



The Role of Forensic Anthropology in Identifying and Investigating Altitude-Related Fatalities in Remote Mountainous Regions of Makassar, Indonesia

Maghfirah Susanto^{1*}, Muhammad Hasan¹

¹Faculty of Health Sciences, Universitas Bosowa, Makassar, Indonesia

ARTICLE INFO

Keywords:

Altitude-related fatalities
Forensic anthropology
Mountain deaths
Postmortem interval
Victim identification

***Corresponding author:**

Maghfirah Susanto

E-mail address:

maghfirah.susanto@gmail.com

All authors have reviewed and approved the final version of the manuscript.

<https://doi.org/10.59345/sjfm.v1i2.64>

ABSTRACT

Introduction: Altitude-related fatalities pose significant challenges in remote mountainous regions due to harsh environments, limited accessibility, and postmortem changes. Forensic anthropology plays a pivotal role in identifying victims, determining the cause and manner of death, and aiding investigations. This study aimed to explore the contribution of forensic anthropology in investigating altitude-related deaths in the challenging terrain of Makassar, Indonesia. **Methods:** A retrospective analysis was conducted on 35 cases of altitude-related fatalities in the mountainous regions of Makassar between 2018 and 2023. Data were collected from forensic reports, autopsy records, and scene investigations. Anthropological methods, including skeletal analysis, postmortem interval estimation, and trauma analysis, were employed to aid in identification and death investigations. **Results:** The majority of victims were male (80%), with an average age of 32 years. The most common causes of death were falls (45.7%), followed by hypothermia (28.6%) and avalanche/landslide (14.3%). Postmortem interval estimation was challenging due to environmental factors, with a mean interval of 5.3 days. Anthropological analysis assisted in identifying 91.4% of the victims, even in cases with advanced decomposition or skeletal remains. **Conclusion:** Forensic anthropology is indispensable in identifying and investigating altitude-related fatalities in remote mountainous regions. Anthropological techniques contribute significantly to victim identification, cause and manner of death determination, and the reconstruction of events, assisting legal authorities and providing closure to families.

1. Introduction

The allure of mountainous regions, with their majestic peaks, breathtaking vistas, and challenging terrains, has captivated humanity for centuries. These landscapes, while awe-inspiring, present a unique set of risks and challenges for human exploration and adventure. Altitude-related fatalities, encompassing deaths resulting from falls, avalanches, hypothermia, and other environmental factors, remain an unfortunate reality in these environments. The remote and often rugged terrain of mountainous regions, coupled with unpredictable weather patterns and

limited accessibility, can significantly complicate search and rescue operations, scene investigations, and postmortem examinations. In such demanding scenarios, the discipline of forensic anthropology emerges as an indispensable tool in the identification and investigation of altitude-related deaths. Forensic anthropologists, armed with their expertise in human skeletal anatomy, taphonomy (the study of postmortem changes), and trauma analysis, play a pivotal role in assisting legal authorities and providing closure to grieving families. Their contributions range from identifying victims, often in cases with advanced

decomposition or skeletal remains, to determining the cause and manner of death, and reconstructing the events surrounding the incident. The mountainous regions of Makassar, Indonesia, with their diverse ecosystems, varying altitudes, and challenging terrains, attract adventurers and trekkers from around the world. The allure of these mountains, however, is accompanied by inherent risks. The rugged landscapes, unpredictable weather patterns, and limited infrastructure in remote areas create a unique set of challenges for forensic investigations. Delayed discovery and recovery of victims, fluctuating environmental conditions impacting the preservation of remains, and limited resources for conducting investigations in remote areas are just a few of the obstacles faced by forensic practitioners in this region.^{1,2}

Altitude-related fatalities encompass a wide range of causes, each presenting its own set of challenges for forensic investigation. Falls from cliffs, steep slopes, or unstable terrain are a common occurrence in mountainous regions. The impact of a fall can cause severe trauma to the body, including fractures, internal injuries, and head trauma. In cases where the body is not immediately recovered, environmental factors such as scavenging, weathering, and insect activity can further complicate the identification and analysis of injuries. Hypothermia, another significant cause of death in mountainous environments, poses unique challenges for forensic investigation. The body's response to cold temperatures can lead to paradoxical undressing, where victims remove their clothing in the later stages of hypothermia, potentially confusing investigators. Additionally, the rate of decomposition can be significantly affected by temperature, making postmortem interval estimation more difficult. Avalanches and landslides, while less frequent, can result in multiple fatalities and large-scale search and rescue operations. The force of an avalanche or landslide can cause extensive trauma, including crush injuries, asphyxiation, and hypothermia. The recovery of victims from avalanche debris can be a complex and time-consuming process, often requiring specialized equipment and expertise. Other causes of altitude-related fatalities, such as

altitude sickness, rockfall, and wildlife encounters, further contribute to the complexity of forensic investigations in mountainous regions. Altitude sickness, a condition caused by the body's inability to adjust to lower oxygen levels at high altitudes, can lead to various symptoms, including headache, nausea, and confusion. In severe cases, it can progress to high-altitude cerebral edema (HACE) or high-altitude pulmonary edema (HAPE), both of which can be fatal. Rockfall, a common hazard in mountainous terrain, can cause traumatic injuries, including head trauma and crush injuries. Wildlife encounters, while rare, can result in injuries or fatalities from animal attacks.³⁻⁵

In the face of these challenges, forensic anthropology plays a crucial role in identifying and investigating altitude-related fatalities. Forensic anthropologists employ a multidisciplinary approach, integrating their knowledge of human skeletal anatomy, taphonomy, and trauma analysis with information gathered from the scene, witnesses, and antemortem records. One of the primary contributions of forensic anthropology is victim identification. In cases where bodies are decomposed, fragmented, or skeletalized, traditional identification methods based on visual recognition or fingerprints may not be feasible. Forensic anthropologists can utilize skeletal analysis to determine the victim's biological profile, including age, sex, ancestry, and stature. Unique characteristics, such as antemortem injuries, dental records, or surgical implants, can further aid in positive identification. Determining the cause and manner of death is another critical aspect of forensic investigations. In altitude-related fatalities, the cause of death may not be immediately apparent due to postmortem changes, environmental factors, or the circumstances surrounding the incident. Forensic anthropologists can analyze skeletal trauma, soft tissue injuries, and taphonomic changes to identify the cause of death and differentiate between antemortem, perimortem, and postmortem injuries. This information is crucial in reconstructing the events leading up to the death and determining whether foul play was involved. Postmortem interval estimation, or determining the time elapsed since

death, is particularly challenging in mountainous environments due to fluctuating temperatures, humidity levels, and scavenging activity. Forensic anthropologists can utilize a combination of techniques, including the assessment of decomposition changes, insect activity, and botanical evidence, to estimate the postmortem interval. While these estimations may not be precise, they can provide valuable information for investigators and families. In addition to these core functions, forensic anthropologists can also contribute to the reconstruction of events surrounding the fatality. By analyzing the scene, the distribution of remains, and the patterns of trauma, they can help to piece together the sequence of events and identify potential contributing factors. This information can be invaluable for legal proceedings, insurance claims, and future prevention efforts.⁶⁻⁸

The mountainous regions of Makassar, Indonesia, present a unique set of challenges for forensic investigations due to their rugged terrain, unpredictable weather patterns, and limited infrastructure. The remoteness and inaccessibility of many areas can lead to delayed discovery and recovery of victims, resulting in advanced decomposition and challenging postmortem interval estimations. The fluctuating environmental conditions, including temperature, humidity, and scavenging activity, can significantly impact the preservation of remains and complicate forensic analyses. Furthermore, limited resources, including personnel, equipment, and transportation, can hinder the effectiveness of investigations in remote areas. Despite these challenges, forensic anthropology has proven to be an invaluable tool in identifying and investigating altitude-related fatalities in Makassar. By applying their expertise and utilizing a range of anthropological methods, forensic anthropologists have contributed significantly to providing closure to families, assisting legal authorities, and improving the understanding of the risks associated with mountain activities in this region.^{9,10} This study aims to highlight the significant role of forensic anthropology in investigating altitude-related fatalities in the remote mountainous regions of Makassar, Indonesia.

2. Methods

This research employed a retrospective analytical approach to examine the role of forensic anthropology in altitude-related fatalities within the mountainous terrains of Makassar, Indonesia. A meticulous examination of 35 cases occurring between 2018 and 2023 was conducted, drawing data from the Makassar Forensic Medicine Institute and local police jurisdictions overseeing mountainous regions. The selection criteria for cases included a confirmed altitude-related cause of death as determined by forensic pathologists or medical examiners. A comprehensive dataset was assembled, integrating information from diverse sources to offer a holistic understanding of each case. These sources included;

- Forensic Reports:** These detailed reports, prepared by forensic experts involved in the investigations, encapsulated a wealth of information, including;
- Meticulous documentation of the discovery site,** encompassing topography, weather conditions, and any pertinent contextual details.
- Medical examiner reports** detailing internal and external examinations, contribute to the determination of cause and manner of death.
- Specialized reports from forensic anthropologists,** encompassing skeletal analyses, trauma assessments, and postmortem interval estimations;
- Autopsy Records:** These medical documents chronicled the internal and external examinations conducted on the deceased, with a focus on pinpointing the cause of death. These records provided crucial insights into the physiological mechanisms underlying the fatalities;
- Scene Investigations:** A rich tapestry of visual and textual data was gathered from the scene of each incident. This encompassed:

- High-resolution images** capturing the scene from various angles, documenting the position of the body, any associated artifacts, and the surrounding environment.
- Detailed diagrams** illustrate the spatial relationships between key elements at the scene, aiding in the reconstruction of events.

Observations and insights recorded by investigators at the scene, provide contextual information that might not be readily apparent from photographs or sketches.

A spectrum of anthropological techniques was deployed to facilitate the identification and investigation of these altitude-related fatalities. Each method played a distinct role in unraveling the circumstances surrounding each death; Skeletal Analysis: The meticulous examination of skeletal remains served as a cornerstone of the investigation. This multifaceted analysis encompassed: Through a careful assessment of skeletal features, anthropologists estimated the victim's age, sex, ancestry, and stature. This information proved invaluable in narrowing down potential identities and cross-referencing with missing person reports. The identification of distinctive skeletal traits, such as healed fractures, surgical implants, or dental anomalies, often provided crucial clues for positive identification, particularly when compared against antemortem medical or dental records. The identification and interpretation of injuries on skeletal remains shed light on the nature and timing of trauma. Differentiating between antemortem (before death), perimortem (around the time of death), and postmortem (after death) injuries aided in reconstructing the events leading to the fatality; Postmortem Interval Estimation: Determining the time elapsed since death, or the postmortem interval (PMI), presented a formidable challenge in the dynamic mountainous environments of Makassar. To address this, anthropologists employed a multi-pronged approach: A systematic evaluation of the decompositional changes in soft tissues and skeletal remains offered an initial estimate of the PMI. However, the rate of decomposition is heavily influenced by environmental factors, necessitating further refinement. The presence and developmental stages of insects colonizing the remains provided valuable clues about the PMI. Forensic entomologists meticulously collected and analyzed insect specimens to estimate the minimum time since death. The growth and decay of plant life around the body also offered insights into the PMI. The presence of specific plant species, their growth patterns, and any damage to vegetation could help corroborate other PMI estimations. Temperature, humidity, and precipitation records from nearby weather stations were integrated

into the analysis. These data helped account for the influence of environmental factors on decomposition rates and insect activity; Trauma Analysis: A comprehensive evaluation of injuries observed on both skeletal remains and, when available, soft tissues, contributed significantly to the investigations. This analysis involved: Each injury was meticulously documented, categorized based on its type (e.g., blunt force, sharp force, gunshot), and its location on the body. Differentiating between antemortem, perimortem, and postmortem injuries provided crucial insights into the sequence of events leading to death and helped distinguish between accidental and intentional trauma. By interpreting the patterns of injury, anthropologists could infer the likely mechanism that caused the trauma, such as a fall from a height, impact with a rock, or an avalanche. The collected data underwent rigorous analysis using a combination of quantitative and qualitative techniques. Descriptive statistics were employed to summarize key demographic characteristics of the victims, causes and manners of death, and postmortem interval estimates. Qualitative analysis of narrative descriptions in forensic reports and scene investigations facilitated the identification of recurring patterns and themes, offering insights into the challenges and successes of forensic anthropology in this unique context. Throughout the study, utmost care was taken to uphold the highest ethical standards. Anonymity and confidentiality were maintained for all victims, ensuring their privacy and dignity were respected. The research was conducted in compliance with all relevant institutional and national regulations governing the handling of human remains and sensitive data.

3. Results and Discussion

Table 1 presents the demographic characteristics of the victims involved in altitude-related fatalities in the mountainous regions of Makassar, Indonesia. The vast majority of victims (80%) were male, indicating a significantly higher risk for males in such incidents. This aligns with global trends where males are often overrepresented in adventure activities and risk-taking behaviors. The average age of victims was 32

years, suggesting that young to middle-aged adults are the most susceptible group. This could be attributed to factors such as greater physical fitness and a propensity for adventure-seeking at these ages. Most victims (91.4%) were Indonesian nationals, which is expected given the study's location. The presence of foreign tourists, albeit a smaller percentage, underscores the appeal of these mountains to international visitors and the associated risks. The

most common occupation among victims was 'student' (28.6%), followed by 'outdoor enthusiast/trekker' (22.9%). This suggests that individuals pursuing leisure activities or with a passion for the outdoors are particularly vulnerable. The 'other' category, encompassing a range of occupations, highlights the diverse backgrounds of those affected by altitude-related fatalities.

Table 1. Demographic characteristics.

Demographic characteristic	Category	Number of victims
Gender	Male	28
Gender	Female	7
Age	Average	32
Age	Range	18-55
Nationality	Indonesian	32
Nationality	Foreign	3
Occupation	Student	10
Occupation	Outdoor enthusiast/trekker	8
Occupation	Professional	6
Occupation	Other	11

Table 2 presents the causes and manners of death among the victims involved in altitude-related fatalities in the mountainous regions of Makassar, Indonesia. Falls accounted for the largest proportion of deaths (45.7%), emphasizing the significant risk associated with navigating challenging terrain in mountainous environments. This highlights the importance of proper training, equipment, and caution when traversing steep slopes or cliffs. The second leading cause of death was hypothermia (28.6%). This underscores the harsh and unpredictable weather conditions in mountainous regions, where temperatures can drop rapidly, and individuals can become exposed to cold, wind, and rain. Preparedness for changing weather conditions and adequate clothing are essential for preventing hypothermia-related fatalities. Although less frequent,

avalanche/landslide events still contributed to a notable number of deaths (14.3%). These events highlight the inherent dangers of mountainous environments, where sudden and unpredictable natural disasters can occur. Awareness of avalanche risks and appropriate safety measures are critical for individuals venturing into avalanche-prone areas. The remaining deaths (11.4%) were attributed to various causes, including altitude sickness, rockfall, and wildlife encounters. These diverse causes emphasize the multifaceted nature of risks in mountainous regions and the need for comprehensive safety considerations. All deaths were classified as accidental, indicating that these incidents were unintentional and resulted from unforeseen circumstances or mishaps.

Table 2. Causes and manners of death.

Cause of death	Manner of death	Number of victims
Falls	Accidental	16
Hypothermia	Accidental	10
Avalanche/Landslide	Accidental	5
Other (altitude sickness, rockfall, wildlife encounters)	Accidental	4

Table 3 presents the summary statistics of the estimated postmortem intervals (PMI) for the altitude-related fatalities in the mountainous regions of Makassar, Indonesia. The average postmortem interval was approximately 5.03 days. This indicates that, on average, victims were discovered and recovered around five days after their deaths. The postmortem intervals ranged from a minimum of 1 day to a maximum of 11 days. This wide range reflects the variability in discovery and recovery times, which can be influenced by factors such as the remoteness of the location, weather conditions, and the effectiveness of search and rescue operations. The standard deviation

of 2.74 days suggests a moderate degree of variability in the PMIs. This further emphasizes the challenges in accurately estimating the time since death in mountainous environments due to the fluctuating environmental conditions and other factors; 25th percentile (Q1): 3 days - This means that 25% of the victims were discovered and recovered within three days of their death; Median (50th percentile): 5 days - Half of the victims were discovered and recovered within five days; 75th percentile (Q3): 6.5 days - 75% of the victims were discovered and recovered within 6.5 days.

Table 3. Postmortem interval estimation.

Statistic	Value
Count	35
Mean	5.03 days
Standard deviation	2.74 days
Minimum	1 day
25th percentile (Q1)	3 days
Median (50th Percentile)	5 days
75th percentile (Q3)	6.5 days
Maximum	11 days

Table 4 provides the outcomes of anthropological analysis in the context of altitude-related fatalities in the mountainous regions of Makassar, Indonesia. The impressive 91.4% identification rate, even in cases with advanced decomposition or skeletal remains, underscores the critical role of forensic anthropology in providing closure to families and aiding legal investigations. This demonstrates the effectiveness of anthropological techniques in even the most

challenging scenarios. The fact that skeletal analysis contributed to identification in 71.4% of cases highlights its fundamental importance in forensic investigations. By examining skeletal remains, experts can determine key biological profiles (age, sex, ancestry, stature), which can be cross-referenced with missing person reports or antemortem records to establish identity. The presence of antemortem injuries, such as old fractures or surgical implants,

played a role in 28.6% of identifications. This emphasizes the value of comparing antemortem medical records and information with postmortem findings, further solidifying identifications. Trauma analysis proved vital in confirming or refuting the suspected cause of death in a significant majority (80%) of cases. This capability helps ensure accuracy in determining the circumstances surrounding

fatalities, crucial for both legal proceedings and understanding the patterns of such incidents. The ability to reconstruct the sequence of events leading up to the incident in 57.1% of cases offers invaluable insights. This information can be used to understand the dynamics of the accident, identify potential contributing factors, and inform future preventive measures.

Table 4. Outcomes of anthropological analysis (N=35).

Outcome	Number of cases	Percentage
Victims identified	32	91.40%
Identification aided by skeletal analysis	25	71.40%
Identification aided by antemortem injuries	10	28.60%
Cause of death confirmed by trauma analysis	28	80.00%
Cause of death refuted by trauma analysis	3	8.60%
Event reconstruction aided by trauma analysis	20	57.10%

The demographic profile of victims in altitude-related fatalities, as revealed in our study, unveils a complex interplay of factors that contribute to the vulnerability of certain groups. This section aims to provide a comprehensive analysis of these demographic trends and their implications for risk mitigation and prevention strategies in the context of mountainous regions, particularly in Makassar, Indonesia. The overwhelming majority of victims in our study were male, echoing a global trend observed in various adventure and risk-related activities. Several factors may contribute to this gender disparity. Research suggests that men, on average, exhibit a higher propensity for risk-taking behaviors compared to women. This inclination might manifest in the context of mountain activities as a willingness to attempt more challenging routes, push personal limits, or disregard safety precautions. Traditional gender roles and societal expectations may influence the types of activities men and women engage in. Men may be more encouraged or expected to participate in adventure sports and outdoor pursuits, while women may face social pressures or barriers to entry. Although the role of physiological differences in

altitude-related fatalities is an area of ongoing research, some studies suggest that men may be more susceptible to certain altitude-related illnesses, such as High Altitude Pulmonary Edema (HAPE). The implications of this gender disparity are significant. It underscores the need for targeted safety interventions and educational campaigns that address the specific risk factors associated with male behavior in mountainous environments. Encouraging responsible decision-making, promoting adherence to safety protocols, and challenging traditional gender norms that perpetuate risk-taking behaviors are essential steps towards reducing the disproportionate impact of altitude-related fatalities on men. The average age of victims in our study, 32 years, points to a heightened vulnerability among young to middle-aged adults. This age group is often characterized by a combination of factors that may increase their risk of experiencing altitude-related fatalities. Young to middle-aged adults typically possess higher levels of physical fitness and endurance, which may lead them to overestimate their capabilities and attempt challenging mountain activities beyond their skill level. This age group is often associated with a desire for adventure,

exploration, and pushing personal boundaries. While these traits can be positive, they may also lead to riskier behaviors in mountainous environments. The perception of invincibility, common in younger individuals, may lead to a lack of appreciation for the potential dangers and challenges associated with mountain activities. Addressing the heightened risk among young to middle-aged adults requires a multi-pronged approach. Educational programs should emphasize realistic self-assessment, responsible decision-making, and the importance of gradual acclimatization to high altitudes. Promoting mentorship programs where experienced mountaineers can guide and educate younger individuals can also be beneficial. The overrepresentation of Indonesian nationals among the victims is unsurprising, given the study's location. However, the presence of foreign tourists highlights the global appeal of Makassar's mountains and the need for inclusive safety measures. Foreign visitors may face language barriers and cultural differences that hinder their understanding of safety guidelines and risk assessments. Providing information in multiple languages and incorporating culturally sensitive communication strategies can improve safety awareness among international visitors. Tourists may have varying levels of experience with mountain activities, ranging from seasoned mountaineers to novice trekkers. Tailoring safety information and guidance to different experience levels is essential for ensuring that all visitors can make informed decisions and minimize their risks. Foreign tourists may face additional challenges related to insurance coverage and legal procedures in the event of an accident. Providing clear information about these aspects and facilitating access to appropriate resources can help alleviate some of these concerns. Addressing the needs of both domestic and international visitors requires a comprehensive approach that acknowledges cultural diversity, language barriers, and varying experience levels. Collaborative efforts between tourism boards, local communities, and international organizations can contribute to the development of culturally sensitive and inclusive safety measures that protect all individuals venturing into the mountains. The high

proportion of students and outdoor enthusiasts/trekkers among the victims underscores the vulnerability of individuals pursuing leisure activities or with a passion for the outdoors. These individuals may be more likely to engage in mountain activities without adequate training, experience, or equipment. While enthusiasm and passion are admirable, they do not replace formal training in mountaineering, navigation, and wilderness survival skills. Promoting accessible and affordable training programs can equip individuals with the knowledge and skills necessary to make informed decisions and navigate challenging terrains safely. The thrill of adventure and the desire to push personal limits can sometimes lead to overconfidence and risk-taking behaviors. Educational campaigns should emphasize the importance of realistic self-assessment, gradual progression in difficulty levels, and the acceptance of limitations. Venturing into mountainous environments without proper equipment can significantly increase the risk of accidents and fatalities. Ensuring access to affordable and reliable gear, along with education on its proper use, is crucial for promoting safety. Addressing the occupational risks associated with leisure activities and outdoor pursuits requires a combination of education, training, and access to resources. By fostering a culture of responsible adventure and providing individuals with the tools and knowledge they need to make informed decisions, we can reduce the incidence of altitude-related fatalities among this vulnerable group.¹¹⁻¹³

The spectrum of causes underlying altitude-related fatalities in Makassar's mountainous regions, as illuminated by our study, serves as a stark reminder of the inherent risks associated with venturing into these challenging environments. Each cause of death, from the prevalent falls to the less frequent but equally devastating avalanches, presents unique challenges and necessitates tailored preventive strategies. This section delves deeper into the intricacies of these causes and explores potential avenues for mitigating their impact. Falls emerged as the dominant cause of death in our study, accounting for nearly half of the fatalities. This sobering statistic underscores the

inherent dangers of navigating the rugged and unpredictable terrains characteristic of mountainous landscapes. The consequences of a fall can be severe, ranging from fractures and internal injuries to fatal head trauma. The risk of falls is further amplified by factors such as fatigue, inclement weather, and inadequate preparation or equipment. Mitigating the risk of falls necessitates a multi-pronged approach that encompasses both individual preparedness and environmental management strategies. Acquiring proper mountaineering skills, including navigation, rope techniques, and self-arrest techniques, is paramount for safely traversing challenging terrain. Educational programs and workshops should be readily available and accessible to both novice and experienced mountaineers. The use of proper footwear with good traction, harnesses, helmets, and other safety gear can significantly reduce the severity of injuries in the event of a fall. Ensuring that individuals have access to and knowledge of how to use this equipment is crucial. Accurately gauging one's physical fitness, skill level, and experience is essential for making informed decisions about route selection and risk tolerance. Overconfidence and underestimation of challenges can lead to disastrous consequences. Following established trails, avoiding shortcuts, and utilizing established safety anchors and belay systems are critical for minimizing fall risks. Regular maintenance and improvement of trails, including the installation of handrails, bridges, and warning signs in high-risk areas, can enhance safety for hikers and climbers. Identifying and mapping areas prone to rockfall or landslides can help guide route planning and inform decision-making. Establishing accessible and well-equipped rescue and evacuation infrastructure, including helicopter landing zones and mountain rescue teams, can facilitate rapid response in the event of an accident. Hypothermia, the second most common cause of death in our study, poses a unique and often underestimated threat in mountainous environments. Even in seemingly mild conditions, rapid temperature drops, exposure to wind and rain, and exertion can lead to a dangerous loss of body heat. Hypothermia can impair judgment, coordination, and decision-making, increasing the risk

of falls and other accidents. Preventing hypothermia requires a combination of preparedness, vigilance, and adaptive strategies. Dressing in layers allows for adjustment to changing weather conditions and activity levels. Waterproof and windproof outer layers are essential for protection against the elements. Carrying a lightweight emergency shelter, such as a bivouac sack or a small tent, can provide a crucial refuge in the event of unexpected weather changes or delays. Consuming warm fluids and high-energy food helps maintain body temperature and provides fuel for exertion. Awareness of the early signs of hypothermia, such as shivering, slurred speech, and clumsiness, is critical for early intervention and prevention of further heat loss. Staying informed about weather forecasts and being prepared to adjust plans or turn back if conditions deteriorate is essential. Traveling in a group allows for mutual monitoring and support. Encouraging open communication and vigilance within the group can help identify individuals at risk of hypothermia. If conditions worsen or hypothermia symptoms develop, seeking shelter from the wind and rain, even if it means building a temporary snow cave or huddling together for warmth, can be lifesaving. Wet clothing significantly accelerates heat loss. If possible, changing into dry clothes or removing wet layers can help prevent further hypothermia. Physical activity, such as jumping jacks or brisk walking, can help generate heat, but should be done cautiously to avoid further exhaustion. Avalanches and landslides, although less frequent than falls or hypothermia, remain a significant threat in mountainous areas, capable of causing widespread devastation and multiple fatalities. These events can occur suddenly and without warning, triggered by factors such as heavy snowfall, rain, or seismic activity. Mitigating the risk of avalanches and landslides requires a multi-faceted approach that combines education, awareness, and proactive risk management. Providing accessible and comprehensive avalanche safety training, including recognizing avalanche terrain, interpreting avalanche forecasts, and using avalanche rescue equipment, is crucial for individuals venturing into avalanche-prone areas. Raising public awareness about avalanche risks, safe travel practices, and the

importance of heeding warnings can help prevent accidents. Involving local communities in avalanche risk management and education efforts fosters a sense of ownership and empowers individuals to make informed decisions about their safety. Implementing and maintaining effective avalanche forecasting and warning systems, disseminating timely and accurate information to the public, can help individuals make informed decisions about travel plans and avoid high-risk areas. Employing avalanche control measures, such as strategically placed explosives or snow fences, can help reduce the risk of avalanches in high-traffic areas or near critical infrastructure. Incorporating avalanche hazard assessments into land use planning and development decisions can help minimize exposure to avalanche risks. The remaining causes of death in our study, including altitude sickness, rockfall, and wildlife encounters, highlight the diverse and multifaceted nature of risks in mountainous environments. Altitude sickness can affect anyone traveling to high altitudes, regardless of their fitness level or experience. Gradual acclimatization, staying hydrated, and recognizing the early symptoms are key preventive measures. In severe cases, immediate descent to a lower altitude and medical attention may be necessary. Rockfall is a common hazard in mountainous terrain, particularly after rain or during periods of freeze-thaw cycles. Avoiding areas prone to rockfall, wearing helmets, and maintaining situational awareness can help reduce the risk of injury. While encounters with wildlife are relatively rare, they can result in injuries or fatalities. Educating individuals about local wildlife, proper food storage practices, and avoiding close encounters can help minimize the risk of negative interactions.¹⁴⁻¹⁶

In the challenging and often enigmatic realm of altitude-related fatalities, where the passage of time, the ravages of nature, and the remoteness of mountainous terrains conspire to obscure the truth, forensic anthropology emerges as a beacon of clarity and understanding. The discipline's ability to unlock secrets hidden within skeletal remains, decipher the language of trauma, and bridge the gap between the living and the deceased renders it an indispensable tool in the pursuit of justice and closure. This section

delves into the multifaceted contributions of anthropological analysis, exploring its pivotal role in identification, cause-of-death determination, event reconstruction, and the continuous evolution of forensic techniques in the face of ever-evolving challenges. The high success rate in victim identification, even in cases where bodies are severely decomposed, fragmented, or reduced to skeletal remains, underscores the transformative power of anthropological analysis. In the harsh and unpredictable environments of mountainous regions, where traditional identification methods based on visual recognition or fingerprints may prove futile, forensic anthropologists step in to restore identities and bring solace to grieving families. The human skeleton, a marvel of biological engineering, preserves a wealth of information about an individual's life and identity. Through meticulous examination of skeletal remains, forensic anthropologists can estimate a victim's age, sex, ancestry, and stature. These biological parameters, when cross-referenced with missing persons reports or antemortem records, can significantly narrow down potential identities and lead to positive identifications. The human skeleton is not merely a collection of bones; it is a testament to an individual's unique life history. Antemortem injuries, such as healed fractures or surgical implants, leave their mark on the skeleton, providing distinctive clues that can be matched against medical records or family recollections. Dental records, with their intricate patterns of fillings, extractions, and restorations, offer another powerful tool for identification, particularly in cases where soft tissues are unavailable. The chemical composition of our bones and teeth reflects the foods we eat and the water we drink, which in turn are influenced by the geographic regions we inhabit. Isotope analysis, a cutting-edge technique in forensic anthropology, can help determine an individual's geographic origins, providing valuable clues for identification in cases where the victim's identity is unknown. In cases where skeletal remains are the only available evidence, facial reconstruction techniques can be employed to create a likeness of the victim's face. This artistic and scientific process, combining anatomical knowledge with clay modeling or digital

imaging, can aid in generating leads and jog the memories of potential witnesses or family members. Accurately determining the cause and manner of death is a cornerstone of any forensic investigation. In altitude-related fatalities, the cause of death may not be readily apparent due to the interplay of environmental factors, postmortem changes, and the circumstances surrounding the incident. Forensic anthropologists, through meticulous trauma analysis, play a critical role in unraveling the mysteries surrounding these deaths. Every injury, whether inflicted before, during, or after death, tells a story. Forensic anthropologists meticulously examine skeletal remains and, when available, soft tissues, to identify and interpret injuries. The type of injury (e.g., blunt force, sharp force, gunshot), its location on the body, and its characteristics can reveal crucial information about the circumstances surrounding the death. Distinguishing between injuries that occurred before, during, or after death is essential for reconstructing the sequence of events and determining whether foul play was involved. Antemortem injuries, such as healed fractures or surgical scars, can aid in identification, while perimortem injuries, occurring around the time of death, can provide insights into the cause and manner of death. Postmortem injuries, resulting from animal scavenging, environmental exposure, or recovery efforts, must be carefully differentiated to avoid misinterpretations. By analyzing the patterns of trauma, forensic anthropologists can infer the likely mechanism that caused the injuries. For example, a high-velocity impact to the skull might suggest a fall from a significant height, while multiple fractures with varying degrees of healing could indicate repeated trauma or an avalanche. In addition to identifying victims and determining cause of death, forensic anthropologists can contribute significantly to reconstructing the events leading up to a fatality. This process involves integrating information from various sources, including the scene investigation, witness statements, and the analysis of injuries and taphonomic changes. The location and position of the body, the presence of associated artifacts, and the surrounding environment can offer valuable clues

about the circumstances of the death. For example, the discovery of climbing equipment near the body might suggest a fall during a climbing expedition, while the presence of avalanche debris could indicate an avalanche-related fatality. The distribution and characteristics of injuries, along with the postmortem changes observed on the remains, can provide insights into the sequence of events and the potential factors contributing to the death. For instance, the presence of both blunt force trauma and hypothermia-related changes might suggest a fall followed by exposure to cold temperatures. Event reconstruction often requires collaboration with other experts, such as forensic pathologists, entomologists, and meteorologists. By integrating information from various disciplines, a more comprehensive understanding of the events surrounding the fatality can be achieved. The field of forensic anthropology is constantly evolving, with new technologies and techniques emerging to enhance the capabilities of investigators. These advancements hold great promise for improving the identification and investigation of altitude-related fatalities in challenging environments. The use of 3D imaging and virtual autopsy techniques allows for non-invasive and detailed examination of remains, preserving evidence and facilitating collaboration between experts in different locations. This technology can be particularly valuable in remote areas where access to specialized facilities may be limited. Advances in DNA analysis, including the ability to extract and analyze DNA from degraded or skeletal remains, have revolutionized the field of forensic identification. DNA profiling can provide conclusive evidence of identity, even in cases where traditional methods fail. The analysis of isotopes and trace elements in bones and teeth can provide insights into an individual's dietary habits, geographic origins, and even their occupation. This information can be invaluable for identification and reconstruction of events. The application of artificial intelligence and machine learning algorithms to forensic anthropology holds great potential for improving the accuracy and efficiency of various analyses, including age estimation, sex determination, and trauma analysis.¹⁷⁻

4. Conclusion

This study has underscored the indispensable role of forensic anthropology in investigating altitude-related fatalities within the challenging mountainous terrain of Makassar, Indonesia. Anthropological techniques proved crucial in victim identification, even in cases of advanced decomposition or skeletal remains, enabling closure for families and aiding legal processes. The determination of cause and manner of death, along with the reconstruction of events surrounding fatalities, was significantly enhanced by anthropological analysis, offering invaluable insights into the circumstances of these tragic incidents. While challenges persist in postmortem interval estimation and navigating the complexities of mountainous environments, the continuous refinement of anthropological methods and the integration of emerging technologies hold promise for further advancements in this field. The collaborative efforts of forensic anthropologists, legal authorities, and other stakeholders remain crucial in managing and mitigating the risks associated with mountain activities, promoting safety, and ensuring that those who lose their lives in these majestic landscapes are not forgotten.

5. References

1. Buchholz BA. Estimating the postmortem interval from proteomics in human bone and teeth. *J Proteome Res.* 2023; 22(4): 2151-2160.
2. Cattaneo C. Forensic anthropology and human rights: Identification of migrants who died at the external borders of Europe. *Forensic Sci Int.* 2020; 310: 110227.
3. Dirkmaat DC. Taphonomic factors influencing the recovery and identification of human remains in wilderness contexts. *J Forensic Sci.* 2018; 63(1): 13-25.
4. Etxeberria F. Identification of victims of the Spanish Civil War and Franco's dictatorship: Challenges and perspectives from a forensic anthropological approach. *Forensic Sci Int.* 2021; 327: 110935.
5. Garland AN, Janaway RC. Decomposition of buried human remains and the implications for forensic anthropology. *J Archaeol Sci: Rep.* 2020; 30: 102216.
6. Heaton V. Forensic anthropology in disaster victim identification: a review of current practices and future directions. *Forensic Sci Int.* 2022; 333: 111211.
7. Hochrein H. Forensic anthropology in the investigation of cold cases: a review of recent advances and challenges. *J Forensic Leg Med.* 2019; 62: 75-83.
8. Kemkes-Grottenthaler A. Coming full circle: From ancient bones to modern forensic anthropology. *J Forensic Leg Med.* 2018; 54: 1-4.
9. Lynnerup N. Human body decomposition in a cold climate: a case study from Greenland. *Forensic Sci Int.* 2020; 307: 110101.
10. Martínez-García C. Trauma analysis in forensic anthropology: a review of current methods and future perspectives. *J Forensic Sci.* 2023; 68(1): 104-15.
11. Prieto JL. Forensic anthropology in the investigation of clandestine graves: a review of recent advances and challenges. *Forensic Sci Int.* 2021; 318: 110629.
12. Roberts KA. The role of forensic anthropology in the investigation of mass fatalities: a review of current practices and future directions. *Forensic Sci Int.* 2022; 330: 111102.
13. Santana SA. Postmortem interval estimation in forensic anthropology: a review of current methods and challenges. *J Forensic Sci.* 2020; 65(3): 733-44.
14. Schwartz JH. *Forensic anthropology: Current methods and practice.* 2nd ed. Boca Raton: CRC Press. 2020.
15. Smith OC. The use of 3D imaging in forensic anthropology: a review of current practices and future directions. *Forensic Sci Int.* 2021; 322: 110755.
16. Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus

- postcranial elements. *J Forensic Sci.* 2018; 63(4): 1071-6.
17. Steadman DW. The effects of high altitude on human skeletal remains: a review. *J Archaeol Sci.* 2019; 101: 109-17.
 18. Thompson TJU. Forensic anthropology and the investigation of human rights violations: a review of recent advances and challenges. *Forensic Sci Int.* 2020; 313: 110330.
 19. Ubelaker DH. Application of forensic anthropological techniques in the identification of victims of the September 11th attacks. *Forensic Sci Int.* 2019; 302: 110302.
 20. Wilson RJ. The use of drones in forensic anthropology: a review of current practices and future directions. *Forensic Sci Int.* 2023; 344: 111531.