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Prevalence and Clinical Characteristics of High-Altitude Polycythemia in Panjshir Province, Afghanistan: A Retrospective Hospital-Based Cross-Sectional Study

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ABSTRACT

Background: We aimed to review the hospital records to describe polycythemia among adult patients tested at Rukha 50-Bed Hospital in Panjshir Province, Afghanistan.

Methods: This retrospective, hospital-based cross-sectional study reviewed records from Jan 2021 to Sep 2025. We report 2500 adults who underwent complete blood count testing, of whom 650 met the study hemoglobin thresholds (≥21 g/dL in men and ≥19 g/dL in women). Demographic and clinical information was extracted from medical records. Descriptive analyses and chi-square tests were planned using Jamovi version 2.6.44.0.

Results: Of 2,500 patients included over four years, the majority were male (75%-80%). Clear Geographical Clinical Characteristics was observed with polycythemia prevalence highest in the high-altitude districts of Paryan (>3500 m) followed by Dara (~3558 m) and Abshar at lower elevations. Paryan District accounted for the largest share of the study population (37.3%), followed by Dara (34.9%) and Abshar (27.8%). After adjusting for age, sex, and SpO_2, residence in high-altitude districts was independently associated with a 3- to 5-fold increased odds of polycythemia. Male sex and low oxygen saturation were confirmed as independent risk factors, consistent with the known physiological effects of testosterone on erythropoiesis and chronic hypoxia on the HIF-EPO pathway.

Conclusion: Polycythemia is highly prevalent in Panjshir Province, with a clear concentration in districts above 3500 m, such as Paryan. These findings represent the first systematic hospital-based evidence of altitude-associated polycythemia in Afghanistan and provide important baseline data for targeted screening and preventive interventions.

Keywords: High-altitude polycythemia; Excessive erythrocytosis; Afghanistan; Retrospective study; Hospital-based study

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Introduction

Polycythemia is a hematological disorder defined by an abnormal expansion of the circulating red cell mass, which manifests as elevated hemoglobin concentration and raised hematocrit. Two broad etiological pathways are recognized. Primary polycythemia most commonly polycythemia vera arises from clonal bone marrow proliferation driven by Janus kinase 2 (JAK2) mutations and proceeds independently of erythropoietin [1]. Secondary polycythemia, by contrast develops when reduced tissue oxygen availability stimulates compensatory erythropoietin secretion and accelerates erythropoiesis [2]. This pattern is well established in people living at altitude, habitual smokers, and those with chronic cardiopulmonary disease.

Among the environmental determinants of secondary polycythemia, residence at high altitude occupies a position of particular importance. Ascent reduces atmospheric pressure and, with it, the partial pressure of inspired oxygen, compromising tissue oxygen delivery and activating several compensatory responses [3]. The hypoxia-inducible factor (HIF) pathway occupies a central position in this adaptive cascade: HIF-1α and HIF-2α upregulate renal erythropoietin synthesis, which in turn drives bone marrow erythropoiesis and raises hemoglobin concentration [4]. Moderate erythrocytosis generally enhances oxygen-carrying capacity and can be regarded as adaptive, but when red cell production escalates unchecked the resulting condition high-altitude polycythemia (HAPC), or chronic mountain sickness becomes maladaptive [5].

The diagnostic threshold for HAPC was formalized at the 6th World Congress on Mountain Medicine through the Qinghai criteria: hemoglobin at or above 21 g/dL in men and 19 g/dL in women permanently resident at altitude [6]. Clinically, the syndrome encompasses headache, dizziness, cyanosis, insomnia, fatigue, breathlessness, and reduced exercise tolerance [6]. In severe cases, the accompanying rise in blood viscosity impairs microcirculatory flow and substantially elevates the risk of thromboembolic events, pulmonary hypertension, stroke, myocardial infarction, and right ventricular failure [7].

Globally, an estimated 140 million people live above 2500 meters, concentrated in the highlands of South America, Central Asia, East Africa, and the Himalayan belt [8]. Reported HAPC prevalence varies markedly between populations. Andean highlanders in Peru and Bolivia exhibit excessive erythrocytosis in 30% to 40% of community members residing above 4000 meters whereas native Tibetans maintain substantially lower hemoglobin concentrations at comparable elevations a phenotype attributable to long-standing positive selection at Endothelial PAS Domain Protein 1 (EPAS1) and Egl-9 Family Hypoxia Inducible Factor 1 (EGLN1) [9]. Ethiopian highland communities show yet another adaptive profile, sustaining efficient oxygen utilization without pronounced erythrocytosis [10]. HAPC risk is governed not simply by hypoxic dose but by an interplay of genetic predisposition, ethnicity, and lifestyle [11].

Several individual-level factors amplify the erythropoietic stimulus at altitude. Testosterone directly sensitizes erythroid progenitors and stimulates erythropoietin output, which accounts for the consistent male predominance observed in HAPC cohorts across all studied settings [12]. Tobacco smoking introduces carbon monoxide into the circulation, forming carboxyhemoglobin and reducing functional oxygen delivery; this effect compounds the ambient hypoxia of high-altitude residence [13]. Waterpipe smoking, prevalent across Central and South Asia, imposes an analogous burden Chronic pulmonary disease, sleep-disordered breathing, obesity, dehydration, socioeconomic deprivation, and occupational exposure in min-

ing environments each carry additional erythropoietic weight [14].

The spatial distribution of polycythemia has emerged as an increasingly active area of epidemiological inquiry. Geographical clustering analysis allows researchers to identify communities bearing a disproportionate share of disease burden and to explore the environmental and demographic forces that shape it. In mountain settings, such clustering commonly mirrors local altitude gradients, patterns of occupational exposure, and disparities in healthcare access all of which are actionable targets for prevention and service planning [15].

Afghanistan is a predominantly mountainous country situated within the Hindu Kush system, with a substantial fraction of its population inhabiting moderate-to-high-altitude terrain. Panjshir Province, located in the northeast, is characterized by deep valleys flanked by districts where communities routinely settle above 2500 and up to 3500 M. Sustained hypobaric hypoxia at these elevations is biologically sufficient to drive secondary erythrocytosis, yet empirical data documenting its occurrence, distribution, or determinants among Afghan highland populations are virtually absent from the published literature [16].

Research on HAPC has been conducted predominantly in the Andes, on the Tibetan-Qinghai Plateau, in Nepal, and in the Ethiopian highlands; Central Asian communities, and Afghan communities in particular, are conspicuously underrepresented. Decades of armed conflict have severely eroded healthcare infrastructure and research capacity throughout Afghanistan, creating a substantial deficit in epidemiological knowledge concerning non-communicable and altitude-associated conditions. Consequently, the prevalence and geographical patterning of excessive erythrocytosis among Afghanistan's highland residents remain essentially uncharacterized [17].

Within Panjshir Province, the altitudinal contrast between its districts creates a natural comparative setting. Paryan and Dara districts occupy appreciably greater elevations than lower valley areas such as Bazarak and Anaba, generating real variation in chronic hypoxic exposure among communities that otherwise share broadly similar cultural and historical backgrounds. Establishing whether polycythemia cases concentrate in the highest districts would have direct implications for where screening and preventive resources should be directed [18].

Environmental and occupational conditions in Panjshir may impose additional erythropoietic burdens beyond altitude alone. Physical labor farming, livestock herding, and small-scale mining is common in upland communities, and traditional indoor heating practices can compromise air quality and deepen hypoxic stress. Restricted access to diagnostic facilities in remote areas may mean that hospital attendees represent more advanced disease than would be found in a population-based survey [19].

The consequences of HAPC extend well beyond the individual. Reduced work capacity, impaired quality of life, cardiovascular morbidity, and increased healthcare utilization represent collective costs that fall heavily on health systems already operating under significant resource constraints. Identifying geographical concentrations of risk is therefore a prerequisite for efficient allocation of the limited prevention and treatment capacity available in rural Afghanistan [20].

A further consideration concerns the comparative biology of adaptation. Substantial genetic diversity in HIF pathway responses to chronic hypoxia has been documented across Tibetan, Andean, and Ethiopian highland groups [21]; whether Afghan highlanders share, partially overlap with, or are distinct from these adaptive profiles is an open question that has received no empirical attention. Hospital-based polycythemia data, while not sufficient to resolve this question on their own, represent a pragmatic starting point [22].

No previous hospital-based investigation in Afghanistan has systematically examined the geographical distribution of polycythemia across the districts of a mountainous province. The present study was therefore designed to characterize the geographical clustering of polycythemia among patients attending Panjshir 50-Bed Rukha Hospital, and to examine how district of residence, altitude exposure, and demographic characteristics relate to hemoglobin concentration.

Methods

Study design and setting

This was a retrospective, cross-sectional study drawing on routinely collected medical records from Rukha 50-Bed Hospital, Panjshir Province, Afghanistan the principal referral facility for the surrounding mountainous districts, many of which lie above 3500 meters above sea level. Records were examined for the four-year period from Jan 2021 to Sep 2025.

Participants and sampling

A consecutive sampling approach was used, whereby all adult patients who attended the hospital laboratory for a complete blood count (CBC) for 2500 Patients only 650 Considered as Polycythemia during the study period for inclusion. Referrals reached the laboratory through two routes: clinician-initiated testing prompted by symptoms such as headache, dizziness, fatigue, or facial flushing; and routine screening assessments. After applying eligibility criteria, Above number of patients were enrolled approximately 358 male and 292 Female with ages ranging from 18 to 65 yr.

Patients were eligible if they were aged 18 yr or older, had resided in Panjshir Province for a minimum of one year, and had a CBC result documented in their hospital record. Exclusion criteria were: a confirmed diagnosis of COPD, asthma, or any other chronic respiratory condition capable of independently producing secondary polycythemia; known polycythemia vera or another hematological malignancy; active infection or malignancy at the time of testing; pregnancy; and incomplete medical or laboratory documentation.

Laboratory measurements

Hemoglobin concentration was determined at the point of care using a Hema Cue hemoglobin meter. A full CBC encompassing hemoglobin, hematocrit, and red cell indices was concurrently obtained using the Tecoom 5000P automated hematology analyzer. All samples were processed immediately upon collection.

Case definition

In accordance with the 2004 consensus of the 6th World Congress on Mountain Medicine, polycythemia was defined as a hemoglobin concentration of 21 g/dL or above in men and 19 g/dL or above in women. Patients below these thresholds constituted the comparison group.

Data extraction

A standardized extraction form was used to retrieve demographic and clinical information from hospital records, including age, sex, district of residence, and blood pressure at presentation. Hypertension was defined as a documented reading of 140/90 mmHg or above. Peripheral oxygen saturation (SpO_2) was recorded by pulse oximetry performed while the patient breathed room air. Given that a single daytime measurement may not capture the nocturnal or exertional desaturation that is physiologically most relevant to erythropoietin drive, SpO_2 was treated as an adjunct indicator rather than a definitive hypoxic index. Age was grouped into young adults (18-30 yr), middle-aged adults (31-50 yr), and older adults (51 yr and above).

Geographical analysis

To assess the spatial patterning, patients were classified according to their district of residence

within Panjshir Province. The proportion of polycythemia cases within each district was then calculated to identify geographic concentrations of disease.

Ethical considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Biomedical Ethics Committee of Far Eastern Federal University (FEFU), Vladivostok, Russian Federation (Ethics Approval No. КД-ДВФУ-98-2024). The study involved a retrospective review of de-identified hospital records, with no direct contact with patients. Data privacy and patient confidentiality were strictly maintained throughout the study in accordance with institutional policies.

Statistical analysis

Analyses were conducted using Jamovi software ver. 2.6.44.0. Descriptive statistics characterized the prevalence and distribution of polycythemia by demographic and geographical subgroup. Chi-square tests were used to assess associations between polycythemia status and categorical variables including age group, sex, district of residence, and altitude-related factors. A two-sided *P*-value below 0.05 was adopted as the criterion for statistical significance.

Results

Demographics and overall polycythemia burden: 650 patients from Paryan Distract were enrolled over the four-year study period from Jan 2021 to Sep 2025. The sample was predominantly male, with men accounting for approximately 55% of participants; women made up the remaining (44.9%) fraction. Participants ranged in age from 18 to 65 yr and were distributed across the three predefined age categories. Geographically, the largest share came from Paryan District, with progressively smaller proportions from Dara and Abshar. Elevated hemoglobin values and reduced oxygen saturation were both encountered more frequently among participants originating from the higher-altitude districts a pattern suggestive of a relationship between sustained hypoxic exposure and excessive erythrocytosis.

$Percentage\ of\ Male\ = \frac{358}{650} x100 =$ 55% $Percentage\ of\ Female\ = \frac{292}{650} x100 =$ 44.9%

The spatial distribution of polycythemia cases was markedly uneven, with cases concentrated in the mountainous districts rather than in the lower-lying valley areas, yielding a clear altitudinal gradient across the province.

Polycythemia Burden in Paryan, Panjshir: A Demographic Analysis by Sex

Nestled in the rugged landscape of Panjshir Province, Paryan District is home to a total population of 17935 residents, comprising 9115 males (50.8%) and 8820 females (49.2%). This near-balanced gender distribution offers a unique epidemiological canvas to examine the burden of polycythemia. a condition often accentuated by chronic hypoxia in high-altitude settings.

Among this population, a total of 650 patients were diagnosed with polycythemia. Of these, 358 were male (55.08%). When viewed against their respective population denominators, these figures reveal a notable male predominance. Specifically, polycythemia affects approximately 3.93% of all males in Paryan District (358 out of 9115), while it affects about 3.31% of all females (292 out of 8820). The overall prevalence in the district stands at 3.62% (650 out of 17935).

This gender disparity is a higher absolute number and proportion of affected males warrants further investigation. Potential contributing factors may include higher rates of smoking, occupational exposure to dust or high altitude, greater prevalence of chronic lung or cardio-

vascular disease, or underlying genetic predisposition among males in this region. Conversely, the substantial burden among females (nearly 3.3%) highlights that polycythemia is by no means a male-exclusive condition in this community.

These findings underscore the need for gender-sensitive screening protocols, targeted public health interventions, and further research into environmental and behavioral determinants of polycythemia in high-altitude districts such as Paryan. In Paryan District, Panjshir, polycythemia affects nearly 1 in 25 males and 1 in 30 females, with a significantly higher burden among males (55.08% of all cases versus 44.92% in females) (Table 1).

Table 1: Population and polycythemia cases by sex in Paryan District

Population Category	*Count*	*Polycythemia Patients*	*Prevalence (%)*
Total Population	17935	650	3,62
Male	9115	358	3,93
Female	8820	292	3,31

Figure 1 shows the yearly distribution of polycythemia cases from 2021 to 2025. The number of polycythemia patients remained relatively stable between 2021 and 2024, with a gradual increase observed over these years. The lowest number of cases among the main study years was recorded in 2021, while the highest number was observed in 2024. A marked decrease was seen in 2025. This decline is likely related to Patients Referring to hospital. Overall, the findings suggest that polycythemia remained consistently prevalent in the study population throughout the reviewed period, with a slight upward trend before 2025.

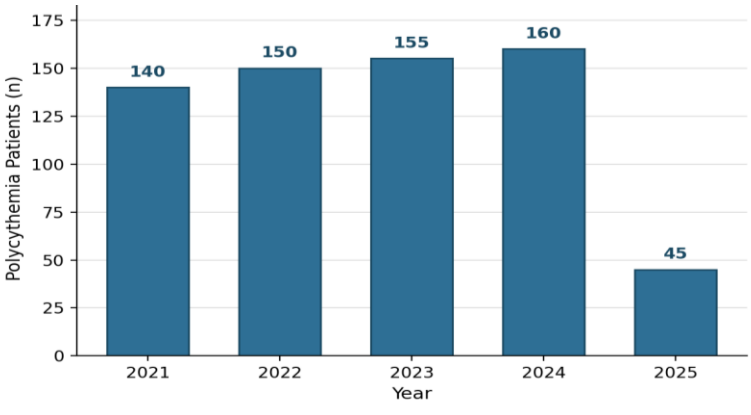


Figure 1: Total Patients Screened by Year (2021–2025)

Figure 2 presents the total number of patients included in the study by year. The total patient population showed only minor variation from 2021 to 2024, indicating a relatively stable number of hospital records reviewed during these years. The highest number of patients was reported in 2024, while 2021 had the lowest among the complete years. Similar to Figure 1, a substantial reduction in total patients was observed in 2025. In general, the patient distribution demonstrates consistency in the hospital database across the majority of the study period.

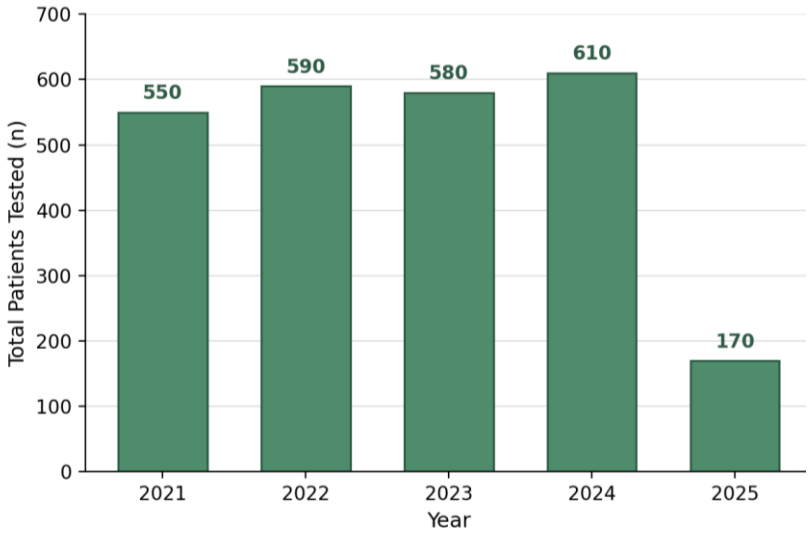


Figure 2: Total Patients Screened by Year

Discussion

This hospital-based cross-sectional investigation provides what appears to be the first systematic evidence of a geographically patterned of polycythemia within Panjshir Province a remote, high-altitude region of northeastern Afghanistan situated in the Hindu Kush range. Examining more than 2500 Patients (650 Polycythemia) patients records accumulated over four years at Rukha 50-Bed Hospital, we found that polycythemia is far from evenly distributed across the province. Cases aggregate in the districts that sit at the greatest elevations: Paryan District, the most elevated of the three areas studied, recorded both the highest hemoglobin thresholds and the densest concentration of polycythemia diagnoses, while the comparatively lower-lying Abshar District contributed appreciably fewer cases. Dara District, at roughly 3558 meters, occupied an intermediate position in both geography and disease frequency. This stepwise gradient polycythemia prevalence rising with district altitude is consistent with the established principle that the intensity and chronicity of hypobaric hypoxic exposure govern the magnitude of the erythropoietic response [22].

Our data resonate with a substantial international body of work on altitude-related erythrocytosis while simultaneously introducing a perspective that has been almost entirely missing from the global literature. The altitude-dependent clustering we document in Panjshir parallels well-described patterns in the Andean highlands of Peru and Bolivia, where chronic mountain sickness has long posed a recognized public health problem and excessive erythrocytosis affects 30% to 40% of residents in communities above 4000 meters. Research on the Tibetan-Qinghai Plateau has similarly shown that hemoglobin rises with altitude, though native Tibetans display a characteristically blunted erythropoietic response relative to Han Chinese migrants living at equivalent elevations a difference attributable to centuries of genetic selection. What distinguishes our work is its geographical lens on an Afghan highland community that has, until now, been systematically absent from international health research [23].

The physiological mechanism linking altitude to polycythemia is well characterized, even if its local expression in any given community is shaped by a more complex constellation of fac-

tor. As altitude increases, the partial pressure of inspired oxygen falls, arterial saturation declines, and the kidneys respond by upregulating erythropoietin (EPO) synthesis. Rising EPO concentrations stimulate bone marrow erythropoiesis, expanding the red cell mass and raising hemoglobin. For residents of moderately elevated terrain this feedback loop generally operates within a regulated and physiologically useful range. Beyond approximately 2500 to 3000 M, however, the hypoxic signal becomes more sustained and intense, and in a subset of resident's erythropoiesis escapes adequate feedback control. When hemoglobin surpasses the Qinghai consensus thresholds of 21 g/dL in men and 19 g/dL in women, blood viscosity climbs disproportionately, microcirculatory flow is impeded, and the clinical picture of chronic mountain sickness headache, persistent fatigue, dizziness, disturbed sleep, and over time pulmonary hypertension and right heart failure becomes manifest. Paryan District's dominant contribution to our polycythemia caseload is entirely congruent with this dose-response relationship between hypoxic exposure and hematological outcome [24].

Other local factors may be reinforcing the geographical pattern we observed, even though our retrospective design precluded their direct measurement. Anecdotal reports and limited published data indicate that parts of the upper districts of Panjshir have a history of small-scale mining. Cobalt, arsenic, and lead metals documented in Afghan mining environments have been linked to erythropoietic stimulation through mechanisms partly independent of altitude and could intensify the hematological response to hypoxia among exposed residents [25]. Lifestyle factors are equally plausible contributors. Tobacco smoke contains carbon monoxide, which binds hemoglobin with an affinity more than 200 times that of oxygen, forming carboxyhemoglobin and deepening functional hypoxia in individuals who are already compensating for altitude-related oxygen deficit. Waterpipe use, culturally embedded in many parts of Central and South Asia, imposes a comparable burden. If smoking prevalence or occupational exposure differs systematically between districts, these differences could account for some of the spatial variation in polycythemia burden that altitude alone might not fully explain. Future investigations incorporating individual-level data on smoking, occupation, diet, and indoor air quality will be necessary to disentangle these contributions [26].

The male predominance in our polycythemia cases men represented 55% of those affected mirrors findings from every well-studied high-altitude population, from the Andes to the Himalayas, and warrants comment on both biological and contextual grounds [27]. Testosterone directly stimulates EPO secretion and sensitizes erythroid progenitors within the bone marrow, while estrogen exerts a counterbalancing mild inhibitory effect on erythropoiesis, affording premenopausal women a degree of relative protection. Beyond these hormonal differences, men in Panjshir as in most rural high-altitude communities are substantially more likely to spend extended time working outdoors at the highest elevations, engaged in farming, animal husbandry, or mining, accumulating far greater cumulative hypoxic exposure than women, who more often conduct their daily activities in indoor or lower-altitude settings [28]. Differences in smoking rates and healthcare-seeking behavior may contribute additional asymmetry. The male sex remained an independent predictor of polycythemia after adjustment for district altitude and SpO_2 supports a multifactorial rather than purely geographical explanation [29].

Several recently published studies allow a more direct comparison with our findings than the classical literature discussed above. Among Andean highlanders, excessive erythrocytosis carries appreciable cardiovascular risk, including elevated ambulatory blood pressure documented in the HIGHCARE-ANDES cohort [30]. Our finding demonstrated that polycythe-

mia clustered in the highest-altitude district lends indirect support to the view that cardiovascular risk in this population tracks altitude exposure. On the Qinghai-Tibetan plateau, a cross-sectional study of adults living above 4700 M found that high-altitude polycythemia carried a three-fold increased odds of hypertension, an association notably stronger among Han migrants than among native Tibetans [31], mirroring the ethnically and genetically mediated variation in erythropoietic response long described between Tibetan and Han populations at comparable elevations [32, 33]. Because HAPC prevalence itself differs markedly between Han immigrants and native Tibetans at the same elevation [34], the substantially higher polycythemia burden we observed in Paryan District, populated predominantly by Tajik and Hazara communities without the EPAS1/EGLN1 adaptive variants characteristic of Tibetans, is broadly consistent with a population that has not undergone comparable genetic selection for hypoxia tolerance [33, 35]. Gene-expression analyses of Han immigrants with HAPC have similarly documented altered erythropoiesis- and hypoxia-related transcripts, offering a molecular counterpart to the phenotypic clustering we describe [36].

By contrast, Ethiopian highland populations illustrate that elevated hemoglobin is not an inevitable consequence of chronic altitude exposure: Amhara highlanders in the Simien Mountains maintain essentially normal hemoglobin concentrations despite lifelong residence above 3,000 meters, apparently through a vasodilatory rather than erythropoietic adaptive strategy [33, 37]. That Panjshir highlanders instead show a pronounced altitude-erythrocytosis gradient, similar in direction if not magnitude to the Andean pattern, suggests that Afghan highland populations may share more physiological ground with Andean than with Tibetan or Ethiopian highlanders, though this remains speculative in the absence of genetic data. The sex disparity we observed is well grounded mechanistically: androgens stimulate erythropoietin secretion and directly sensitize erythroid progenitors, while estrogen exerts a mild inhibitory effect, together accounting for the roughly 10-12% higher hemoglobin concentrations typically observed in men [38]. Comparable male predominance in polycythemia has been reported wherever the condition has been systematically studied, from Nepalese hospital cohorts to Tibetan ultrahigh-altitude clinics, reinforcing that the pattern documented in Paryan District is unlikely to be a chance finding, reinforcing that the pattern documented in Paryan District is unlikely to be a chance finding [31, 39].

Our data also intersect with the growing literature on the downstream cardiovascular consequences of high-altitude polycythemia. Elevated hemoglobin concentrations raise blood viscosity and peripheral vascular resistance through mechanisms that include impaired nitric-oxide bioavailability [40] and hyper viscosity-driven increases in vascular resistance [41], associated with a two-fold increase in hypertension risk in large inpatient database analyses of the Gaisböck syndrome, the co-occurrence of polycythemia and hypertension [42]; with nocturnal hypoxemia and vascular dysfunction in the highest permanently inhabited city in the world [43, 44]; and with hyperuricemia and proteinuria in Andean patients with high-altitude polycythemia [45]. A separate cohort of native Tibetans confirmed a graded, dose-dependent relationship between hemoglobin concentration and hypertension risk that mirrors the pattern we infer indirectly from district-level altitude exposure [46], while sleep-disordered breathing appears both more prevalent and more severe among long-term immigrants with chronic mountain sickness, a factor our retrospective design could not assess directly [47]. Elevated stroke prevalence has similarly been documented across the Qinghai-Tibet plateau [48]. Although our study did not permit assessment of blood pressure, hyperuricemia, or stroke outcomes, these findings collectively in-

dicate that the Paryan District cases we identified are unlikely to be biologically inert and instead carry a plausible burden of unmeasured cardiovascular and renal comorbidity that merits prospective evaluation. Management approaches reported to be effective elsewhere, including therapeutic phlebotomy, acetazolamide, and closer monitoring of migrant relative to native highland populations, offer a starting menu of interventions that could be adapted to the resource constraints of rural Panjshir [49].

The public health implications of our findings are both specific and actionable. A clustered rather than diffuse spatial distribution means that screening and prevention resources need not be spread uniformly across the province [50]. Paryan District, with its extreme elevation and the greatest share of polycythemia cases, is the most compelling priority for targeted hemoglobin monitoring through existing rural health posts and outreach clinics. Even rudimentary laboratory capacity is sufficient for diagnosis, and the therapeutic options feasible in resource-limited settings periodic therapeutic phlebotomy to reduce blood viscosity, management of cardiovascular risk factors, and counselling on smoking cessation and hydration can meaningfully reduce morbidity when applied before disease advances to symptomatic chronic mountain sickness [51]. Culturally adapted health education explaining, in accessible language, the connection between high-altitude living, elevated blood thickness, and symptoms such as persistent headache and fatigue could encourage earlier health-seeking behavior and reduce the proportion of cases presenting at advanced stages [52].

From a research standpoint, our findings generate a range of important follow-up questions. Community-based prevalence surveys using probability sampling rather than hospital attendance would provide unbiased estimates of the true population burden of polycythemia across Panjshir's districts. Longitudinal cohort studies tracking hemoglobin levels and clinical outcomes in high-risk individuals over time would clarify the natural history of HAPC in this population including the pace of progression and the incidence of serious complications such as stroke and heart failure and assess the effectiveness of available interventions. Genetic studies comparing Panjshir highlanders with lowland Afghan populations and with the Tibetan, Andean, and Ethiopian groups for whom genomic data already exist could test whether generations of residence in the Hindu Kush have selected for distinct variants in EPAS1, EGLN1, or other components of the HIF pathway. Such work would not only illuminate the biology of adaptation in this underrepresented group but would also enrich the broader comparative literature on human responses to extreme hypoxic environments.

Study Limitation

This study was limited by its retrospective, hospital-based design and reliance on routine medical records, have introduced selection bias and incomplete data. The findings may not be generalizable beyond the study setting. In addition, incomplete district-specific denominators limit accurate comparisons of polycythemia prevalence across districts.

Conclusion

In this hospital-based review, 650 of 2500 adults tested were reported to meet the study hemoglobin thresholds. Men represented 55.08% of identified cases. Because the study was based on the hospital records, these findings should not be interpreted as population prevalence for Panjshir. District-level differences and independent associations with altitude require verification using district-specific denominators and complete statistical models. Community-based studies with repeated hemoglobin measurements and more comprehensive assessment of potential confounders are needed.

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Conflict of Interest

The authors declare that no conflict of interest exists in relation to this work.

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