to commercially driven factors and "top fever," is associated with organized treks. The causes of this increased mortality rate are well described and can be applied to all organized expeditions. With this in mind, the MEPE concept is introduced.

FIGURE 1 *Military Expedition Performance Environment (MEPE) concept.*



The primary aim of this study was to provide guidance on possible essential pre-expedition and per-expedition factors for successful achievement of the predefined goal. The secondary aim was to assess ability to meet all key aspects proposed in the MEPE concept

Methods

This study was approved by the Ministry of Defense and the Institutional Review Board of Leiden University, the Netherlands. Twenty carefully selected military specialist climbers (mountain leaders [MLs]/Heeres Bergführer [HBF (German: Army mountain guide)]) were involved in determining factors for success and performance. Prospective data were collected during the RNLMC organized expedition with individuals from Austria and the United Kingdom attached. This military expedition distinguished itself from regular, commercial high-altitude expeditions in two ways. First, there was a well-defined mission objective: enabling at least one climbing team (two climbers) to undergo a summit attempt on Manaslu and the imperative condition for all climbers to return safely. This should encourage the solidarity behavior that is part of the RNLMC values of solidarity, strength, and dedication. Second, the concept of operations combined with a military command and control structure well embedded with the assist and advice of five Sherpas created shared responsibility for preparation and tasks (i.e., local knowledge).

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Military Expedition Performance Environment

The MEPE is versatile and the performance depends on the following four interacting factors that go beyond traditional psychosocial and physical domains:

1. Selecting individual members: The selection of individual members is the backbone of the MEPE and is based on two criteria. The first selection criterion is made by the expedition leader in conjunction with the project team, on the basis of two questions: (1) How do you assess the skills, besides the physical competencies, of the team members required for the team's task or goal? (2) How do you assess the skills necessary for effective collaboration and interaction among the team members? The second selection criterion includes the physical competencies (i.e., prebiometry measurements, maximum exercise stress test, and spirometry).

2. Medical Planning and Support: Medical support for remote extended expeditions is complex and requires in-depth planning. The medical planning was done according to the guidelines presented by Iserson et al.[3] The optimization of the workers' fitness is presented in selecting individual members, but the other key elements about medical planning are assigned to this factor.[3]

3. Competencies in the field: Competencies in the field are described as team work and human factors. We defined human factors as anticipatable, treatable problems and changes during the course of the expedition. Three self-developed questionnaires were used to test social cohesion, self-performance, and buddy performance (Table 1).

Human factors were determined before and during the expedition. Participants were screened for pre-existing and recent physical problems and basic clinical measurements related to altitude (Lake Louise Self-Report Score) and acclimatization. The Lake Louise Self-Report Score was used to diagnose acute mountain sickness (AMS) and a score ≥3 was considered as having AMS. Psychological factors were assessed with the rate of perceived exertion (RPE) and the profile of mood states (POMS) tests (Supplement 1).[4] The daily tasks of the individual climbing members were expressed by the RPE. The climbers were asked to fill out the RPE score every active day and the score was presumed to be 0 on rest days. The POMS test was performed four times during the course of the expedition: (1) at arrival in Kathmandu, (2) at arrival in base camp, (3) after returning from camp 1 the first time, and (4) on return to Kathmandu. The Injury and Illness Severity Classification Union Internationale des Associations d'Alpinisme Medical Commission score was used by the expedition physician to grade the severity of the complaints members experienced during the expedition.[5]

4. Chain of command (accountability): The setup of the expedition team was based on a military mission command structure. The organization has a number of overlapping work units in a hierarchy under the expedition leader. The team leaders make decisions on their own; however, all decisions regarding the team's composition, concept of operations, risks, and rescues must be approved by the expedition leader. The Sherpas' knowledge was used in the decision process. The expedition leader keeps the responsibility during the whole expedition, unlike during commercially organized expeditions.

Statistical Analysis

Statistical software (SPSS, version 25; IBM Corp., www.ibm.com) and GraphPad Prism (version 7.00 for Mac; GraphPad Software, https://www.graphpad.com/) were used for data analysis. A *t* test was used to determine differences between the summiteers and nonsummiteers when values were normally distributed; if the distribution was skewed, we used the Mann-Whitney *U* test to analyze continuous values. Mean (standard deviation) values are reported if data were normally distributed; median (quartiles 1–3) is reported if the data were skewed. The Spearman product-moment correlation was used to determine the strength and direction of continuous variables. The Kruskal-Wallis H test was used to determine differences in urine osmolality, heart rate, and pulse oximetry readings of oxygen saturation on different days during the acclimatization trek into base camp. Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. The Friedman test, a nonparametric alternative to the one-way repeated measures analysis of variance, was used to determine whether there were statistically significant differences between the measurement points of the different mood states and teamwork questionnaires. A p value ≤ .05 was considered statistically significant.

Results

The 20 MLs/HBFs were all men. Their median age was 32 (29–40) years, mean height was 181.2 (3.0) cm, and mean weight was 82.5 (3.3) kg. The respective median ages (38 [32–40] versus 32 [28–38] years; p = .503), heights (181.4 [9.4] cm versus 181.1 [3.4] cm; p = .922), and weights (78.6 [5.0] kg versus 84.0 [4.2] kg; p = .123) of the summiteers (n = 7) and nonsummiteers (n = 13) did not differ significantly.

Selecting Individual Members

Four assessment criteria were used to classify the potential team members. First, the military competence dictionary was used to judge the 76 potential team members of the RNLMC ML community according to the following five competence clusters:

TABLE 1 *Three Questionnaires to Test Social Cohesion, Self-Performance, and Buddy Performance*

Social Cohesion	Self-Performance	Buddy Performance
I consider my team members to be friends.	I am reliable.	My buddy is trustworthy.
I feel connected to my team.	I am motivated.	My buddy is motivated.
I can get along well with my team.	I mix well with other people.	My buddy is able to mix with other people.
I like my team.	I show a great commitment.	My buddy shows a great commitment.
	I perform well.	My buddy performs well.
	I am well able to deal with medical problems.	My buddy is well able to deal with medical problems.
	I am able to deal with personal problems.	My buddy is well able to deal with personal problems.
	I think my buddy is sympathetic.	My buddy thinks I am sympathetic.

(1) thinking power, (2) personal effectiveness, (3) interpersonal effectiveness, (4) working approach, and (5) management. Second, soft skills were judged on experiences gained during visits or prior experience in extreme team projects. Third, technical skills were assessed during a project performed a year earlier, the Alps project 2015. Fourth, the physical fitness of the selected members was judged during the Alps project 2015 and also objectified by an incremental cycling test.

Because of the limited access to healthcare on the mountain, all team members were preliminarily screened by following a thoroughly designed screening protocol (Table 2) as a precautionary measure against possible preventable medical issues. This revealed relevant issues in the medical history of two climbers but did not lead to their exclusion after multidisciplinary consultations (both climbers were summiteers). None of the team members was excluded after the preliminary physical screening.

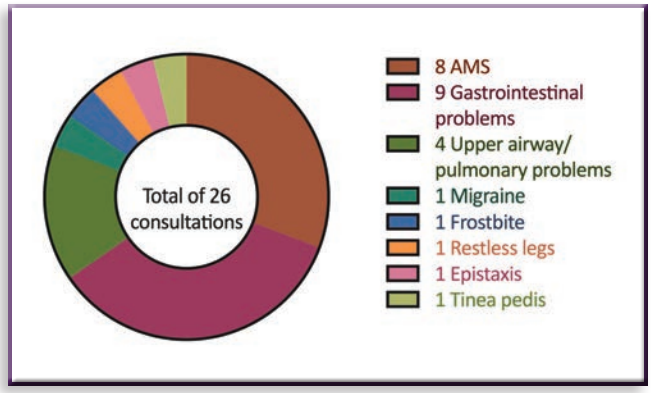
TABLE 2 *Pre-expedition Screening Tests*

Screening	Test
Anamnestic consultation	• Pre-existing medical complaints and/or chronic diseases • Medical history • Medication use • Allergies • Previous high-altitude experience • Previous altitude-related problems
Physical examination	• Musculoskeletal problems • Incremental cycling test • Resting 12-lead electrocardiogram • Lung function test during rest and directly after finishing the incremental cycling test
Vaccinations check	• Hepatitis A and B • Diphtheria, tetanus, polio • Measles • Typhoid fever (*Salmonella typhi*) • Rabies • Japanese encephalitis.
Blood analyses	• Hemoglobin
Anthropometrics	• Height (cm) • Body weight (kg)

Finally, the five teams were formed around a team leader in a way that was highly flexible, coherent, and complementary. All scenarios were rehearsed in brainstorm sessions and the definitive teams were presented a year before the expedition; however, changes could be and were made until base camp and even before and during the expedition if personal gain extended above the team goal or altitude-related disabilities occurred.

The group was divided into summiteers and nonsummiteers retrospectively. Besides hemoglobin (9.1 [0.4] versus 9.6 [0.2]; $p < .05$) and hematocrit (42.6 [1.4] versus 45.1 [0.9]; $p < .01$) values of summiteers and nonsummiteers, respectively, there were no differences between the groups in physical competencies (Table 3). One climber consulted the expedition doctor with symptoms related to his medical history (an episode of recurrent migraine; Figure 2).

FIGURE 2 *AMS, acute mountain sickness.*



Medical Planning and Support

Stock appropriate medications

Medication and equipment for advanced remote trauma care and resuscitation therapy were stocked at base camp. The required climate conditioning of medication was achieved with a portable heating and cooling system and guaranteed by regular temperature controls.

Provide appropriate medication and equipment

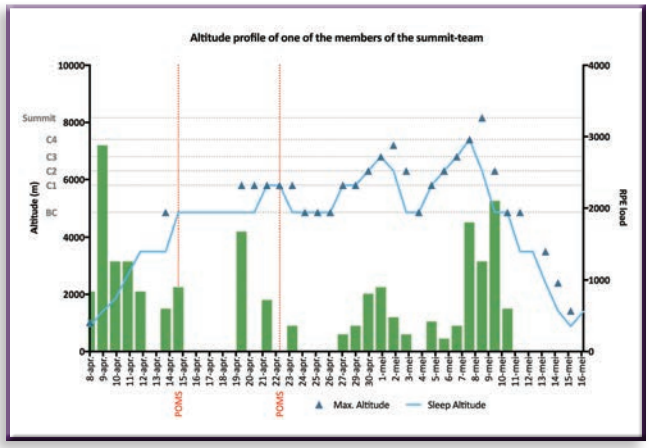
A first aid trauma kit was provided to all climbing teams, including medication for altitude sickness (namely,. ibuprofen, acetazolamide, nifedipine ,and dexamethasone, following the treatment protocols of the Wilderness Medical Society).[6] In anticipation of the most common illnesses and injuries, a selection of medication was made on the basis of their possible multipurpose functionality, weight, usability, durability in extreme climates, and ease of use. Extra oxygen canisters for treatment, in addition to the canisters reserved (from point of injury to hospital) for the planned supportive oxygen at higher than 7,000m, were stocked at each camp with a mobile stretcher. Because of the identified technical route from camp 1 up to camp 2, a portable hyperbaric chamber was stocked at camp 2 (Figure 3) in case of the need for prolonged field care.[7]

TABLE 3 *Average Overall Characteristics (Medical Competencies) of the Team Members*

	W_{max}	W/kg	Vo_{2max}, mL/min	HR at Rest, per min	HR_{max}, per min	VC_{max}, L	FVC, L	FEV_1, L/sec	PEF, L/min	Hb,[a] mmol/L	Hct,[b] %
Summiteer	357.8 (39.3)	4.52 (0.25)	53.4 (52.6–55.6)	56.8 (12.0)	185.2 (7.3)	7.1 (0.4)	7.1 (0.4)	5.6 (0.6)	11.8 (2.3)	9.1 (0.4)	42.6 (1.4)
Nonsummiteer	387.1 (24.0)	4.64 (0.32)	54.4 (49.1–55.8)	61.2 (5.2)	183.5 (6.6)	6.5 (0.7)	6.3 (0.6)	4.9 (0.5)	10.4 (1.0)	9.6 (0.2)	45.1 (0.9)

Team members were divided into two group, summiteers and nonsummiteers, before the expedition. Data are presented as mean (standard deviation) or median (interquartile range).
FEV_1, forced expiratory volume in the first second of expiration; FVC, forced vital capacity; Hb, hemoglobin; Hct, hematocrit; HR, heart rate; PEF, peak expiratory flow; VC_{max}, maximum vital capacity; Vo_{2max}, maximum oxygen uptake; W, weight; W_{max}, maximum weight.
[a] $p < .05$.
[b] $p < .01$.

FIGURE 3 *Altitude profile of one of the members of the summit team. Max, maximum; POMS, profile of mood states; RPE, rate of perceived exertion.*



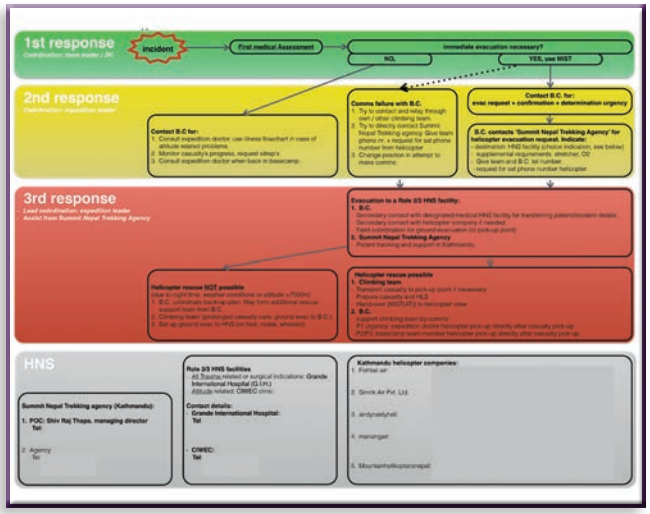
Provide adequate logistical support

The expedition team had to be self-sufficient.

Provide adequate medical communication

Several communication systems were available during the expedition. On the mountain, between the climbing teams and base camp staff, the primary system used was VHF/UHF Porta phones (http://www.portaphone.com/); Thuraya phones (https://www.thuraya.com/) were used secondarily. For communication between base camp and all counterparts located outside the Manaslu area, either in Nepal or the homeland, Thuraya phones were the primary system and Broadband Global Area Network phones were used secondarily. To establish a reliable communication chain in case of a medical incident, a flowchart was followed (Figure 4).

FIGURE 4 *Flowchart followed to establish a reliable communication chain in case of a medical incident.*



Know the environmental limitations on patient access and evacuation

The remoteness and extreme altitude of the Manaslu mountain area greatly influenced access to healthcare and evacuation timelines (Supplement 1).

Use qualified providers

A mandatory training program was designed for all members of the climbing teams. The intent was to increase the collective team level and was focused less strictly on the individual (Supplement 1).

Arrange knowledgeable and timely consultations

The expedition doctor and senior medical advisor in the Netherlands was accessible 24/7 for consultations at base camp or through telemedicine for climbers located at the higher camps. All climbers were encouraged to self-evaluate their physical and mental conditions by keeping a medical diary to stimulate timely consultations.

Competencies in the Field

To anticipate treatable problems, the medical plan should ensure the ability to treat the most common injuries, like gastrointestinal (GI) problems, skin conditions, and minor trauma. The plan should also provide treatment options for a selection of less common life-threatening conditions as well as less common non–life-threatening ophthalmological, dental, and respiratory problems. Only 1% of illnesses or injuries are classified as major life-threatening conditions in which immediate evacuation is needed or results in death.[3] For this expedition, a thorough battle assessment was performed and the in particular life-threatening conditions were identified: severe altitude sickness and trauma due to a fall or avalanche.

Human Factors

During the course of the expedition, 17 of the 20 climbers (85%) consulted the expedition physician (Figure 2). GI problems (35%) and AMS (31%) were the most prevalent. AMS was the most debilitating, causing a reduced employability in 87% of the cases. Also, in the group of the summiteers, five climbers (71%) consulted the expedition physician. In three of the five cases (60%), this resulted in a reduced employability, including one case of frostbite (grade 1).

The reduction in body weight among the climbers during the time spent at altitude was not different for summiteers and nonsummiteers, but there was a strong negative correlation between the time spend at altitude and the reduction in overall weight ($r = -0.508$; $p < .01$).

During the acclimatization phase of the expedition, the climb up to base camp, urine osmolality, oxygen saturation, and resting heart rate were monitored. Urine osmolality decreased during ascent from 980 (910–1,010) mOsm/kg at 1,020m to 270 (250–380) mOsm/kg on day 14 arriving at base camp (4,800m). Distributions of osmolality were not similar for all days but significantly different between the days ($H_5 = 40.020$; $p < .001$). Post hoc analysis revealed significant differences in osmolality between the 8 April 2016 and all other days climbing to base camp (10 April 2016: $p = .011$; 12 April 2016: $p < .001$; 14 April 2016: $p < .001$; 16 April 2016: $p < .001$; and 19 April 2016: $p = .009$). Pulse oximetry readings for oxygen saturation decreased during the climb into base camp from 95% (94%–97%) at 1,020m to 85% (79%–86%) at 4800m ($p < .001$). There were no differences between the summiteers and nonsummiteers in the median oxygen saturation values during the climb to base camp. There were also no differences in resting heart rate during the acclimatization climb to base camp between the two groups.

The members filled out the RPE assessment during the acclimatization climb (n = 15); however, most of the expedition members stopped filling them out when they arrived at base

TABLE 4 *Mood State Changes During the Expedition*

Mood States	Arrival in Kathmandu	Arrival at BC	Return From Camp 1	Return to Kathmandu	*p* Value[a]
Tension	0.52 (1.12)	0.80 (1.28)	0.54 (1.13)	0.66 (1.30)	.05
Anger	0.27 (0.93)	0.37 (0.97	0.32 (0.95)	0.20 (0.74)	.252
Confusion	0.54 (1.17)	0.46 (1.06)	0.39 (1.00)	0.44 (1.09)	.295
Vigor	2.36 (1.54)[b]	2.56 (1.19)	2.37 (1.30)[bc]	2.42 (1.42)[c]	.003
Fatigue	0.08 (0.43)	0.17 (0.46)	0.16 (0.37)	0.31 (0.70)	.110
Depression	0.08 (0.48)	0.09 (0.61)	0.03 (0.16)	0.01 (0.21)	.011

Data are given as mean (standard deviation), although the assumption of normality was markedly violated.
BC, base camp.
[a]Related-samples Friedman's two-way analysis of variance by ranks.
[b]Arrival in Kathmandu versus return from Camp 1, $p = .018$.
[c]Return from Camp 1 versus return to Kathmandu, $p = .017$.

camp. During the acclimatization climb into base camp (8 days), there was no difference detectable in the perceived load between the future summiteers and nonsummiteers. The load correlated moderately ($r = 0.40$; $p < .01$) with the increase in altitude during the days of the acclimatization climb. On all the measurement points, the graph showed a typical "iceberg profile," reflecting adequate mental health.[8] An overview of the different mood states is shown in Table 4. Tension increased on arrival in base camp and decreased when the members returned from camp 1, but this was not significant over time. Anger, confusion, and fatigue followed the same pattern. Depression was scored as maximum at arrival at base camp and the scores differed significantly over time ($p = .011$), but depression was mainly scored as 0 after arrival at base camp. The most interesting changes occurs with vigor. The changes in vigor over time were statistically significantly different at the different time points of the expedition (χ^2 (d.f. 3) = 13.906; $p = .003$).

The social cohesion questionnaires were scored on a scale from 1 (totally disagree) to 10 (totally agree). The social cohesion questionnaire returned mean scores by measurement location (i.e., arrival in base camp, after returning to camp 1, and on return in Kathmandu) of, respectively, 8.4 (1.6), 8.6 (1.5), and 8.5 (1.5). The mean scores of the individual questions were not different in time (measurement moments [MM]) as were the overall scores. The response rate for this questionnaire differed from 85.0%, 40.0% to 65.0% during the different MMs. The self-perception and performance scores also were high. The mean scores were 8.9 (1.1), 8.8 (1.1), and 8.9 (1.2) during the different MMs, with a same response rate as for the social cohesion questionnaire. The mean scores of the individual questions were not different in time, as were the overall scores. The buddy-perception and performance questionnaire scores were very high for the different MMs (9.3 [1.0], 9.1 [1.0], and 8.9 [1.3]), these scores did not differ statistically from each other. The mean scores of the individual questions also did not differ by time.

Chain of Command (Accountability)

Administrative rules were established and distributed.[3] This mission command military expedition was based on hierarchy within the concept of operations. The command and control given to the expedition leader gave full potential clearance within the boundaries of the expedition plan and provided "checkpoints" for clearance from the Ministry of Defense (commander of the RNLMC). The mission command structure was identical for the team, and the team leader of the summit climbing team perceived the role of the expedition leader as functional in these type of extreme expeditions. The summit team leader assessed his judgement and communication on altitude as good, and did so, as well, after return to base camp, indicating a solid command and control structure. The Sherpas' local knowledge was also assessed as vital in each phase of the expedition by the expedition team. The expedition doctor (a military medical officer) was responsible for coordinating the remote expedition's healthcare, including management of medical queries by telemedicine or physical consultation. The expedition leader, advised by the expedition doctor, was responsible for the decision to evacuate a patient.

Discussion

The MEPE setup is a novel approach in the preparation and execution of an expedition. In the case of this Manaslu expedition, it resulted in achieving the predefined goal of the expedition.

The process of selecting the individual members for this expedition was an intensive, time-consuming process performed by the expedition leader and staff members. Information known beforehand influenced selection of the individual team members and could have biased the selection criteria. The physical competence expressed in maximum oxygen uptake was excellent in most of the expedition members (>50 mL/kg/min); there were no differences between the two groups. Selection on this physical parameter is not justified; successful participant selection and team composition must be based on all variables within the MEPE model. GI problems were most prevalent (incidence of approximately 35%). Almost all GI consultations were during the trek to base camp and back to Kathmandu. In contrast to the base camp meals, which were prepared by the Nepalese support team, the meals during the treks were prepared by local Nepalese cooks in small diners along the trek. In future expeditions, rations should be considered as an effective solution in preventing GI problems during the complete expedition. Symptoms like nausea and vomiting can also be manifestations of AMS and are often seen in mountaineers along with anorexia also caused by altitude, including GI problems.[9,10] The decrease in expedition members' body weight could be a reflection of this problem. The significant decrease in weight of expedition members correlated with the duration at altitude ($r = -0.508$; $p < .01$).

The detection of transient, distinct mood states was done using the POMS test and showed the classic iceberg profile for vigor, representing the desirable emotional health status. Only the maximum score was lower than normally found in athletes. This profile of the mental health is associated with high performance levels.[11] The change in vigor during the course of the expedition might be explained by the fact that altitude causes

sleep deprivation, which might interfere with mood state,[12] although the mood state fatigue was not statistically significant.

The team performance, and thereby the goal, could also be influenced by social cohesion and performance scores. Higher cohesion is associated with top-level classifications among soccer teams.[13] The mean scores during different time points in the expedition were very high, even though the representability of the scores can be argued. On the other hand, individuals' targets superseding those of the team goals, and micromanagement by the expedition leader can also interfere with the tasks of the climbing teams. The mission command in this complex environment and dynamic team structure, including local knowledge and embedding Sherpas in the decision process, have contributed to the success.[14] The solidarity behavior, as stated in the values of the RNLMC, differs significantly from that of commercially led expeditions.

Medical delegation of tasks can fall to either medically qualified professionals or to others providing medical care in addition to their primary duty, with a direct consultation line. It is important to recognize that the role of expedition medic is multifaceted and requires an extensive skill set. Expedition medical planning should enable all these aspects to be considered so that appropriate personnel can be selected and trained. Telemedicine contributed to the situational awareness of the expedition doctor and may have reduced stress levels, due to early prehospital involvement.[15] Additional research should focus on real-time imaging. The cost (and weight) of such electronic devices may outweigh the benefits; however, use of this technology should be explored because it could also be useful in a combat environment.

This article provides guidance on the medical competencies required during the expedition and on other essential ingredients for a successful expedition such as medical planning, team work, human factors, medical kits, chain of command, and leadership.

The limitations of the current concept are the poor questionnaire completion rate and the extreme values. The POMS test results showed an overall low mean for each mood state compared with what was expected and the social cohesion questionnaire scores were rated very high. One of the suggested reasons for the participants' decline in commitment to the research program is that it was seen as a distraction from achieving the primary goal of reaching the summit. Contributing to the research program was stated as a secondary goal. Most measurements demanded a certain discipline and accuracy from the participants. Future extreme expeditions following this MEPE model should pay more attention to objective data collecting.

Conclusion

A high-altitude expedition is a challenging team process. Selection solely based on physical parameters is not justified. Preparation is essential for a successful expedition, including specific tasks for every team member. Delegation of medical responsibility to nonmedical personnel is feasible in extreme environmental circumstances. The MEPE model seems to describe a solid basis for planning of military and other expeditions. Additional research should focus on implementation of this model in commercial expeditions.

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The authors have indicated they have no financial relationships relevant to this article to disclose.

Author Contributions

All authors approved the final manuscript.

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Rate of Perceived Exertion

The rate of perceived exertion (RPE) is a subjective method of quantifying the day's intensity experienced by the climber. The load is calculated by multiplying the day's intensity by the duration of the activity of that day (in minutes) to provide an expression of the load in arbitrary units (Foster, Daines, et al. 1996). The intensity is described as a number (0–10) on the CR-10 Rating of Perceived Exertion scale proposed by Borg (Borg 1982; Borg and Kaijser 2006).

Profile of Mood States

Profile of Mood States (POMS) is a standard validated psychological test formulated by McNair et al. (1971). The test requires the climbers to subjectively indicate for each word or statement how they have been feeling in the past day, using the 5-point Likert scale, and represents six dimensions of the mood construct: tension, anger, confusion, vigor, fatigue, and depression.

Training Program for All Team Members
The program contained the following components:

- Self-study: A selection of chapters from the Dutch Special Forces Medic handbook for trauma care based on the respected Tactical Combat Casualty Care military guidelines (Montgomery, Butler et al. 2017)
- Individual medical first responder training, including teaching basic life-saving skills to self-execute or to support other healthcare providers
- Live-tissue exercise for teaching five essential life-saving skills: coniotomy, needle thoracentesis, applying a chest drain, intravenous infusion, and intraosseous infusion.
- Scenario-based evaluation checkpoint is implemented during the team-building week in Andermatt, Switzerland. In this scenario, the whole medical evacuation plan is stressed from the point of injury to a pretended base camp and, on paper, from base camp to hospital. The concept of telemedicine was also successfully tested.
- Classes on high-altitude physiology and pathology, and practical field care during team-building week in December 2015 in Andermatt, Switzerland.

Environmental Limitations on Patient Access and Evacuation

The preferred way of a medical evacuation in case of a major incident was by rotary wing. This service was facilitated by multiple helicopter companies located in Kathmandu, which were visited before the expedition. The following limitations were identified: (1) the maximum flying altitude at which a rescue could be performed was between 6,000 and 7,000m, depending on the helicopter type. At these maximum altitudes, person capability was limited to one or two, excluding the helicopter personnel; (2) by default, not capable of medical evacuation by air, casualty evacuation only with medical equipment on request; (3) estimated prolonged evacuation timelines to a Kathmandu hospital with ideal conditions: 2.5 to 4 hours with no execution after 16:00 and before sunrise.

Textbox: One Sherpa presented with clinical high-altitude cerebral edema while fixing ropes near camp 4 (7,000m) and descended to camp 2 (6,300m). In camp 3, treatment was started and evacuation to lower altitude was executed by an established RNLMC mountain rescue team.

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