ORIGINAL ARTICLE

Mountaineering And Altitude Sickness: A Study of AMS Prevalence among Climbers of Mount Kinabalu, Malaysia

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ABSTRACT

Introduction: Adventure tourism has become one of Malaysia's most attractive tourism demands, and mountain climbing is rapidly becoming a popular recreational sport. Exploring mountain adventures offers a dynamic experience, preserving this fascinating activity, yet the climbers are exposed to the risk of altitude sickness, such as Acute Mountain Sickness (AMS). This study aimed to evaluate the prevalence of AMS and investigate the effects of high-altitude sickness on the climber profile associated with climbing at Mount Kinabalu, Malaysia. **Methods:**. The Lake Louise acute mountain sickness LLS score questionnaire collected 95 climber's data at four different altitudes. SPO2 and Pulse rate was (PR) measured using a finger pulse oximeter. In a cohort study, AMS was measured on day one at 1866m (1st station), 3622m (2nd station), and day two at 3810m (3rd station), and 4095m (4th station). **Results:** At the altitude of 1866 (Timpohon Gate), the prevalence of AMS was 0%, 30% at 3622m (Laban Rata), 34.7% at 3810m (Sayat-Sayat), and 37.9% at 4095m (Low's Peak). The overall prevalence of AMS was 37.9% and the majority of AMS cases were moderate in severity and the LLS score is significant with Pulse Rate and peripheral capillary oxygen saturation (SPO2). **Conclusion:** Concisely, this finding has triggered a need for consideration from multi agencies to enhance mountaineering guidance, especially for beginners or inexperienced hikers, for a suitable package for climbing attempts to reduce the incidence of AMS among Mount Kinabalu climbers.
Malaysian Journal of Medicine and Health Sciences (2023) 19(1): 10-16. doi:10.47836/mjmhs19.1.3

Keywords: Adventure tourism, Acute Mountain Sickness (AMS), Mount Kinabalu, High-altitude

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INTRODUCTION

The three most common types of altitude sickness are Acute Mountain Sickness (AMS), High-altitude Cerebral Edema (HACE), and High-altitude Pulmonary Edema (HAPE), with AMS being the most prominent (1,2). A syndrome of AMS develops in those who have not yet acclimated to high elevations and normally manifests at heights greater than 2500 meters. However, high-risk, or susceptible individuals such as those with pre-existing diseases, might also develop AMS at lower altitudes. It is a type of acute altitude disease that develops as the altitude rises and hypoxia is brought on by the decreasing atmospheric partial pressure of oxygen (1–3). AMS has non-specific symptoms such as headaches, lethargy, loss of appetite, nausea, dizziness, sleep disturbance, and vomiting (1,4,5). AMS also could make climbing painful and uncomfortable for climbers (6), with a probability of getting into life-threatening high-altitude cerebral oedema (HACE) (2,7).

The researchers that are studying AMS may utilise the Lake Louise AMS score. The Lake Louise Score (LLS) is AMS's most widely used symptom severity assessment. However, for diagnosing or treating AMS, it is not meant for use by physicians, professional outdoor guides, or non – professionals individuals (1,8). Headaches, lethargy, dizziness, nausea, and vomiting are common symptoms of various forms of altitude sickness after at least 4-6 hours at an altitude over 2000-2500m (2,9). From previous studies, AMS estimated prevalence varies from 8% to 25% probability of being affected at 2500-3000m and increases to 40% to 60% chances at 4500m (10). Nonetheless, no single factor can explain the risk of developing AMS, and the variance in probability is associated with several factors such as the technique of climb, mountain location, sleeping altitude and sleep quality (4,5,9,11). On top of that, AMS is a common condition that, when appropriately treated, is typically benign and self-limiting (7).

Mountaineering presents a leisure-time physical activity and has been linked to considerable health

benefits, yet mountain activities also have an inherent risk of injury and death. As climbing has become a more popular activity for recreation, the purpose of work or competition in sports, it has also resulted in a rising number of incidents (6,12,13). Previous research discovered patterns in mountaineering variables like age, sex, and experience that might affect their chances of reaching the summit or dying during the climbing (4,7). The oxygen level is thin in high mountain (high altitude) areas; thus, it is physically challenging, demanding, and precarious for climbers (13). Due to low air pressure at high altitudes, low oxygen saturation levels or desaturation of a person's blood can occur at high elevations (7,13). The environment conduction, such as air pressure, partial pressure of oxygen (PO2) in inhaled air, arterial PO2, and blood oxygen saturation measurements, will become low when a climber ascends to greater altitudes. Subsequently, a previous study also presented various high-altitude illnesses such as individuals at risk of developing one of the forms of acute mountain sicknesses (2).

Malaysia has over 300 mountains suitable for tourism, with an increasing demand for mountaineering activities (12,14). Mount Kinabalu is one of Malaysia's most iconic mountains, and it has become a popular hiking destination with breathtaking scenery. The highest scalable mountain in Malaysia, with 4095m, put Mount Kinabalu as the most climbable and tactical mountain that requires skill and experience to reach the summit (15). Mount Kinabalu also can be considered one of the busiest high-altitude mountains in the world with more than 29,000 climbers every year, with the maximum daily limit for climbing issued by Sabah Parks being 185 climb permits per day (16).

Generally, at high elevations (>2500 m), it is known that the prevalence of AMS increases and climbers risk developing AMS (2). The risk factors of AMS have been reported in the literature in various types of mountains such as Mount Fuji, Kilimanjaro, Eastern and Western Alps and others (5,11) such as sex, age, BMI, the altitude of individual's permanent home, smoking, alcohol use, AMS medication, a history of AMS, or physical health. However, the risk factors such as exertion level, migraine experience, and climbing experience were proved to be significant risk factors for the development of AMS in both the Eastern and Western Alps (17). While other studies indicated that the likelihood of getting AMS when climbing Mount Fuji cannot be explained by a single factor such as poor perceived sleep quality that was linked to the severity of AMS (11). On the other hand, for Kilimanjaro Mountain, the previous studies suggested climbers require a more gradual route profile to lower the risk of developing AMS and summiting success (18-19). As in Malaysia, the previous study highlighted that several factors such as sex, previously experienced with AMS, past exposure to high altitude, climbing duration, fluid consumption, acetazolamide use, overall abilities, SPO2 level and pulse rate were not associated with AMS at Mount Kinabalu with 21.7% - 23.9% of incidences reported (6). This study aimed to investigate the prevalence of AMS in Mount Kinabalu with different high-altitude elevations and the association of the climber's profile. Furthermore, the climbers' health characteristic development must be continuously observed and assessed from low altitude to the mountain's highest point with high altitude measurement progress. This research also investigates the prevalence of AMS symptoms and other factors contributing to the high potential risk to the climbers at Mount Kinabalu.

MATERIALS AND METHODS

The study was performed in a cross-sectional study design. The researcher used convenience sampling as it is characterized by the use of a sample that is convenient to the researcher and includes those respondents who agree to participate. Participants in this study were climbers attempting to reach the Summit of Mount Kinabalu (4,095m) between the 2nd to 7th of March 2020 (climbing attempt to reach the Summit in two days one night). Inclusion criteria were climbers aged 18 years and above who hiked from Timpohon Gate (the main trail to reach the Summit of Mount Kinabalu) and hiked to Laban Rata basecamp on Day- 1. Those who did not hike from Timpohon Gate and did not hike to Laban Rata basecamp on Day- 1 were excluded from this study. Climbers need to hike from Timpohon Gate to have the same length of the trail and proceed to Laban Rata basecamp on Day 1 to ensure they have the same period of acclimatization. Individual who met the requirements and agreed to participate in the study were selected as participants. Written informed consent was sought from each respondent involved in this study. All respondents voluntarily participated in the study and were assured of anonymity and confidentiality. The study also approved the collection and use of information in accordance with policy of The Board of Trustee of Sabah Parks.

There are two main entrance trails to the Mount Kinabalu summit, Timpohon Gate and Mesilau Trail. Mount Kinabalu Trail is the main trail to reach the summit of Mount Kinabalu begins at 1866m in height, 1km from the main entrance of the Kinabalu Park office. The trail is about 9 km in length to reach the summit and is the famous and preferred trail among climbers. On the other side, the Mesilau trail requires trekking through Mersilau Station and is 2km longer to reach Laban Rata compared to the Timpohon Gate Trail.

Questionnaire and Measurement

The main survey instrument used in this study was the self-administrated questionnaire form. The questionnaire consisted of socio-demographic information concerning age, gender, weight, height and BMI. The previous

health experience relating to AMS, climbers' profile in mountaineering experience, climbers' skills and history visited at high altitudes for the last six months were also asked. For the climbers' skills, the respondents were asked to rank themselves according to their perceived level of climbing expertise as novice, beginner, intermediate, or experienced climber in order to assess experience (20) . A respondent who considered themselves novice or beginning climbers were classified as inexperienced climbers. Accordingly, a respondent who indicated their ability level as intermediate to advanced were classified as experienced climbers. As for the AMS, the researcher determined the AMS among the climbers based on self-reported Lake Louise Score (LLS) consists of headaches, gastrointestinal symptoms, fatigue or weakness, and dizziness symptoms. These LLS attributes were measured by rating scores between zero to three (0 to 3) (zero, without symptoms, one with mild symptoms, two with moderate symptoms, and three with symptoms severe and disabling signs). Participants who reported a headache with at least a cumulative LLS of three were defined to have AMS (9). The severity of AMS was further classified as mild; with a score of three to five (3-5), moderate; with a score of six to nine (6-9), and severe; with score ten to twelve (10-12) categories. Meanwhile, the researcher used a finger pulse oximeter (Brand: Oxitech) as additional supporting equipment to ease the climbers to measure and record pulse rate and oxygen saturation (SPO2). In addition, finger pulse oximetry is regarded as an effective method for assessing an individual's high altitude acclimatization and monitoring the development of AMS (21).

Prior to taking measurements while seated, the researcher ensured that each participant had received a sufficient amount of rest (30 minutes). Pulse oximetry and SPO2 data were collected immediately after each participant completed the Lake Louise Consensus Questionnaire, and data from all individuals were collected in the same manner (uniformly).

Data collection was carried out at four identified stations, based on days and timeframes. Table I shows the main station established along the trail from Timpohon Gate to Low's peak and marking stations, A, B, C, and D indicate each climber's data collection point. The first data collection point, in Day-1 is at Timpohon Gate (Station A) and 95 questionnaires were distributed to the climbers, with a timeframe between 8 am to 10 am. The pulse rate and peripheral capillary oxygen saturation (SpO2) of each climber were recorded before they started to ascend to the next station. The second data collection took place when the climbers reached Laban Rata basecamp on the same day. At Laban Rata (station B), the timeframe of data collection is between 5pm to 7pm. At these stations, the climbers were asked to complete the LLS self-reported questionnaire on AMS and measure their pulse rate and peripheral capillary oxygen saturation (SpO2). After a few hours of resting at Laban Rata basecamp, the climbers continued to ascend to the next station. On Day-2, the third data collection took place when climbers reached Sayat-Sayat (Station C), around 2 am to 4 am. At this station, the researcher repeated the data collection of the climbers' AMS, pulse rate and (SpO2). The last data collection took place when the climbers completed their ascent and reached the fourth station, Summit (Station D) around 5 am to 7 am. The climbers once again have to self-report their symptoms of AMS using the LLS score and their pulse rate and (SpO2).

Table I: Timpohon Gate checkpoint from starting until summit and station for data collection

Trail (elevation)	Distance (meter)
Timpohon Gate (1866m) – Kandis Shelter (2010m) (Station A)	750
Kandis Shelter (2010m) – Ubah Shelter (2120m)	500
Ubah Shelter (2210m) – Lowii Shelter (2360)	1050
Lowii Shelter (2360m) – Mempening Shelter (2620m)	1000
Mempening Shelter (2620) – Layang-Layang (2740m)	700
Layang-Layang (2740m) – Villosa Shelter (2980m)	900
Villosa Shelter (2980m) – Paka Cave Shelter (3080m)	500
Paka Cave Shelter (3080m) – Laban Rata (3622m)	600
Laban Rata (3622m) – Sayat-Sayat (3810m) (Station B)	1100
Sayat – Sayat (3810m) – Low's Peak (4095m) (Station C) (Station D)	1750
Total	**8850**

RESULTS

Climbers' characterization

A total of 95 climbers were selected from the first station (Station A), Timpohon Gate and completed the questionnaire. All 95 participants successfully reached Summit in two days one night climbing attempt. In Table II, the climber's demographic profile summarizes a dominant representation of men but indicates an interest

Table II: Demographic profile for the climbers

Variable	N	Percentage (%)	Mean (SD)
Gender			
Male	57	60	
Female	38	40	
Age	95	100	34.9 (10.3)
Weight	95	100	68.9 (15)
Height	95	100	166.5 (9.7)
BMI	95	100	24.7 (4.2)
Experiencing in mountaineering			
<1 year	40	42.1	
1-5 years	33	34.7	
6-10 years	10	10.5	
>10 years	12	12.6	
Climber's skill			
Novice	28	29.5	
Beginner	48	50.5	
Intermediate	9	9.5	
Experienced	10	10.5	

of women in mountaineering activities. The climber's profile showed most of the participants were beginners, the majority had less than five years of climbing experience and were considered inexperienced in mountaineering activities. The mean age of climbers was 34.9 ± 10.3 years (range 18 – 67 years).

The overall prevalence of AMS among climbers on Mt Kinabalu

Table III presented the prevalence of AMS by LLS score criterion of ≥ 3 varied with different elevation levels (altitude). No AMS symptoms showed at altitudes 1866m (Timpohon Gate), even though climbers appeared to have mild headaches and lethargy. At an altitude of 3622m (Laban Rata), climbers reported moderate symptoms of AMS (30%), and 27 climbers required assistance with consultation and medication. As the elevation level increased, at 3810m (Sayat-Sayat), climbers claimed to have AMS after rapid ascent in the morning, trying to reach the summit on day two. After getting a rest for less than 30 minutes, they climb for the next approximately one kilometre to submit. Later, climbers represented moderate AMS symptoms at the altitude of 4095m (Low's Peak), 35 metre just before the summit. Of the climbers recruited, 37.9% had AMS, with most AMS cases being moderate in severity, with an LLS mean score of 2.99 to 4.26, as shown in Table III. The descriptive data of participants of this present study also revealed that 43.4% (n=30) of 69 climbers who reported experiencing AMS are older climbers (≥35 years) and 38 (55.1%) have a BMI of ≥ 25 (kg/m^2).

Table III: Number of climbers by severity of Lake Louise Score (LLS) at different level of elevation

Day/ Time	Station	Altitude, m	LLS score (mean, ±SD)/ (min-max)	Prevalence of AMS with ≥ 3 n (%)
1 / 8.00 am – 10.00am	A, Timpohon Gate	1866	0.35±/ (0 – 2)	0 (0)
1 / 5.00pm – 7.00pm	B, Laban Rata	3622	2.99± (0 – 10)	28 (30)
2 / 2.00am – 4.00am	C, Sayat-Sayat	3810	4.08± (0-12)	33 (34.7)
2 / 5.00am – 7.00am	D, Low's Peak	4095	4.26± (0-12)	36 (37.9)

Pulse rate (PR), Oxygen saturation (SPO2) and development of AMS at different levels of elevation

Figures 1 and 2 presented the mean SPO2 and mean pulse rate reading between climbers with no AMS symptoms and with AMS at different altitudes accordingly. The mean of SPO2 value for AMS and non AMS among climbers is significantly different t(6) = 0.0332, p < 0.05. The pulse rate reading is also significantly different among AMS and non AMS, with t(6) = 0.0380, p < 0.05. Table IV presented the finding of comparison between mean pulse rate and mean SPO2 among climbers with AMS and without AMS at a different elevation level. There is a significant difference between the mean Pulse Rate of climbers with AMS and without AMS at a different elevation, with t(94) = -9.199, p<0.05 at

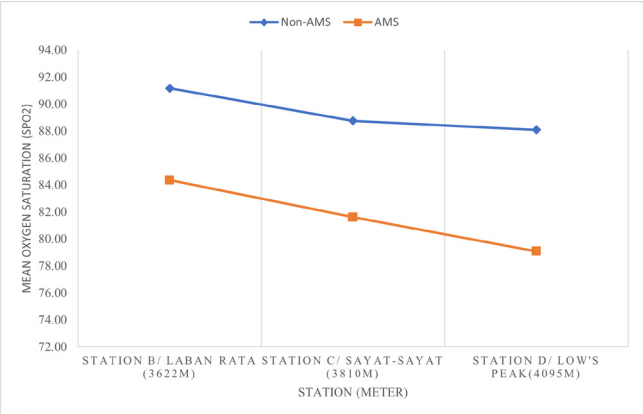

Figure 1: Number of climbers with AMS and non-AMS according to Age (Years) and BMI (kg/m^2). Data are given as N=95

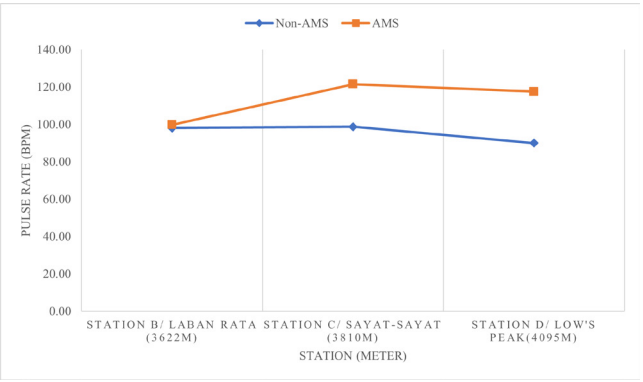

Figure 2: Pulse Rate reading at different altitudes in AMS and Non-AMS group. Mean Pulse Rate at Different Station for AMS and Non-AMS Climbers. Data are given as means ± (n=95).

altitude 4095m, the highest altitude near the summit. As for the mean of SPO2 among climbers with AMS and without AMS, significant differences were found at altitude 3622m with t(94) = -13.365, p<0.05, at altitude 3810m with t(94) = -6.678, p<0.05 and at altitude 4095m with t(94) = -6.678.

A Spearman's rank-order correlation was performed to determine the relationship between the AMS incidence variables using LLS score (mild, moderate, and severe), Pulse Rate and SPO2 at different altitudes. According to Table IV, there was a moderate positive correlation between AMS and pulse rate at altitude 3810m (Sayat-Sayat) and at the highest altitude (4095m), which was statistically significant (rs(93)=0.573, p <0.005) and (rs(93)=0.697, p <0.005) respectively. On the other hand, at altitude 3622m, 3810m and 4095m, the results of correlation also indicated that there was a significant negative correlation between AMS and SPO2 level of climbers with (rs(93) = -0.891, p < 0.005), (rs(93) = -0.731, p < 0.005) and (rs (93) = -0.791, p < 0.005) respectively.

DISCUSSION

The study presented the prevalence of AMS on Mount Kinabalu at various altitudes, indicating the prevalence

Table IV: Comparison on pulse rate and oxygen saturation among climbers at different altitudes

Altitude, m	Variables	With AMS		Non-AMS		t-test	p-value
		N	mean, ±SD	N	mean, ±SD		
1866 (Timpohon Gate)	Pulse rate (bpm)	0	0	95	87.57 (51-124)	57.172	0.000
	SPO_2 (%)	0	0	95	96.09 (90-99)	445.145	0.000
3622 (Laban Rata)	Pulse rate (bpm)	28	99.82 (61-120)	67	98.11 (69-126)	0.505	0.000
	SPO_2 (%)	28	84.35 (81-90)	67	91.16 (86-95)	-13.365	0.000*
3810 (Sayat-Sayat)	Pulse rate (bpm)	33	121.51 (75-142)	62	98.72 (57-140)	6.255	0.000
	SPO_2 (%)	33	81.61 (74-92)	62	88.75 (82-98)	-6.678	0.000*
4095 (Low Peak's)	Pulse rate (bpm)	36	117.52 (97-150)	59	90.01 (59-131)	-9.199	0.000*
	SPO_2 (%)	36	79.08 (70-91)	59	88.08 (79-98)	-7.490	0.000*

* $p < 0.05$

Table V: Lake Louise Score (LLS) at different altitude and Spearman's Correlation Coefficients of Pulse Rate and Arterial Oxygen Saturation (SPO2)

Altitude (meter)	Subjects/ AMS scores	LLS	Correlation Coefficients: LLS vs.	
			SPO2	PR
1866 (Timpohon Gate)	95/0	0.35	-.650**	.208*
3622 (Laban Rata)	95/28 (30%)	2.99	-.891**	.152
3810 (Sayat-Sayat)	95/33 (34.7)	4.08	-.731**	.573**
4095 (Low Peak's)	95/36 (37.8)	4.26	-.791**	.697**

* $p < 0.05$

of about 30% – 37.9% at altitudes between 3622m to 4095m. In the two-day, one-night climbing attempt to reach summit, LLS mean score of ≥4 with headache, which indicated moderate severity of AMS, was reported by 37.9% of climbers. The study was found to be higher than similar studies by (6), which reported the prevalence of AMS in Mount Kinabalu is 23.9% (day one) and 21.7% (day two).

A previous study on Mount Fuji at an altitude of 3776m also reported a lower prevalence, with 29.5% (11). On the other hand, at an altitude of 3658m, the prevalence of AMS experienced by tourists visiting Lhasa, Tibet was close to 36.7% (5). The differences in geographic locations of the mountain (presented different conditions such as infrastructure, technical demands, and altitudes), prevailing with different characteristics of the climbers, weather and many other factors might be the limitation for directly comparing the results among those various studies (2,11). The characteristics of the climbers also might influence their risk of developing AMS. Related factors such as BMI and age are associated with AMS development, partly related to greater nocturnal desaturation with altitude exposure (4,9). In addition, AMS association with weight and BMI (BMI is higher in the AMS group than in the non-AMS groups) might indicate obesity as a significant factor for acute mountain sickness (19). On top of that, this study's limitations and/ or constraints findings also included the researcher's inability to completely rule out these variables as only descriptive data were presented in the results. As for the mountaineering experiences, a skilful and expert climbers may be correlated with greater climbing knowledge and proper behaviour, such as knowing how to regulate the rate of ascent to prevent fatigue, or how to acclimatise efficiently (11). In addition, participants hike in groups, and since no one wants to be the weakest member of their group, AMS symptoms might well be ignored by the participants. As a result, most climbers' lack of understanding regarding high-altitude sickness could have been due to some underestimating and misinterpreting symptoms. Also, it is possible to manipulate the profile climbers because the form is filled up and self-administrated by the participants after the expedition.

In this present study, the participants climbing attempt to arrive at the summit within 48 hours for altitudes more than 4000metre. Previous studies suggested that the fast ascent is often an established risk factor for AMS in multiple-day hikes (2, 11). In addition, according to Schommer et al. (10), individuals at 2500 meters and above might develop high altitude sickness in the classification of altitude levels. Another study showed that, after a fast ascent (more than 300 metres per day) to a height exceeding 4000 m, about every second trekker or climber might get two to three symptoms of high-altitude sickness (3). Thus, in this situation, a package of two days one night climbing attempt is suggested to follow the recommendations for a slower ascent (500m per day) at altitudes greater than 3000m to allow for acclimatisation and lower the risk of developing AMS (2).

The most critical finding in the present study about incidence and determinants of AMS was predictive of subsequent AMS at higher altitude exposure when ascending continued. SPO2 and PR methods were slightly better for impending profile AMS at every station. For example, no AMS symptoms among climbers before the altitude of 2516m (Pondok Mempening). However, the pulse rate reading is slightly lower compared to a higher level. This might be due to the process of the body's acclimatization when exposed to a high altitude. Moreover, with the elevation of the altitudes, climbers who experienced AMS later at an altitude higher than 2500m had shown a significant decrease in the oxygen

saturation level (SPO2) and elevated reading in pulse rate compared to climbers who did not develop AMS. The previous studies in laboratory-simulated research also revealed that AMS-susceptible individuals have lower SPO2 values after exposure to hypobaric hypoxic conditions (20). Even though decreased oxygen saturation is a symptom of AMS, using only the value of SPO2 in AMS diagnosis is still limited and discouraged (2,20). Nevertheless, it isn't easy to make a direct comparison between actual and lab situations, with other factors such as wilderness areas and consider an improvised and skilled person to attend, especially at high altitudes. In addition, a situation out of comfort zone might lead to multiple misinterpreted of data and results, condition of weather and many other factors. Therefore, the lab-based result might not be suitable to be compared to the actual data. However, the measurement of SPO2 can be seen much clear in a more extended expedition like Everest Base Camp (15 days), Annapurna Circuit Treks (15 days), or climbing a peak like Island Peak (6200m) (11,17-18).

CONCLUSION

In conclusion, Mount Kinabalu's climbers may risk developing high-altitude illnesses associated with different elevations at each station. Some possibilities of developing AMS might occur since the current package offer two-day one night trekking that begins at Timpohon Gate (1866m) and ascends rapidly in 5-7 hours to a Rest House at Laban Rata (3622m). On the following day, the climbers must hike to the summit (Low's Peak, 4095m) and achieve a dramatic elevation increase of more than 3000m in less than 24 hours, making them vulnerable to AMS. Although the prevalence of AMS is lower at Mount Kinabalu, with most cases being moderate, it should not be underestimated.

Most high-altitude adventures come with a higher cost. This can be seen on Everest Base Camp commonly. The higher the urban setup is made, the higher the price to pay for their service. For better experience and safety, both are the implication of adventure tourism to the individual who jumps into it. Therefore, a consideration, for those who can afford the expedition, Sabah Parks should widely start 3 day and 2-night packages for better acclimatization especially, beginners or inexperienced climbers. On top of that, the new road establishes a good platform for climbers is about 350m from Laban Rata should be considered for a better route. In addition, Kinabalu Emergency Department also should open soon to provide service in terms of consultation or medical advice for those required. This service might give weightage to the Mount Kinabalu profile, to be the same as other famous adventure tourism mountaineering activities like Annapurna Circuit Treks and Mount Fuji.

ACKNOWLEDGEMENTS

Sabah Parks And Kinabalu Park management and staffs supported this study, and the authors are thankful for their full support on time, hospitality, logistics, and guides throughout the study. The authors also thank and are grateful to those climbers for full support on time and for participating in this study.

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