Effetti dell’altitudine sull’apparato digerente

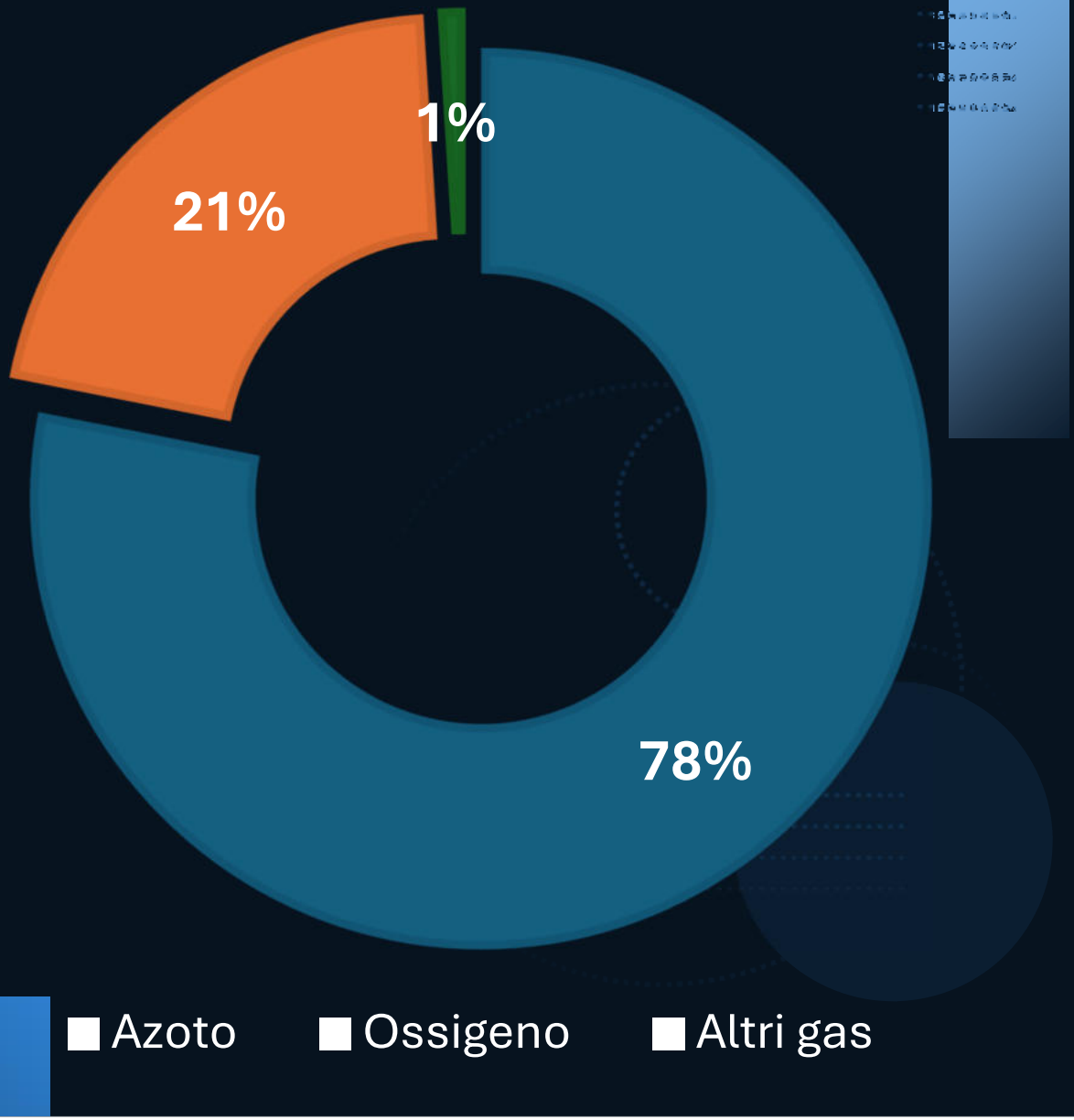
Paolo Sossai, *MD, PhD, AGAF*

CONGRESSO

Commissione Centrale Medica del Club Alpino Italiano

Sulmona, 27 settembre 2025

Composizione aria “secca”



Composizione aria “umida”

Fino al 4% di acqua allo stato gassoso (nebbia, nuvole, …)

L’aria “umida” pesa meno dell’aria “secca”

Vapore acqueo: PM 18
Azoto: PM 28
Ossigeno: PM 32

Pesando meno, l’aria “umida”
si pone al di sopra dell’aria “secca”

In quota cosa succede?

In quota cosa succede?

La percentuale di ossigeno rimane inalterata, ma diminuisce la pressione atmosferica, che a zero metri è di 1.013 millibar.

Altitudine	Temperatura	Pressione atmosferica
0 m	15,0 °C	1.013 millibar
1.000 m	8,5 °C	899 millibar
2.000 m	2,0 °C	795 millibar
2.500 m	-1,3 °C	748 millibar
3.000 m	-4,5 °C	701 millibar
4.000 m	-11,0 °C	616 millibar
5.000 m	-17,5 °C	540 millibar
6.000 m	-24,0 °C	472 millibar
7.000 m	-30,5 °C	411 millibar
8.000 m	-37,0 °C	356 millibar

In quota cosa succede?

Risultato:
diminuisce la quantità e non la percentuale di ossigeno nell'aria.

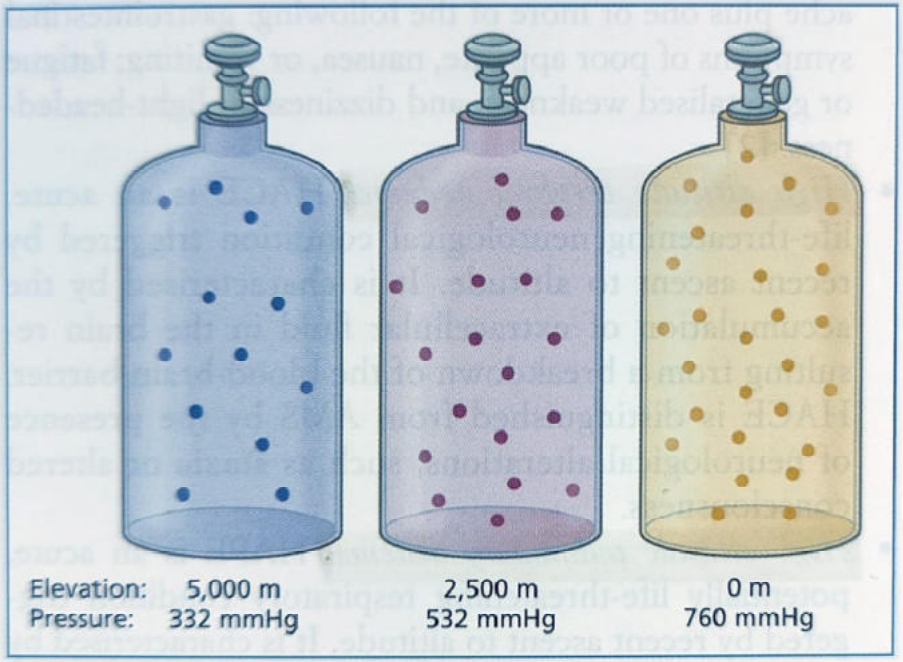
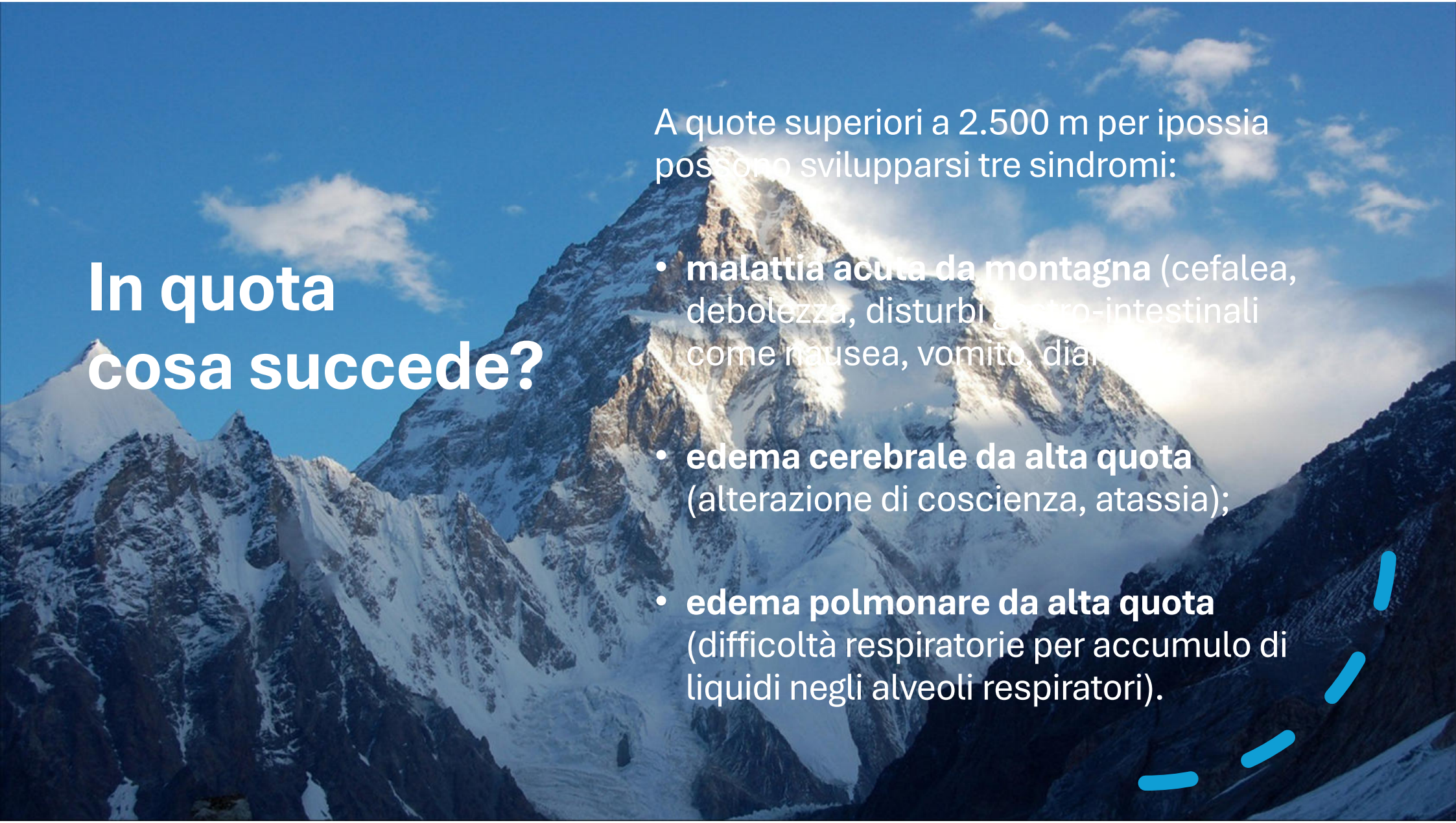


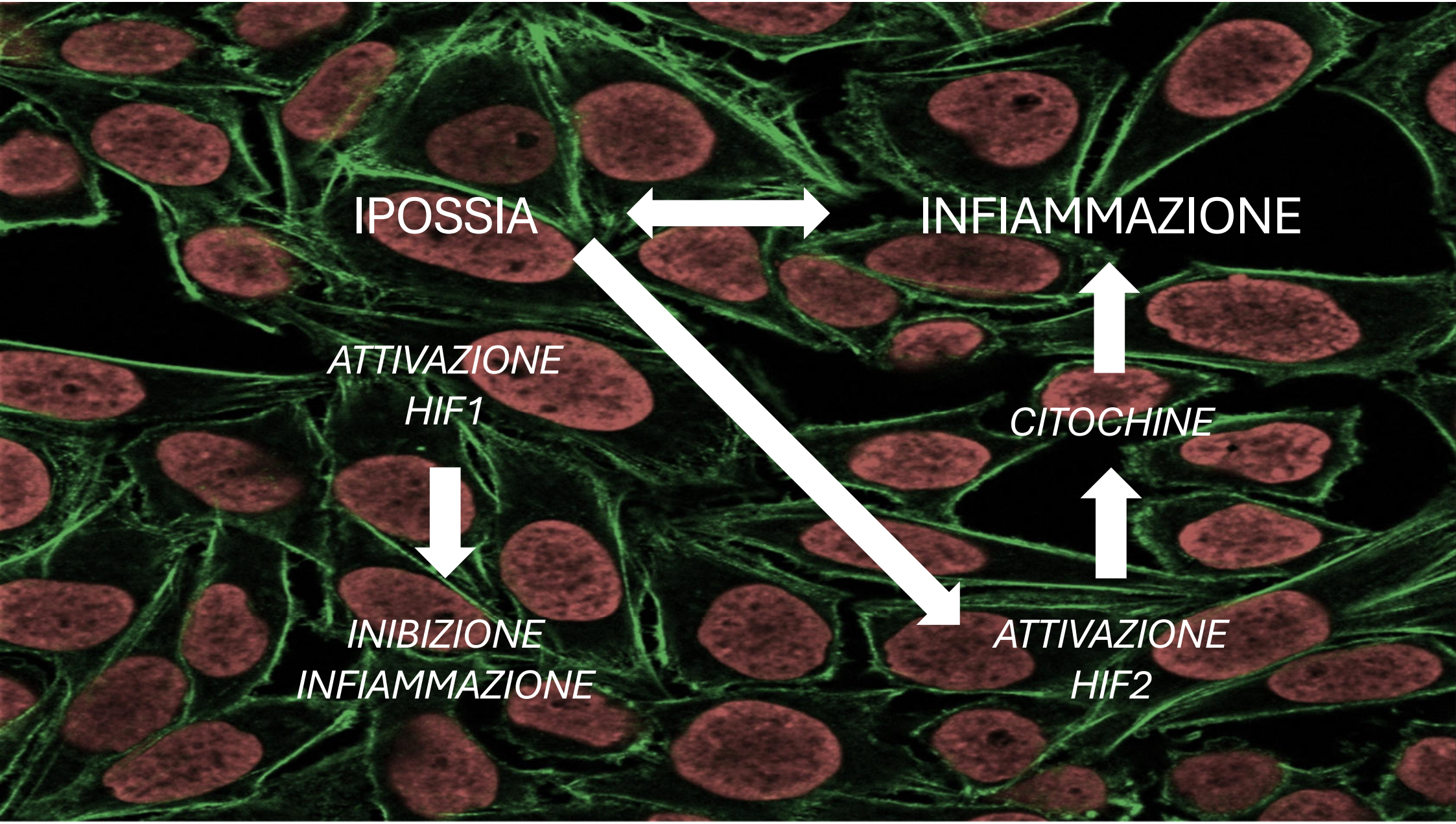
Figure 32.1 At higher altitudes, air is less dense due to decreasing atmospheric pressure. This means that although the percentage of oxygen in the air does not change, the total number of molecules of oxygen in a given volume of air decreases. (Adapted from OpenStax, CC BY 3.0.)



In quota cosa succede?

A quote superiori a 2.500 m per ipossia possono svilupparsi tre sindromi:

- **malattia acuta da montagna** (cefalea, debolezza, disturbi gastro-intestinali come nausea, vomito, dia
- **edema cerebrale da alta quota** (alterazione di coscienza, atassia);
- **edema polmonare da alta quota** (difficoltà respiratorie per accumulo di liquidi negli alveoli respiratori).

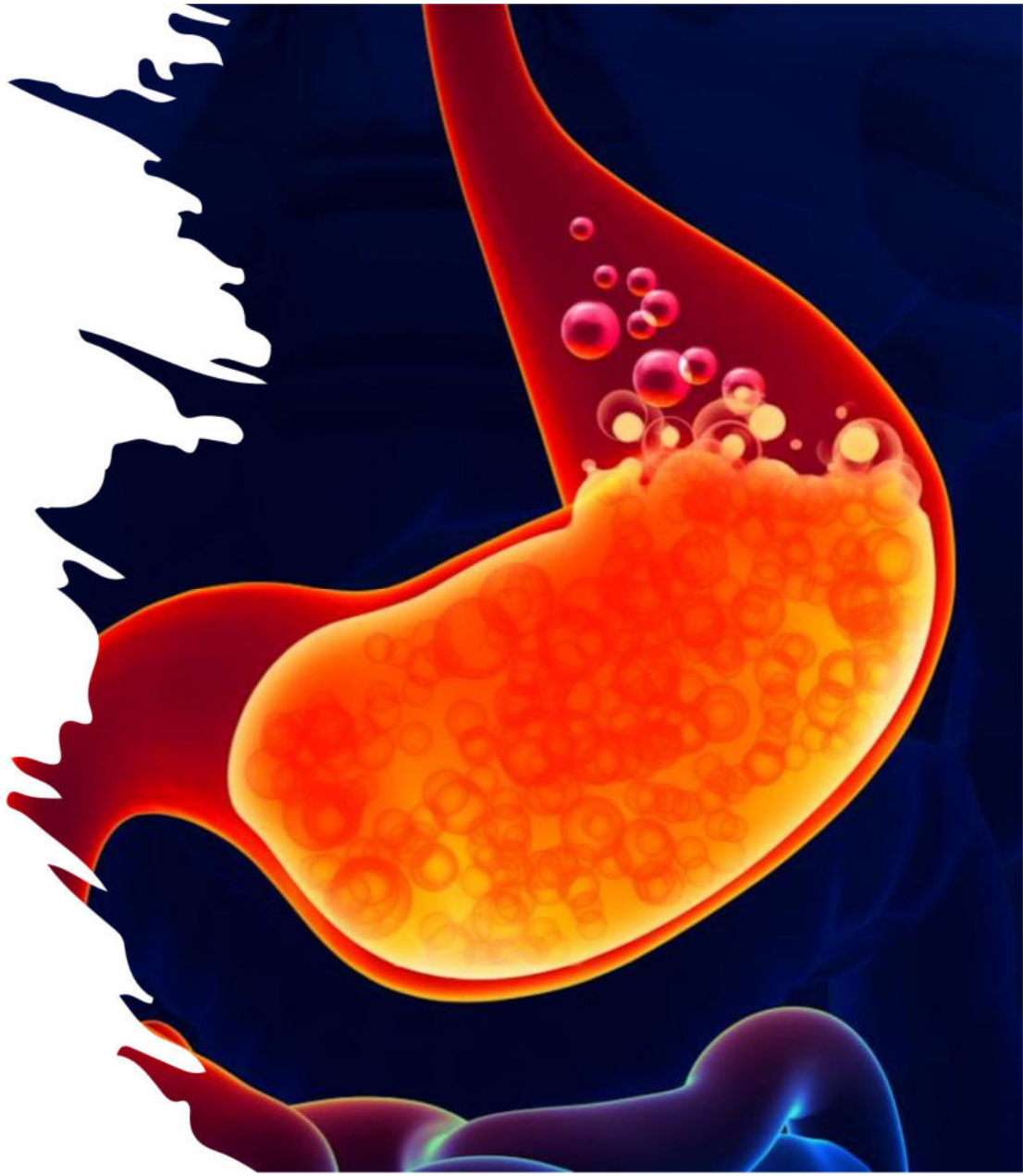

IPOSSIA
INFIAMMAZIONE
ATTIVAZIONE
HIF1
CITOCHINE
INIBIZIONE
INFIAMMAZIONE
ATTIVAZIONE
HIF2

In quota cosa succede?

In tutti e tre i quadri, l’acquisizione di quota in tempi rapidi è la causa principale dei disturbi segnalati, che sono legati a carenza di ossigeno.

In quota cosa succede?

L’80% dei soggetti con la malattia acuta da montagna presenta almeno un sintomo di pertinenza gastroenterologia (nausea, diarrea, vomito).



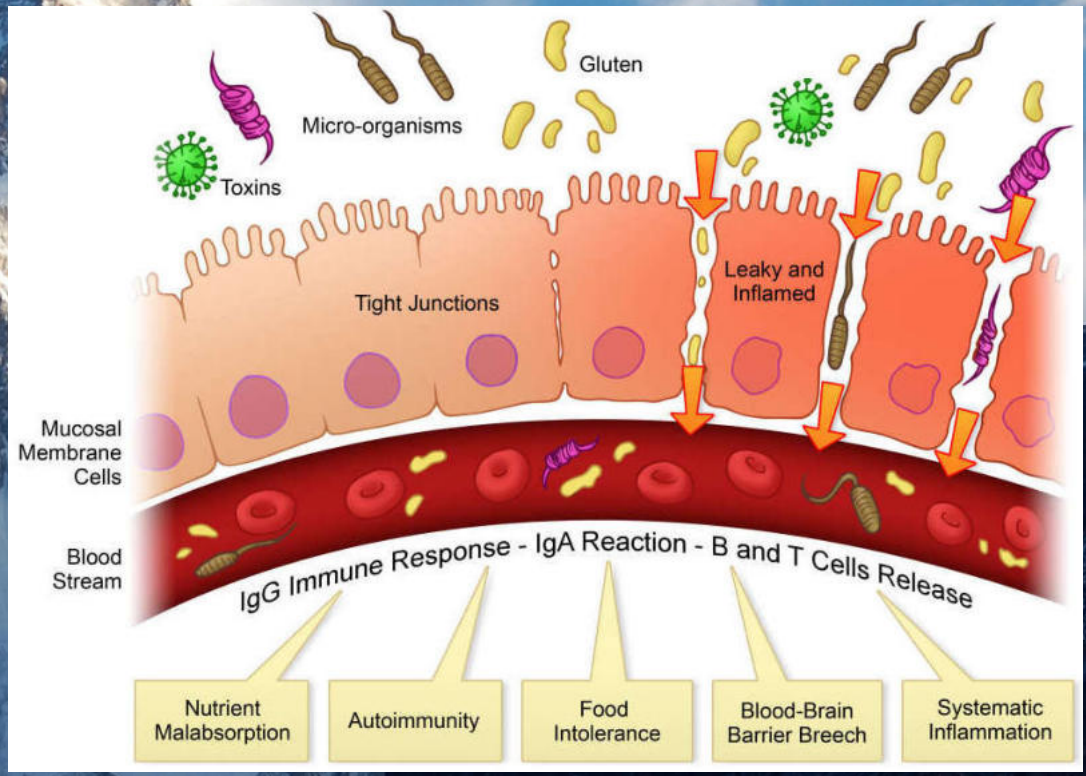
In quota cosa succede?

Almeno un terzo dei soggetti che affrontano l’ascensione a Mt. Everest presenta diarrea.

In quota cosa succede?

A proposito di apparato gastroenterico...

...leaky gut



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Original Article

Oxidative stress is associated with the gastric mucosa lesion of the Tibetans with high-altitude polycythemia

Kang Li[1,2], Luobu Gesang[1]

Departments of [1]High Altitude Medical Research Institute, [2]Gastroenterology, People's Hospital of Tibet Autonomous Region, Lhasa 850000, China

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24 soggetti tibetani (3600-4800 m)

11 soggetti con policitemia (maggiore di 21 g/dl uomo e maggiore di 19 g/dl donna) e lesioni gastriche

Media età: 43 anni

13 soggetti tibetani senza policitemia né lesioni gastriche

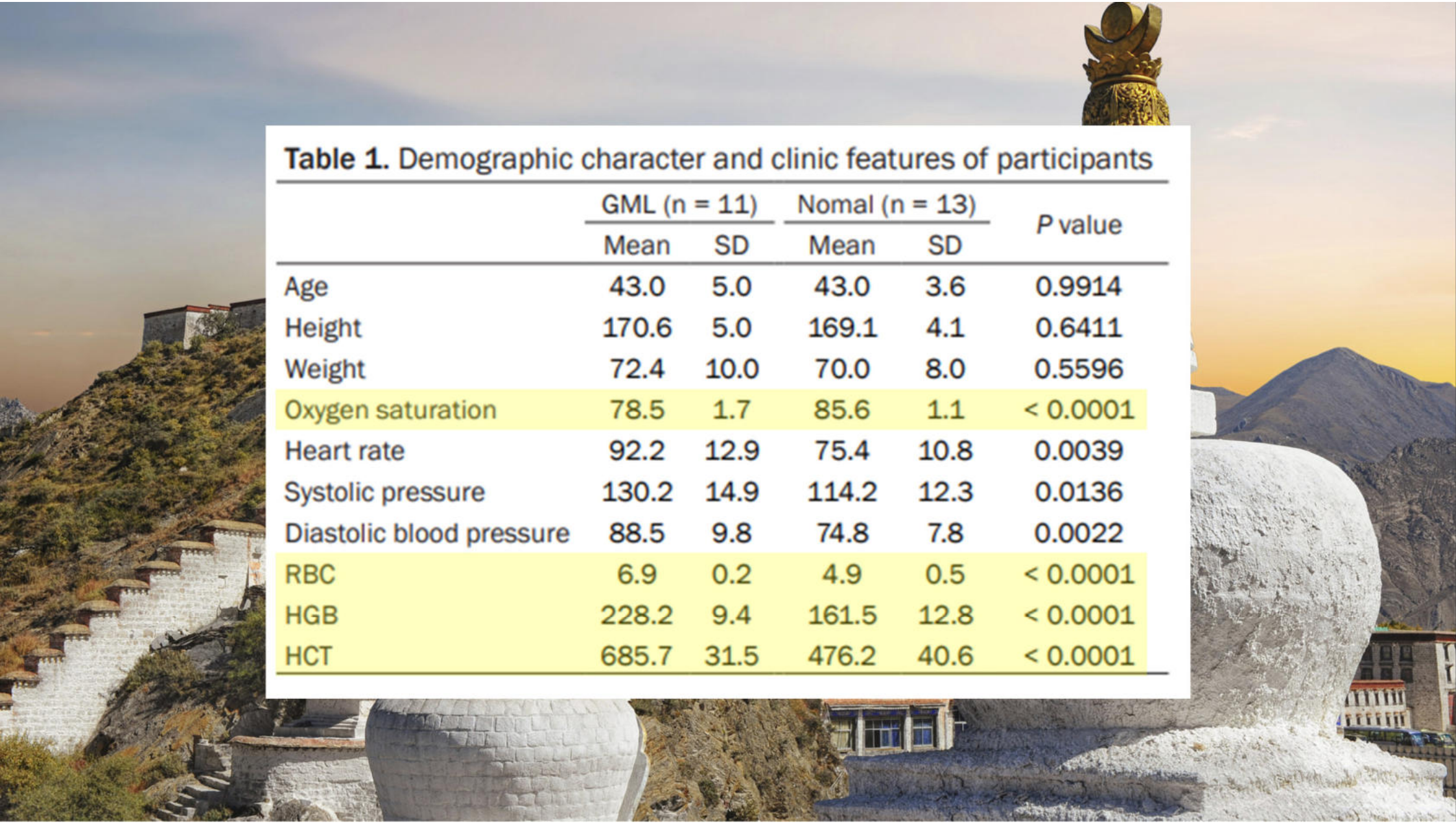

Table 1. Demographic character and clinic features of participants

	GML (n = 11)		Nomal (n = 13)		*P* value
	Mean	SD	Mean	SD	
Age	43.0	5.0	43.0	3.6	0.9914
Height	170.6	5.0	169.1	4.1	0.6411
Weight	72.4	10.0	70.0	8.0	0.5596
Oxygen saturation	78.5	1.7	85.6	1.1	< 0.0001
Heart rate	92.2	12.9	75.4	10.8	0.0039
Systolic pressure	130.2	14.9	114.2	12.3	0.0136
Diastolic blood pressure	88.5	9.8	74.8	7.8	0.0022
RBC	6.9	0.2	4.9	0.5	< 0.0001
HGB	228.2	9.4	161.5	12.8	< 0.0001
HCT	685.7	31.5	476.2	40.6	< 0.0001

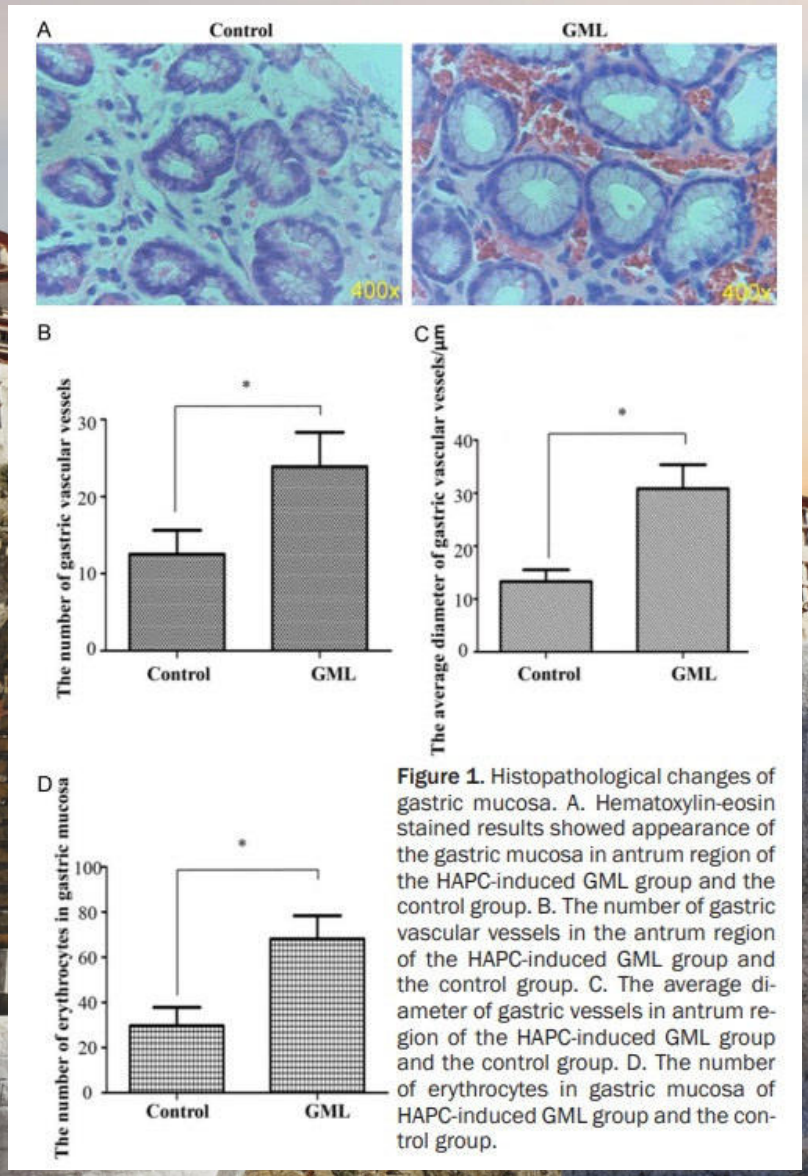

Figure 1. Histopathological changes of gastric mucosa. A. Hematoxylin-eosin stained results showed appearance of the gastric mucosa in antrum region of the HAPC-induced GML group and the control group. B. The number of gastric vascular vessels in the antrum region of the HAPC-induced GML group and the control group. C. The average diameter of gastric vessels in antrum region of the HAPC-induced GML group and the control group. D. The number of erythrocytes in gastric mucosa of HAPC-induced GML group and the control group.


In quota
cosa succede?
Ipossia
↓
Ipertono sistema nervosa simpatico
↓
Vasocostrizione irrorazion stinale
↓
Aumento permeabilità intestinale
↓
↑IL-6 ↑IL-22 ↑IL-17 ↑TNFα LPS
↓
Alterazione microbiota intestinale, atrofia della mucosa

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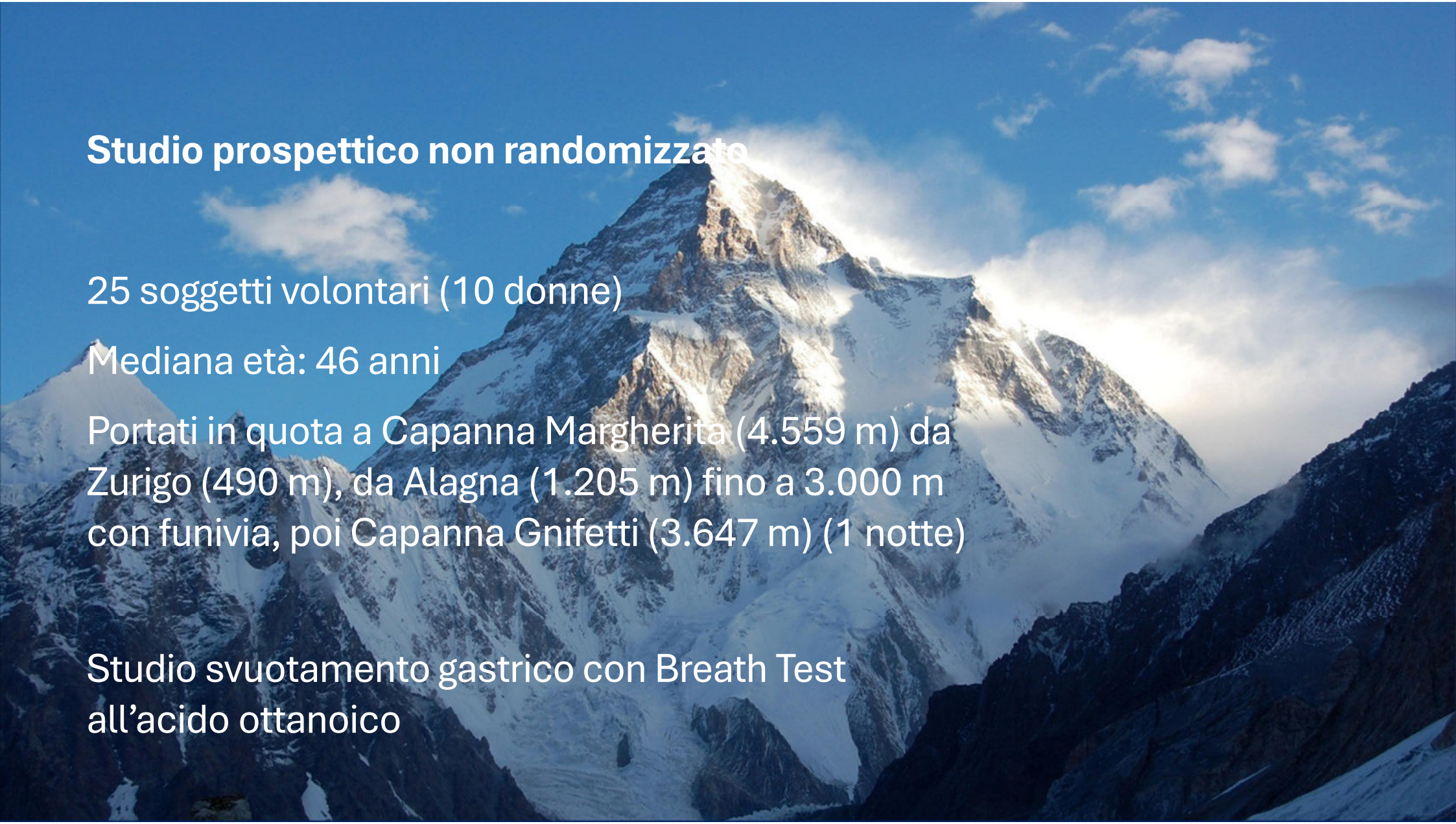
ORIGINAL ARTICLE

Neurogastroenterology & Motility NGM WILEY

Effect of high altitude on human postprandial ^{13}C-octanoate metabolism, intermediary metabolites, gastrointestinal peptides, and visceral perception

Patrick-Pascal Strunz[1] | Raphael N. Vuille-dit-Bille[2] | Mark R. Fox[3,4] | Andreas Geier[5] | Marco Maggiorini[6] | Max Gassmann[7] | Heiko Fruehauf[8] | Thomas A. Lutz[7] | Oliver Goetze[5]



Studio prospettico non randomizzato

25 soggetti volontari (10 donne)

Mediana età: 46 anni

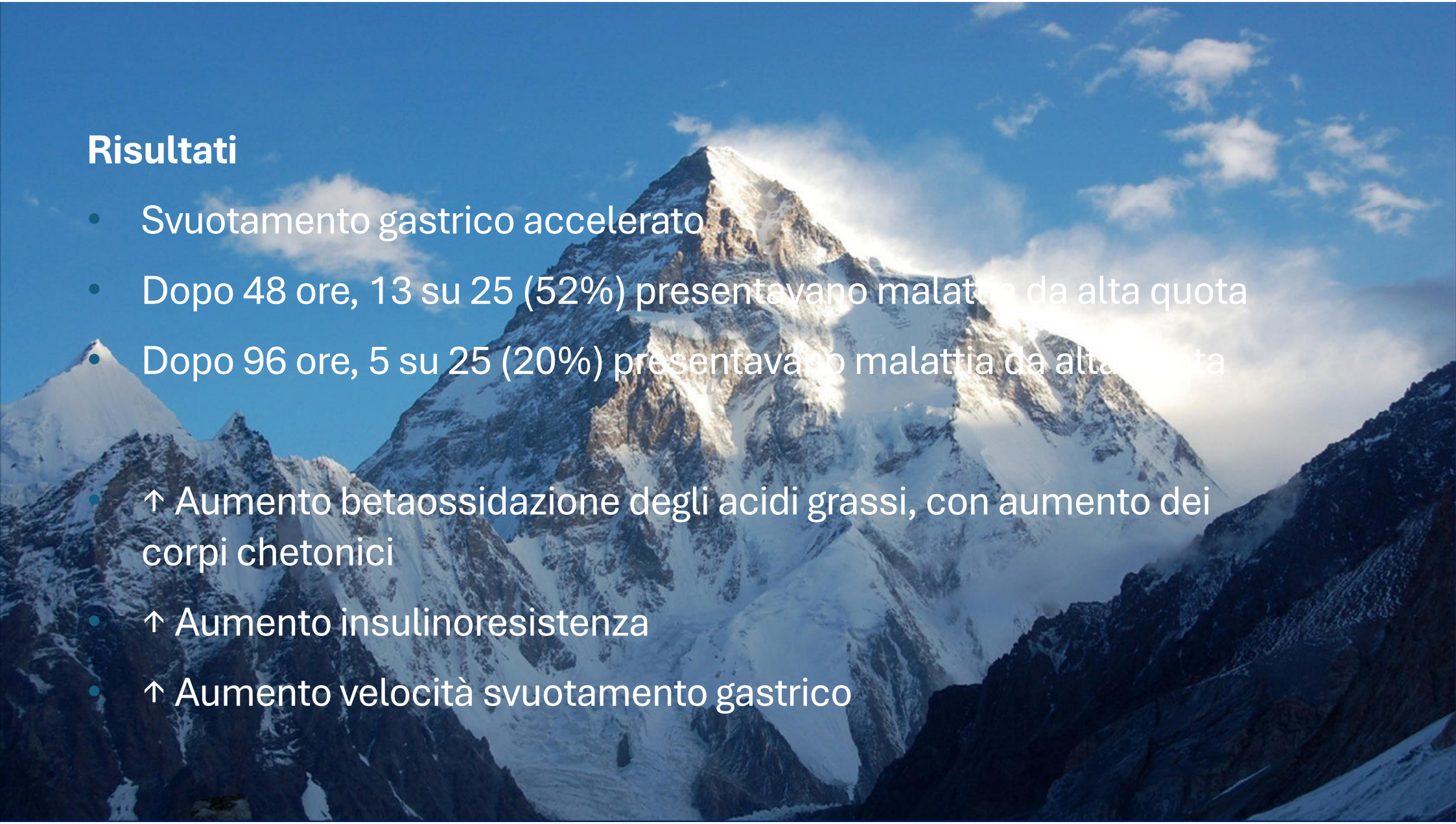
Portati in quota a Capanna Margherita (4.559 m) da Zurigo (490 m), da Alagna (1.205 m) fino a 3.000 m con funivia, poi Capanna Gnifetti (3.647 m) (1 notte)

Studio svuotamento gastrico con Breath Test all’acido ottanoico

Table 1:

Baseline characteristics of the 25 participants subdivided by gender.

		Zurich, 446 m 15 male participants			Zurich, 446m 10 female participants		
parameter	**unit**	**n**	**median**	**25th-75th percentile**	**n**	**median**	**25th-75th percentile**
age	years	15	46	36.0-51.0	10	41	36.3-47.8
BMI	kg/m^2	15	23.6	23.0-25.4	10	23.2	22.0-23.8



Risultati

- Svuotamento gastrico accelerato
- Dopo 48 ore, 13 su 25 (52%) presentavano malattia da alta quota
- Dopo 96 ore, 5 su 25 (20%) presentavano malattia da alta quota

- ↑ Aumento betaossidazione degli acidi grassi, con aumento dei corpi chetonici
- ↑ Aumento insulinoresistenza
- ↑ Aumento velocità svuotamento gastrico

Clinical Gastroenterology and Hepatology 2020;18:2218–2225

Evaluation of Acute Mountain Sickness by Unsedated Transnasal Esophagogastroduodenoscopy at High Altitude

Heiko Fruehauf,[*,‡,a] Stephan R. Vavricka,[*,‡,a] Thomas A. Lutz,[§,‖] Max Gassmann,[§,‖,¶] Kacper A. Wojtal,[*] Annina Erb,[#] Marco Maggiorini,[§,**] Werner Schwizer,[*,§] Michael Fried,[*,§] Mark Fox,[*,§] Oliver Goetze,[*] and Thomas Greuter[*,‡‡]

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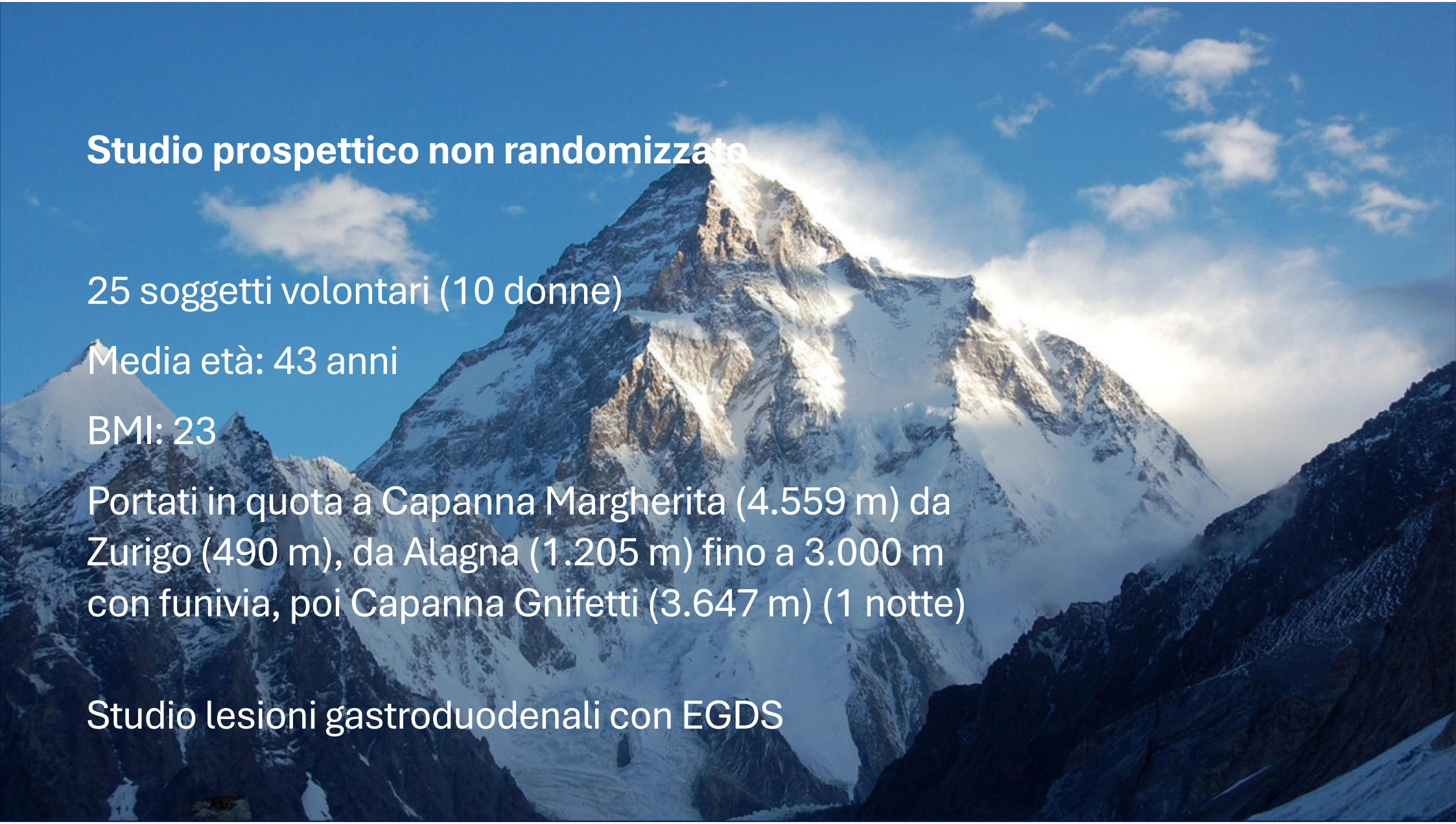


Studio prospettico non randomizzato

25 soggetti volontari (10 donne)

Media età: 43 anni

BMI: 23

Portati in quota a Capanna Margherita (4.559 m) da Zurigo (490 m), da Alagna (1.205 m) fino a 3.000 m con funivia, poi Capanna Gnifetti (3.647 m) (1 notte)

Studio lesioni gastroduodenali con EGDS

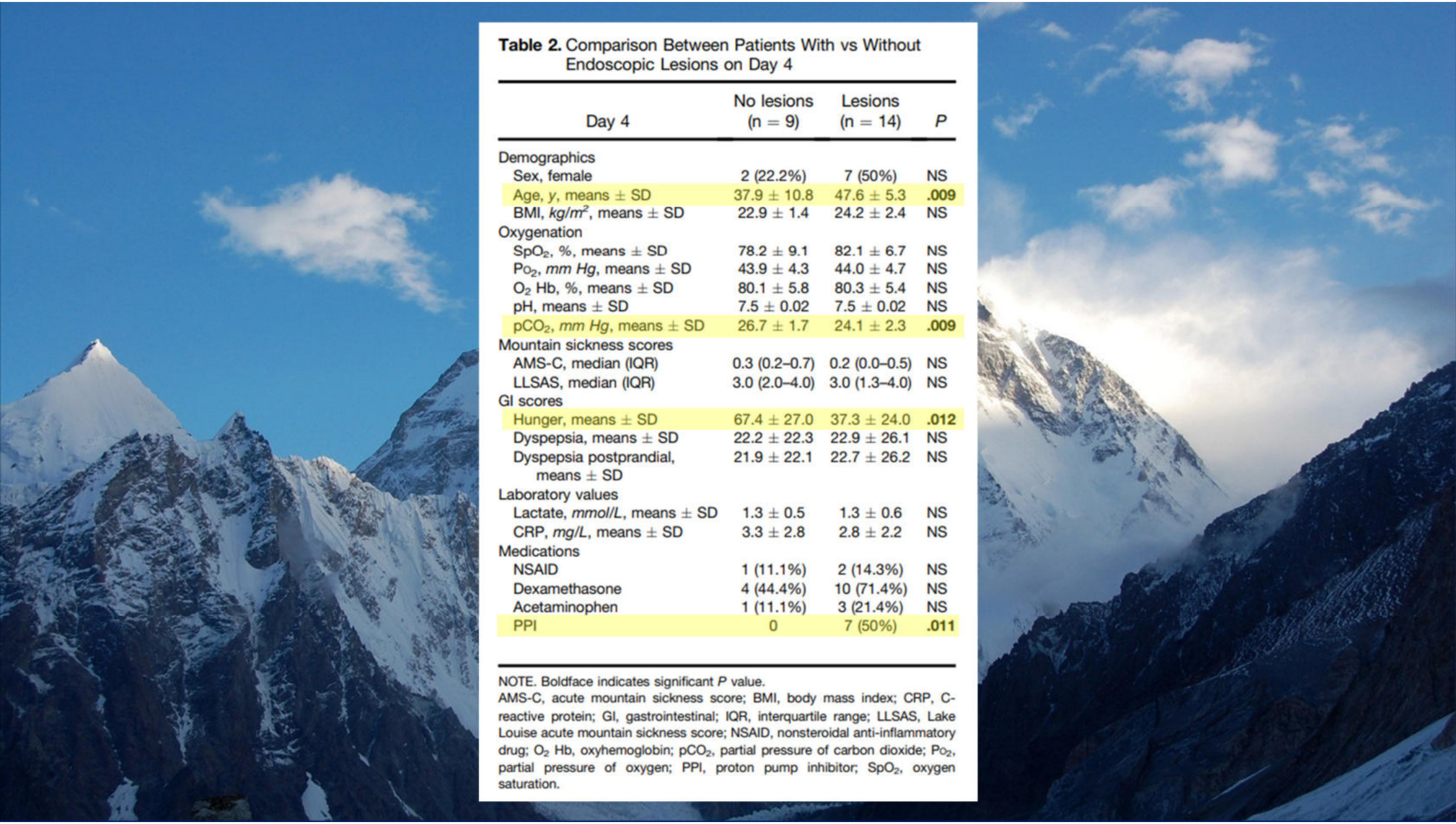


Table 2. Comparison Between Patients With vs Without Endoscopic Lesions on Day 4

Day 4	No lesions (n = 9)	Lesions (n = 14)	*P*
Demographics			
Sex, female	2 (22.2%)	7 (50%)	NS
Age, *y*, means ± SD	37.9 ± 10.8	47.6 ± 5.3	**.009**
BMI, *kg/m²*, means ± SD	22.9 ± 1.4	24.2 ± 2.4	NS
Oxygenation			
SpO_2, %, means ± SD	78.2 ± 9.1	82.1 ± 6.7	NS
Po_2, *mm Hg*, means ± SD	43.9 ± 4.3	44.0 ± 4.7	NS
O_2 Hb, %, means ± SD	80.1 ± 5.8	80.3 ± 5.4	NS
pH, means ± SD	7.5 ± 0.02	7.5 ± 0.02	NS
pCO_2, *mm Hg*, means ± SD	26.7 ± 1.7	24.1 ± 2.3	**.009**
Mountain sickness scores			
AMS-C, median (IQR)	0.3 (0.2–0.7)	0.2 (0.0–0.5)	NS
LLSAS, median (IQR)	3.0 (2.0–4.0)	3.0 (1.3–4.0)	NS
GI scores			
Hunger, means ± SD	67.4 ± 27.0	37.3 ± 24.0	**.012**
Dyspepsia, means ± SD	22.2 ± 22.3	22.9 ± 26.1	NS
Dyspepsia postprandial, means ± SD	21.9 ± 22.1	22.7 ± 26.2	NS
Laboratory values			
Lactate, *mmol/L*, means ± SD	1.3 ± 0.5	1.3 ± 0.6	NS
CRP, *mg/L*, means ± SD	3.3 ± 2.8	2.8 ± 2.2	NS
Medications			
NSAID	1 (11.1%)	2 (14.3%)	NS
Dexamethasone	4 (44.4%)	10 (71.4%)	NS
Acetaminophen	1 (11.1%)	3 (21.4%)	NS
PPI	0	7 (50%)	**.011**

NOTE. Boldface indicates significant *P* value.

AMS-C, acute mountain sickness score; BMI, body mass index; CRP, C-reactive protein; GI, gastrointestinal; IQR, interquartile range; LLSAS, Lake Louise acute mountain sickness score; NSAID, nonsteroidal anti-inflammatory drug; O_2 Hb, oxyhemoglobin; pCO_2, partial pressure of carbon dioxide; Po_2, partial pressure of oxygen; PPI, proton pump inhibitor; SpO_2, oxygen saturation.

Risultati

- Prima EGDS a Zurigo 25 pazienti
- EDGS dopo 2 giorni a Capanna Margherita (4.559 m) 19 pazienti
- EGDS dopo 4 giorni a Capanna Margherita (4.559 m) 23 pazienti

- Prima EGDS a Zurigo: 12% lesioni gastroduodenali
- Seconda EDGS a Capanna Margherita: 26,3% lesioni gastroduodenali
- Terza EDGS a Capanna Margherita: 60,9% lesioni gastroduodenali

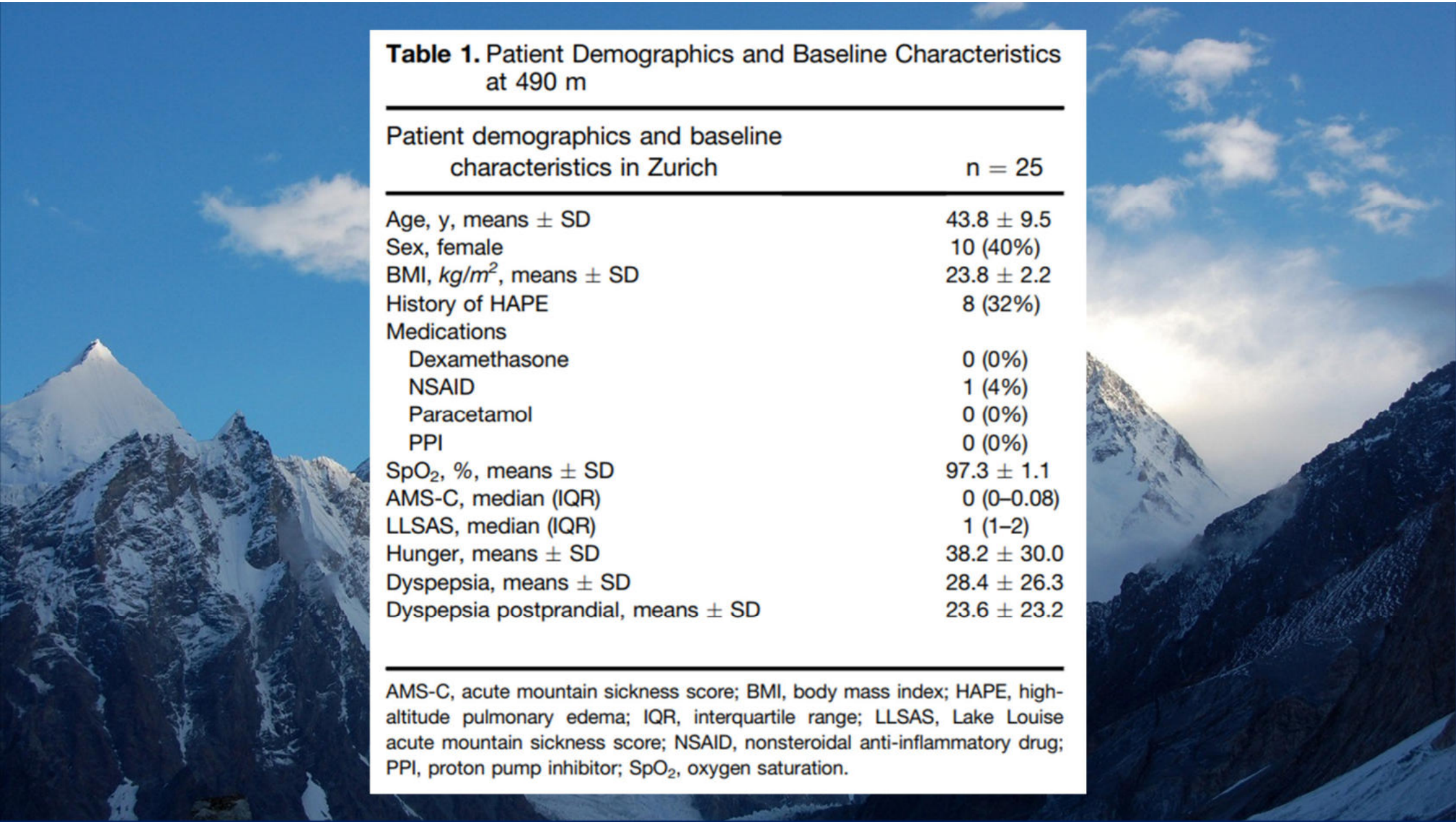


Table 1. Patient Demographics and Baseline Characteristics at 490 m

Patient demographics and baseline characteristics in Zurich	n = 25
Age, y, means ± SD	43.8 ± 9.5
Sex, female	10 (40%)
BMI, kg/m^2, means ± SD	23.8 ± 2.2
History of HAPE	8 (32%)
Medications	
Dexamethasone	0 (0%)
NSAID	1 (4%)
Paracetamol	0 (0%)
PPI	0 (0%)
SpO_2, %, means ± SD	97.3 ± 1.1
AMS-C, median (IQR)	0 (0–0.08)
LLSAS, median (IQR)	1 (1–2)
Hunger, means ± SD	38.2 ± 30.0
Dyspepsia, means ± SD	28.4 ± 26.3
Dyspepsia postprandial, means ± SD	23.6 ± 23.2

AMS-C, acute mountain sickness score; BMI, body mass index; HAPE, high-altitude pulmonary edema; IQR, interquartile range; LLSAS, Lake Louise acute mountain sickness score; NSAID, nonsteroidal anti-inflammatory drug; PPI, proton pump inhibitor; SpO_2, oxygen saturation.

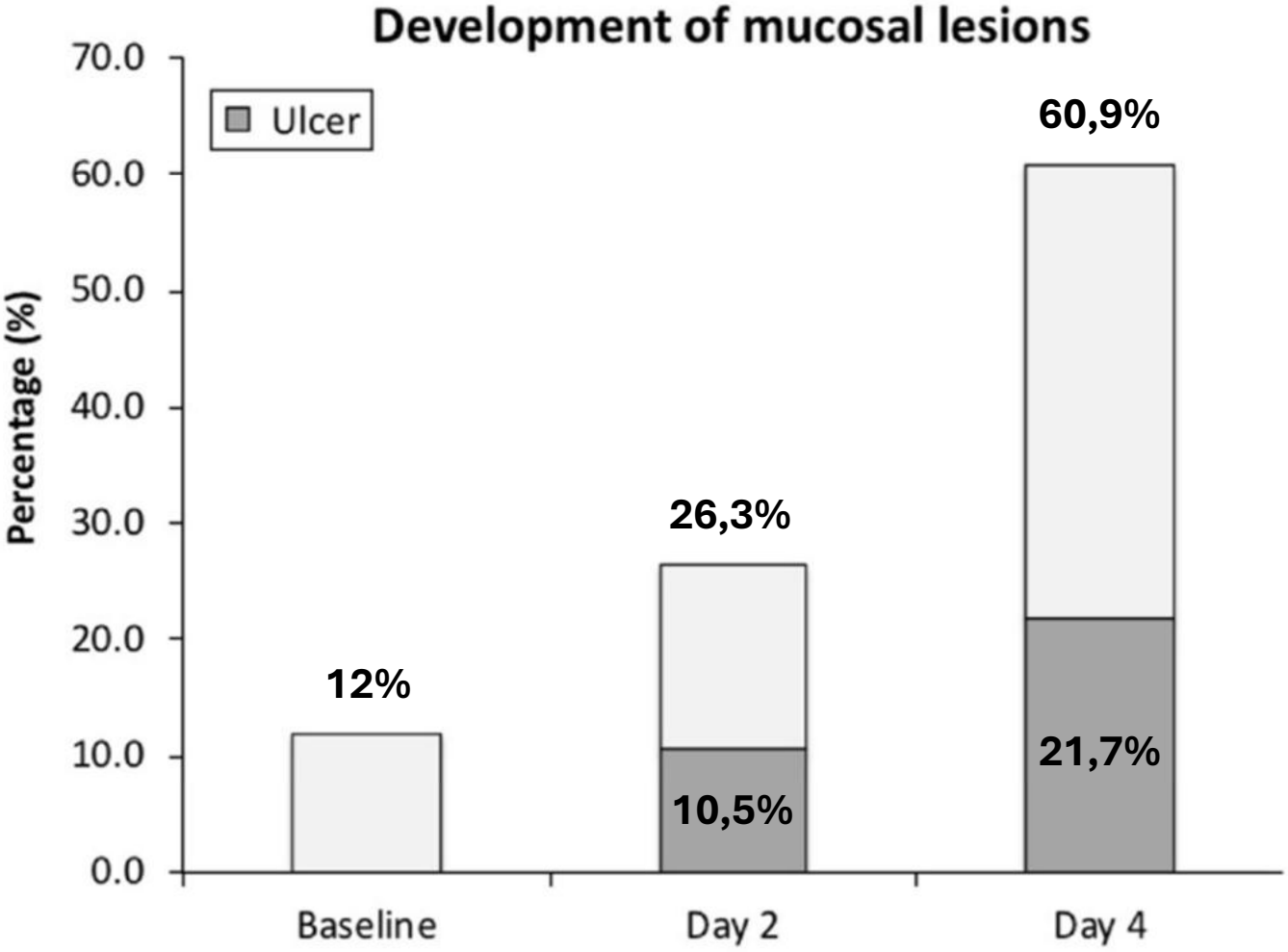
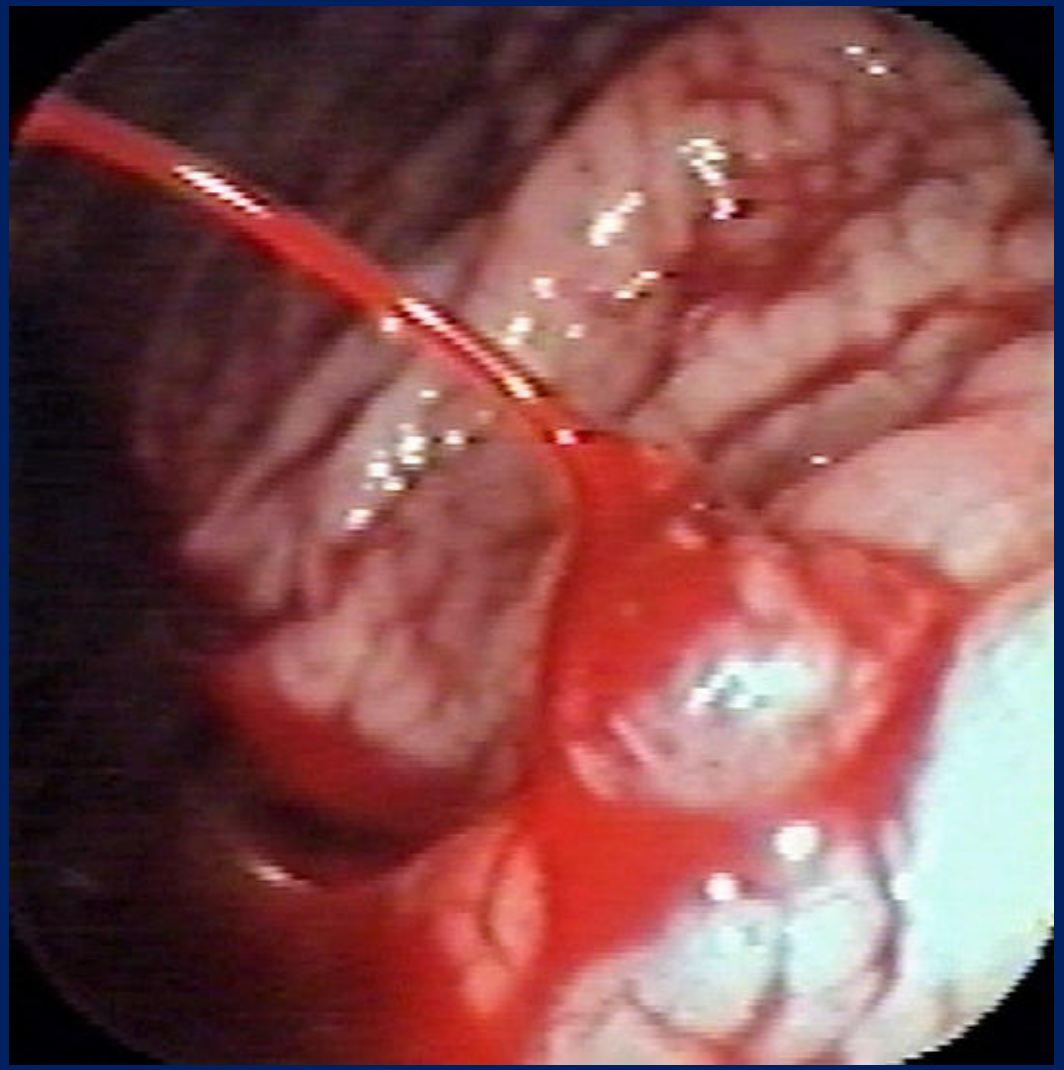


Figure 1. Percentage of patients with endoscopic lesions at baseline and on days 2 and 4 after a rapid ascent to 4559 m. The frequency of mucosal lesions increases from 12% (baseline) to 26.3% (d2) and 60.9% (d4). The incidence of peptic ulcer disease increases from 0.0% to 10.5% (d2) and 21.7% (d4). Dark gray indicates ulcers, and light gray indicates mucosal lesions.




In quota
cosa succede?
I farmaci utilizzati nelle patologie da quota (acetazolamide e desametasone) possono presentare come effetti collaterali proprio disturbi digestivi.


Allora
cosa fare?
Cosa usare in caso di
disturbi digestivi in quota?


Loperamide?
Probiotici?
Acidi grassi a catena corta?
Inibitori di pompa protonica?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Letter: The Italian Conquest of K2: Health-Related Aspects from the Newly Published Documents of Deputy Expedition Leader Ugo Angelino

Paolo Sossai[1,2]

Dear Editor,

To mark the 70th anniversary of the Italian conquest of K2, we are publishing selected health-related content from the diaries and writings of Ugo Angelino, the deputy expedition leader and logistics manager (Palazzi, 2024).

In the expedition's budget, medical, surgical, and pharmaceutical supplies accounted for 8.4% of the total cost, although many pharmaceutical companies generously provided their products free of charge.

The expedition leader was Ardito Desio, a professor of geology at the University of Milan, while the expedition's physician, Guido Pagani from Piacenza, also showcased exceptional mountaineering skills.

Notably, the summit of K2 stands at 28,251 feet (8,611 meters), with the Italian base camp located at an altitude of 16,312 feet (4,970 meters). Achille Compagnoni and Lino Lacedelli successfully reached the summit on July 31, 1954, with indispensable support from Walter Bonatti and Amir Mahdi.

Angelino's diaries contain fascinating health-related notes, which have been categorized into three main areas: acclimatization, minor medical treatments, and major medical interventions.

Angelino reports that, during the trek, all the Italian mountaineers exhibited symptoms typical of acute high-altitude illness (e.g., fatigue and shortness of breath). He himself admitted to already feeling breathless at an altitude comparable to Mont Blanc (15,777 feet [4,805 meters]), which is located on the border between Italy and France (Hackett and Roach, 2001).

During the approach to the base camp, the harsh effects of sunlight were noted, including facial burns despite the use of creams and conjunctivitis, which particularly affected the porters who lacked adequate eye protection. Over 150 porters needed treatment for conjunctivitis on the Baltoro Glacier, as part of a larger group exceeding 600 individuals.

Angelino's diaries also highlight that the presence of a doctor in the regions traversed by the expedition attracted long lines of patients, primarily in need of surgical attention.

Unfortunately, due to logistical constraints, only minimal treatments were possible, often limited to offering "a few pills with the usual instructions to take them before meals or before bed."

Angelino describes Dr. Pagani performing a tooth extraction on a porter, as well as frequent complaints of headaches and stomach pains among the porters. We now understand that hypoxia and alterations in gut microbiota are potential causes of digestive issues (such as gastrointestinal infections). Approximately one-third of those venturing into the Himalayas experience diarrhea, and high-altitude workers may face gastrointestinal hemorrhages (McKenna et al., 2022).

Tragically, the expedition lost one of its most accomplished climbers, Mario Puchoz.

A native of Valle d'Aosta, Puchoz passed away during the night of June 20–21, 1954, at precisely 1:15 a.m. local time, at the second base camp located at 20,000 feet (6,095 meters). Dr. Pagani, who attended to him, recorded the cause of death in Angelino's notebooks as an "incurable pneumonia." Modern understanding suggests this was likely high-altitude pulmonary edema, which prevented Puchoz from descending to a lower altitude, ultimately leading to his death.

Puchoz, a Mont Blanc mountain guide, was just 36 years old at the time of his death. Interestingly, Dr. Pagani, aged 37 during the expedition, spent nearly 40 consecutive days above 19,684 feet (6,000 meters). Despite Puchoz's superior physical fitness, he succumbed to high-altitude pulmonary edema, highlighting the unpredictable nature of altitude-related symptoms.

In conclusion, it is essential to highlight the insights of Carlo Francou, who praised Dr. Pagani's humanity and sensitivity. Pagani consistently refused to write about his experience, finding it impossible to fully convey the emotions, fears, doubts, and nostalgia shared by the expedition members. Francou aptly remarked, "The expedition was richer in emotions than events" (Francou, 2004).

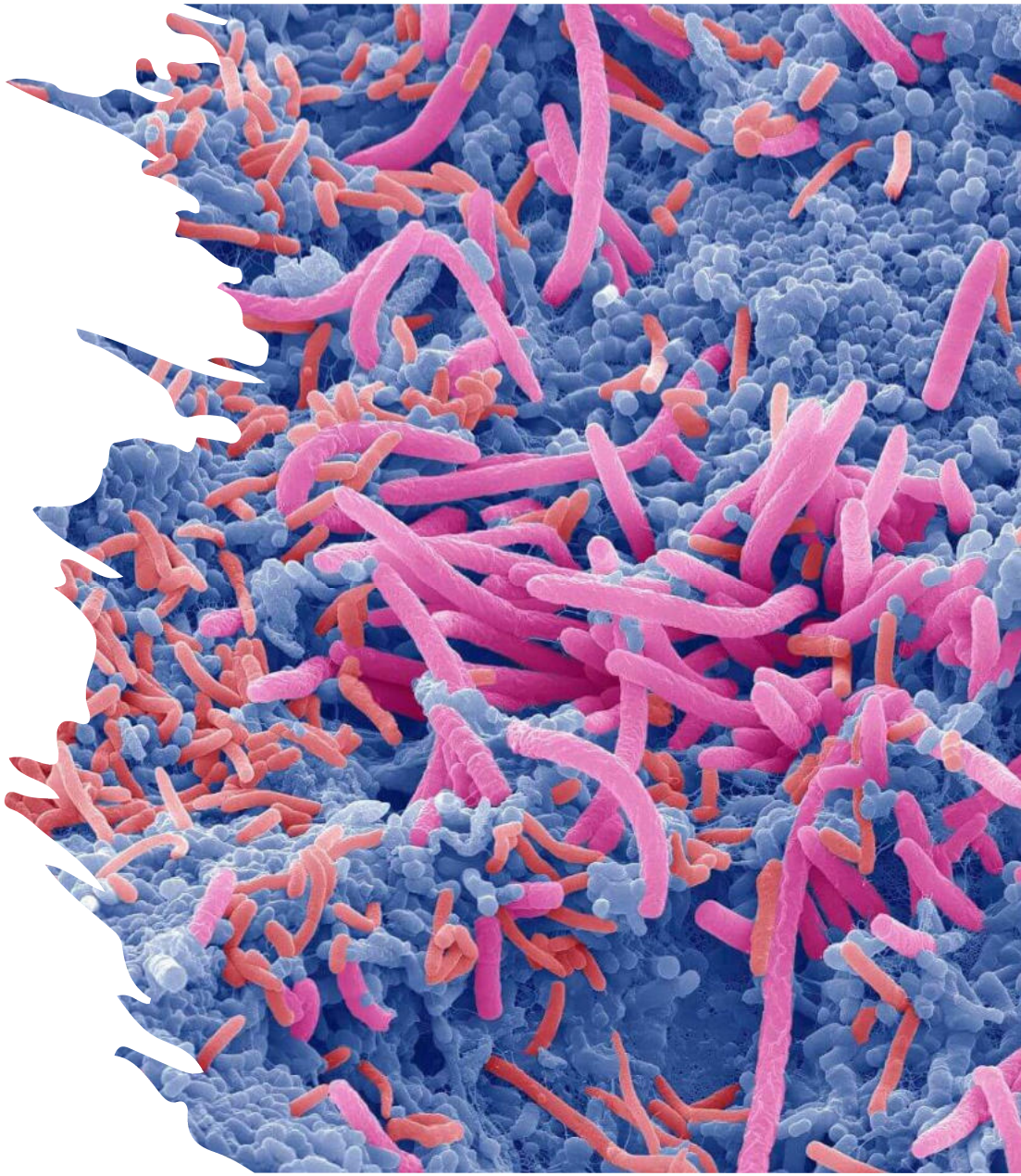
Although all the protagonists of this remarkable achievement are now gone, their writings allow us to remember them not only for their mountaineering and medical feats but also for their humanity.

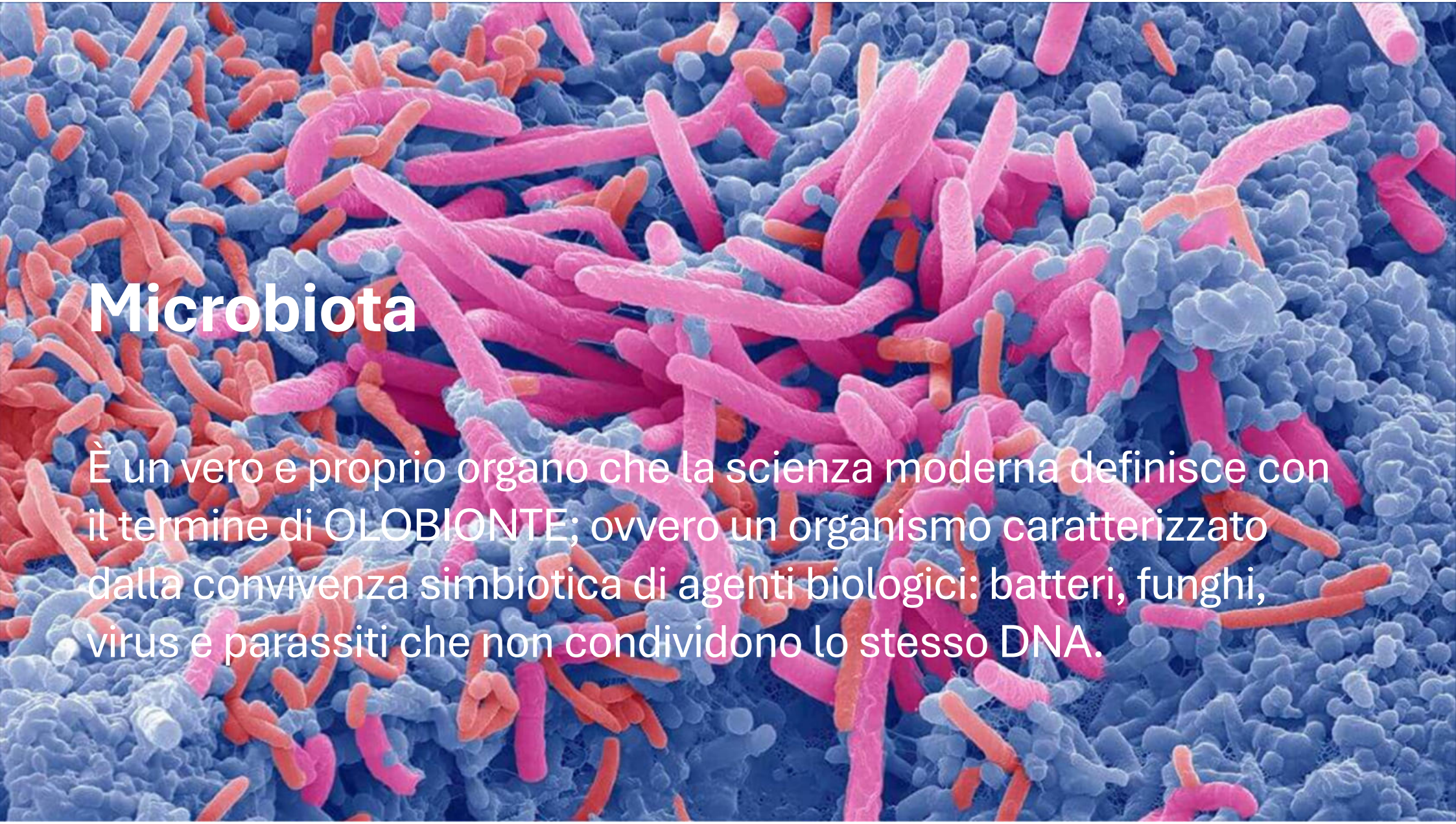
Author's Contributions

P.S.: Data analysis, article writing, and correspondence.

[1]International School of Maxi Emergencies (MEDIS), Modena, Italy.
[2]Medical Commission for the Italian Regions of Marche and Umbria of the Italian Alpine Club (Club Alpino Italiano, CAI).

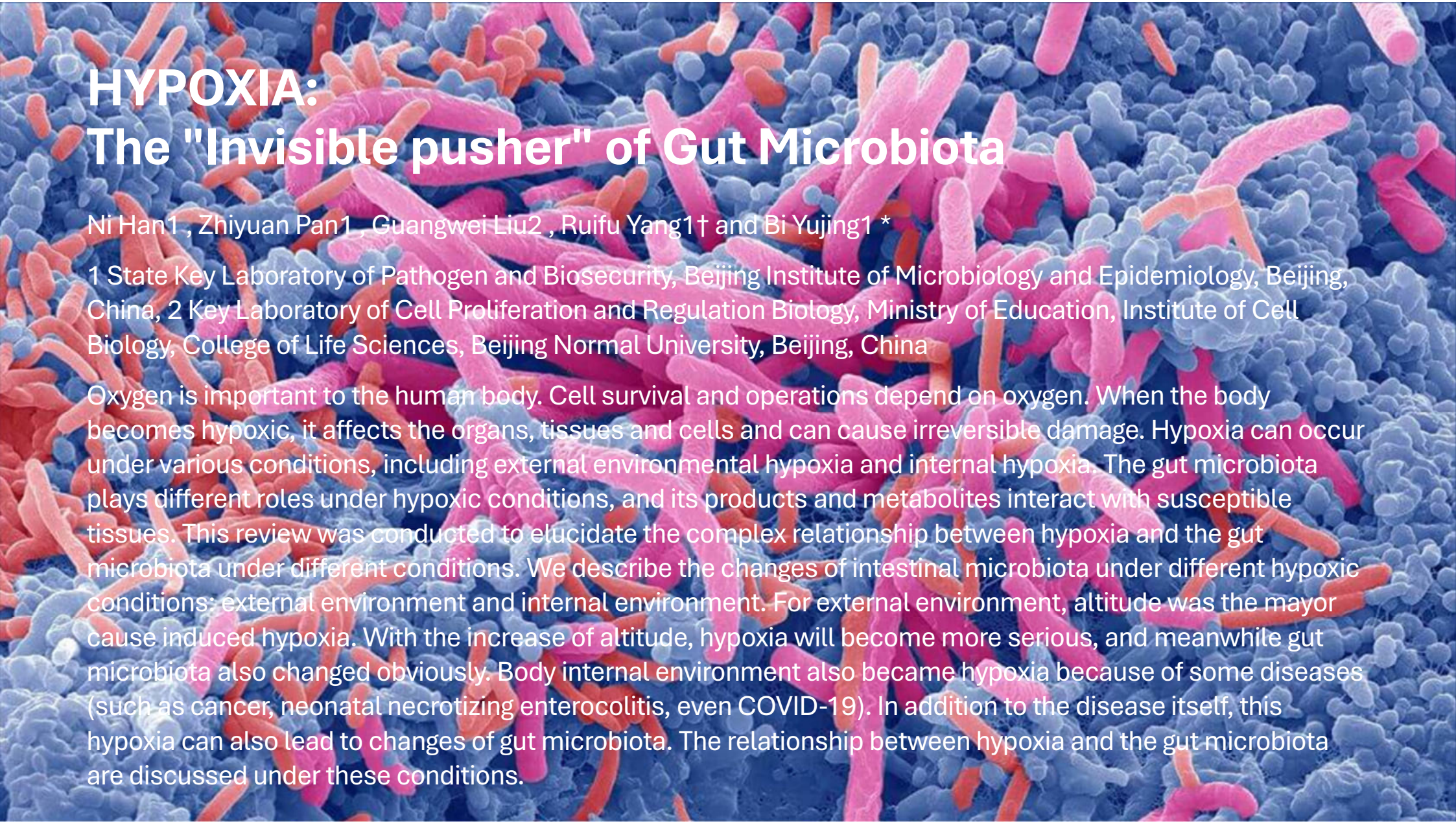
Microbiota in quota





Microbiota

È un vero e proprio organo che la scienza moderna definisce con il termine di OLOBIONTE; ovvero un organismo caratterizzato dalla convivenza simbiotica di agenti biologici: batteri, funghi, virus e parassiti che non condividono lo stesso DNA.



HYPOXIA:
The "Invisible pusher" of Gut Microbiota

Ni Han1 , Zhiyuan Pan1 , Guangwei Liu2 , Ruifu Yang1† and Bi Yujing1 *

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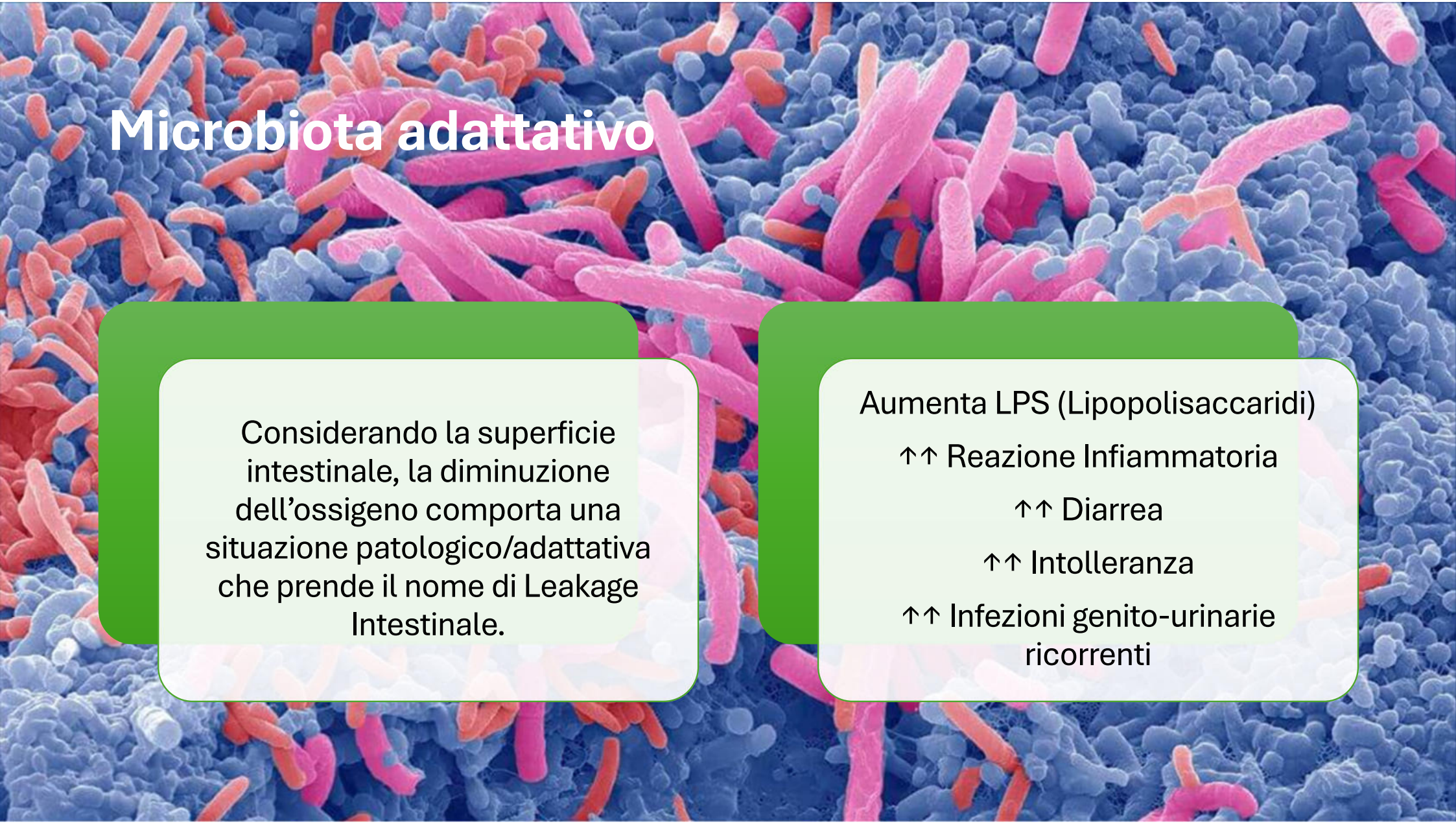
Oxygen is important to the human body. Cell survival and operations depend on oxygen. When the body becomes hypoxic, it affects the organs, tissues and cells and can cause irreversible damage. Hypoxia can occur under various conditions, including external environmental hypoxia and internal hypoxia. The gut microbiota plays different roles under hypoxic conditions, and its products and metabolites interact with susceptible tissues. This review was conducted to elucidate the complex relationship between hypoxia and the gut microbiota under different conditions. We describe the changes of intestinal microbiota under different hypoxic conditions: external environment and internal environment. For external environment, altitude was the mayor cause induced hypoxia. With the increase of altitude, hypoxia will become more serious, and meanwhile gut microbiota also changed obviously. Body internal environment also became hypoxia because of some diseases (such as cancer, neonatal necrotizing enterocolitis, even COVID-19). In addition to the disease itself, this hypoxia can also lead to changes of gut microbiota. The relationship between hypoxia and the gut microbiota are discussed under these conditions.



Microbiota adattativo

Considerando la superficie intestinale, la diminuzione dell'ossigeno comporta una situazione patologico/adattativa che prende il nome di Leakage Intestinale.

Aumenta LPS (Lipopolisaccaridi)

↑↑ Reazione Infiammatoria

↑↑ Diarrea

↑↑ Intolleranza

↑↑ Infezioni genito-urinarie ricorrenti

Metaboliti

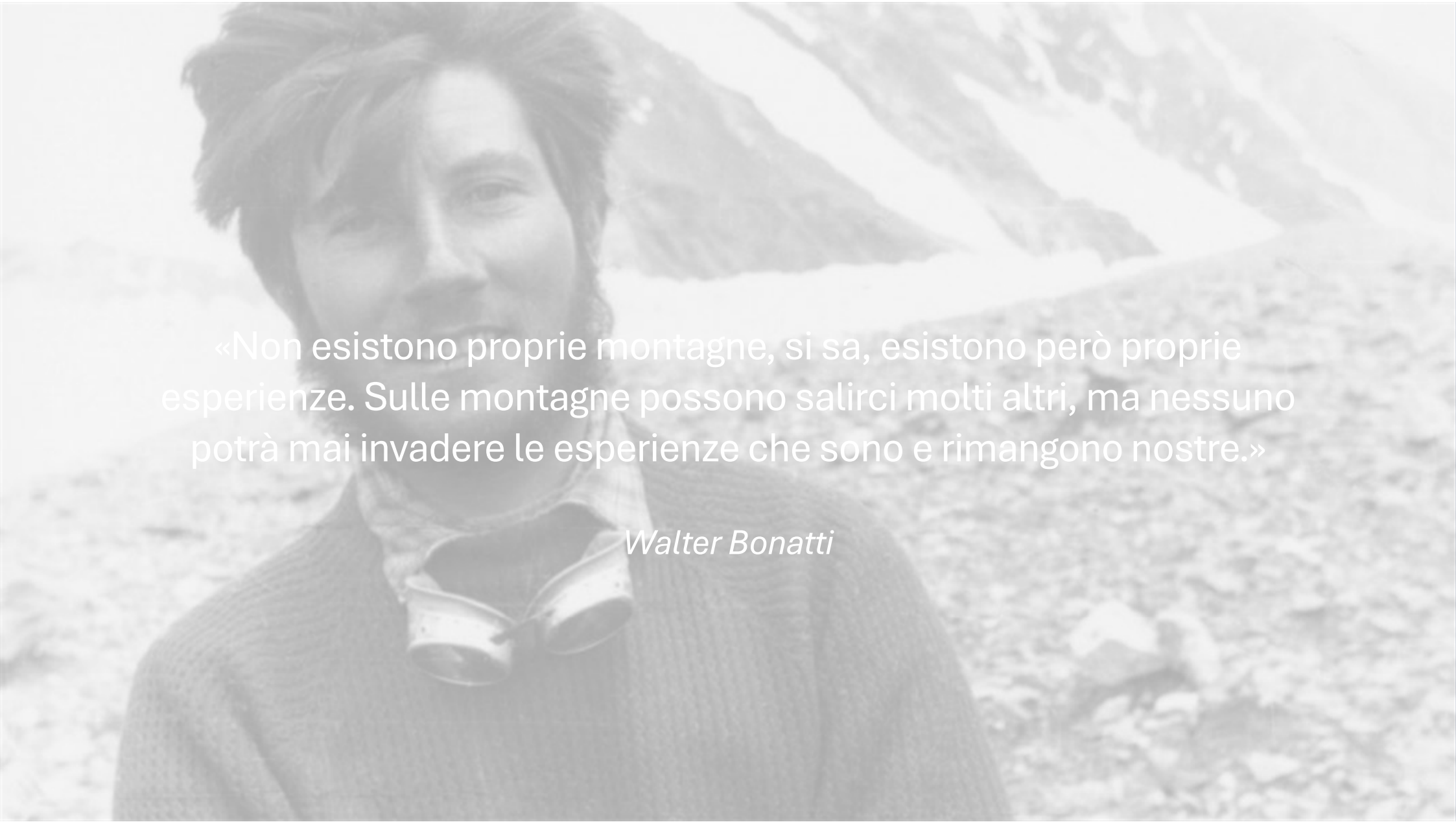
Importante il ruolo della serotonina che oggi ci può indicare la presenza o meno di un alvo diarroico.

Così come importante il ruolo delle Tmao per la componente cardiovascolare.

Nonché degli acidi grassi a corta catena per la reattività immunitaria.

Metabolismo	Carenza⇦ ⇨Eccesso
Acetato	0
Butirrato	1
Propionato	0
Succinato	0
Lattato	4
GABA	0
Istamina	2
Indolo	0
Ac. Indolacetico (IAA)	3
Ac. Indolpropionico (IPA)	2
Triptammina	1
Serotonina	0

Metabolismo	Carenza⇦ ⇨Eccesso
Trimetilammina (TMA)	0
Polifenoli	0
Vitamine gr. B	1
Vitamina K2	0
Degradazione glutine	0
Mucolisi	0
Proteolisi	0
Lipopolisaccaride (LPS)	0
Ac. biliari secondari	0
Etanolo	0
Ac. Solfidrico (H_2S)	0
Metano (CH_4)	0


«Non esistono proprie montagne, si sa, esistono però proprie esperienze. Sulle montagne possono salirci molti altri, ma nessuno potrà mai invadere le esperienze che sono e rimangono nostre.»
Walter Bonatti