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RESEARCH

Comparison of Total Nasal Symptom Score (TNSS) and Nasal Patency Between Lowland and Highland Populations In Klungkung And Bangli Regencies, Bali

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ABSTRACT

Introduction: Rhinitis and nasal dysfunction impose a significant global burden, yet studies simultaneously comparing Total Nasal Symptom Score (TNSS) and objective nasal patency between community-based lowland and highland populations remain scarce. This study aimed to compare TNSS and nasal patency between lowland and highland populations in Klungkung and Kintamani, Bali. **Material & Methods:** This was an observational analytic cross-sectional study conducted during community health screening events in Kecamatan Dawan, Klungkung (lowland) and Kecamatan Kintamani, Bangli (highland). Subjects aged 18–60 years were recruited by consecutive sampling. TNSS was assessed using the validated Indonesian-version TNSS questionnaire. Nasal patency was objectively measured using the Glatzel mirror technique, with condensation area quantified via ImageJ software. Confounding variables including septal deviation, allergic rhinitis, chronic rhinosinusitis, URTI history, smoking, and intranasal medication use were assessed. Data were analyzed using the Mann-Whitney U test and Chi-Square or Fisher's Exact test, with significance set at $p<0.05$. **Results:** A total of 72 subjects were enrolled (lowland n=30, highland n=42). Significant between-group differences were identified in septal deviation ($p<0.001$), allergic rhinitis history ($p=0.001$), and chronic rhinosinusitis history ($p<0.001$). The highland group demonstrated a significantly higher median TNSS compared to the lowland group (7 [range 5–9] vs. 3 [range 2–5], $p<0.001$). Bilateral nasal patency was significantly lower in the highland group across all measurements, including bilateral mean (4.55 cm^2 vs. 6.10 cm^2, $p<0.001$). **Conclusion:** Highland populations in Bali exhibit significantly higher nasal symptom burden and lower objective nasal patency compared to lowland populations, suggesting that geographic environmental characteristics meaningfully influence nasal function and symptom profiles.

Keywords: total nasal symptom score, nasal patency, highland, lowland, Glatzel mirror, rhinitis

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INTRODUCTION

Nasal disorders are among the most prevalent health conditions worldwide and significantly impair quality of life, sleep, and productivity. Rhinitis, an inflammatory condition of the nasal mucosa characterized by obstruction, rhinorrhea, sneezing, and pruritus, represents the most common nasal disorder encountered in clinical and community settings. Epidemiological data indicate a wide global prevalence, ranging from 1% to 63%, with median prevalences of 29.4%, 18.1%, and 12.0% for unspecified, allergic, and non-allergic rhinitis, respectively.[1] In Indonesia, the prevalence of rhinitis has been reported at 38.2% among university students, based on the ARIA-WHO questionnaire. The predominant symptoms include nasal obstruction (90%), nasal pruritus (90%), rhinorrhea (89%), and sneezing (82%).[2] These clinical and societal burden of nasal disorders, highlighting the need for population-level research, particularly across populations exposed to contrasting environmental conditions such as lowland and highland geographic settings.

To evaluate nasal symptom burden in a standardized and quantifiable manner, the Total Nasal Symptom Score (TNSS) has been widely adopted in clinical research. TNSS assesses four cardinal nasal symptoms, namely nasal obstruction, rhinorrhea, nasal pruritus, and sneezing, each rated on a 0–3 severity scale, yielding a composite score ranging from 0 to 12. It has been internationally recommended and validated across multiple languages and populations as a reliable patient-reported outcome measure for rhinitis.[3] Alongside TNSS, objective assessment of nasal function is equally important. Nasal patency, the degree of unobstructed airflow through the nasal cavity, can be measured using rhinomanometry, acoustic rhinometry, and peak nasal inspiratory flow (PNIF), each providing quantitative data on nasal airway resistance and geometry that may not be fully captured by subjective reporting alone.[4,5]

Several confounding factors are known to influence both TNSS and nasal patency measurements, necessitating their identification and control to minimize bias. Among these, septal deviation, a common anatomical variant, is known to directly impair nasal airflow and correlate significantly with the degree of nasal obstruction, with more severe deviation associated with greater obstruction severity.[6] Additional confounders include chronic rhinosinusitis, allergic rhinitis, recent upper respiratory tract infection (URTI), smoking history, and use of intranasal medications, all of which must be accounted for in comparative population studies.

Although TNSS has been established as a valid tool for assessing nasal symptom severity and nasal patency provides objective insight into nasal respiratory function, most prior studies have evaluated these parameters primarily within the context of specific diseases such as allergic rhinitis or chronic rhinosinusitis, or among clinical populations at healthcare facilities. Studies simultaneously comparing TNSS and nasal patency in community-based populations across regions with differing geographic characteristics remain limited, particularly in Indonesia. Moreover, investigations that explicitly examine the role of lowland versus highland environmental factors on both subjective nasal symptoms and objective nasal function, while controlling for clinical confounders such as septal deviation, history of chronic rhinosinusitis, recent URTI, smoking habits, and intranasal medication use, have rarely been reported.

In light of this gap, a comparative analytical study of TNSS and nasal patency between lowland and highland populations in Klungkung and Kintamani, Bali, is highly relevant. This study is expected to provide important local data, including the distribution of TNSS and nasal patency, the distribution of

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relevant clinical conditions (e.g., allergic rhinitis, septal deviation, chronic rhinosinusitis, URTI), and a direct comparison of TNSS and nasal patency between the two geographic groups.

METHOD

Study Design

This study was an observational analytic study with a cross-sectional design using primary data. The study aimed to compare the Total Nasal Symptom Score (TNSS) and nasal patency between lowland and highland community populations. Subjects were residents of Kecamatan Dawan, Klungkung (lowland group) and Kecamatan Kintamani, Bangli (highland group), recruited during community health screening events. Primary data were collected through structured interviews, physical examination (anterior rhinoscopy), the Indonesian-version TNSS questionnaire, and objective nasal patency measurement using the Glatzel mirror technique. The study was conducted in Klungkung and Bangli Regencies, Bali, during December 2026. Minimum sample size was determined using the cross-sectional sample size formula, yielding a minimum of 45 subjects per group, increased to 50 after a 10% dropout allowance. Consecutive sampling was applied, enrolling all eligible subjects who attended the screening events until the required sample size was met.

Research Procedure

Data collection was conducted systematically following approval from the relevant ethics committee. Study subjects consisted of residents aged 18–60 years domiciled in Kecamatan Dawan, Klungkung (lowland group) or Kecamatan Kintamani, Bangli (highland group), who attended community health screening events. Subjects fulfilling inclusion criteria and providing written informed consent underwent a structured interview covering sociodemographic characteristics, clinical nasal conditions (allergic rhinitis, septal deviation, chronic rhinosinusitis, nasal polyps), history of recent URTI, smoking habits, intranasal medication use, and duration of residence. Physical examination, including anterior rhinoscopy, was subsequently performed, followed by administration of the Indonesian version of the TNSS questionnaire. Objective nasal patency was then assessed using the Glatzel mirror technique, in which subjects were seated upright in a stable-temperature room and instructed to perform quiet nasal expiration with the mouth closed. A stainless steel mirror plate, pre-cleaned and at a temperature below body temperature, was placed horizontally beneath the anterior nares without skin contact. The condensation patterns formed on the mirror surface from both nostrils were immediately traced and photographed using a digital camera. Measurements were performed at minutes 0, 5, 15, 25, and 35, and the condensation area of each measurement was quantified using ImageJ software by calculating the ellipse area ($L = \pi ab$) in cm^2. The nasal patency score was determined as the mean condensation area across five measurement time points. All collected data were subsequently compiled and analyzed according to the predetermined statistical methods.

Data Analysis

Data were processed and analyzed using SPSS version 21 for Windows. Univariate analysis was performed to describe subject characteristics and the distribution of each study variable. Numerical variables, including TNSS score and nasal patency value, are presented as median and interquartile range given non-normal distribution, while categorical variables, including age, sex, duration of residence, smoking history, intranasal medication use, and clinical nasal conditions, are presented as frequencies and percentages. Normality testing was conducted using the Shapiro-Wilk test. Bivariate analysis was performed to assess differences in TNSS and nasal patency between the lowland and highland groups using the Mann-Whitney U test, given that both variables were not normally distributed. Associations between categorical confounding variables and group assignment were assessed using the Chi-Square test or Fisher's Exact test where

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applicable, with statistical significance set at $p<0.05$ and a 95% confidence interval.

RESULT

A total of 72 subjects were enrolled, comprising 30 subjects in the lowland group and 42 subjects in the highland group. The univariate analysis representing the distribution of confounding variables is presented in Table 1.

Based on ROC curve analysis of the age variable, the optimal cut-off value with the highest Youden index (sensitivity - [1 - specificity]) was 36.5 years (Youden index: 0.062), which was subsequently used to categorize subjects into young (<36.5 years) and old (≥36.5 years) groups. The median age in the lowland group was 40.5 years (range 21–62 years), while in the highland group it was 44.5 years (range 21–65 years). The older age category predominated in both groups, accounting for 60% in the lowland group and 69% in the highland group. Regarding sex distribution, males were predominant in both groups, comprising 53% in the lowland group and 55% in the highland group.

Concerning clinical nasal conditions, all highland subjects (100%) had a history of septal deviation and allergic rhinitis, whereas in the lowland group, a history of allergic rhinitis was found in 77% of subjects, with no cases of septal deviation. Smoking history was prevalent in both groups, recorded in 53% of lowland subjects and 55% of highland subjects. With respect to duration of residence, subjects who had lived in their respective areas for ≥15 months predominated in both groups, comprising 80% in the lowland group and 79% in the highland group.

Bivariate analysis was performed to assess the association between categorical confounding variables and group assignment (lowland and highland). The Chi-Square test was used for variables meeting its assumptions (denoted by an asterisk) and Fisher's Exact test for those that did not. Results are presented in Table 3.

As shown in Table 3, three confounding variables demonstrated significant differences in proportion between the lowland and highland groups. Septal deviation showed a highly significant difference ($p <0.001$),

Table 1. Characteristics of Confounding Variables

Variable	Lowland n (%)	Highland n (%)
Age		
Young	12 (40)	13 (31)
Old	18 (60)	29 (69)
Sex		
Male	16 (53)	23 (55)
Female	14 (47)	19 (45)
Clinical condition of the nasal cavity		
Absent	6 (20)	0 (0)
Present	24 (80)	42 (100)
Smoking history		
Absent	14 (47)	19 (45)
Present	16 (53)	23 (55)
History of nasal spray use		
Absent	25 (83)	31 (74)
Present	5 (17)	11 (26)
Duration of residence		
<15 months	6 (20)	9 (21)
≥15 months	24 (80)	33 (79)

Table 2. Characteristics of Main Hypothesis Variables

Variable	Lowland		Highland	
	Median	Min-max	Median	Min-max
TNSS	3	2-5	7	5-9
Nasal patency	6,1	5,6-6,8	4,6	4,1-4,9

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Table 3. Results of Chi-Square and Fisher's Exact Tests on Categorical Confounding Variables

Confounding variable	Research group		OR	95% CI	p-*value*
	Lowland	Highland			
Age					
Young	12 (40%)	13 (31%)	1,49	0,56-3,97	0,427*
Old	18 (60%)	29 (69%)			
Sex					
Male	16 (53%)	23 (55%)	0,94	0,37-2,42	0,905*
Female	14 (47%)	19 (45%)			
Septal deviation					
Absent	30 (100%)	0 (0%)	-	-	**<0,001***
Present	0 (0%)	42 (100%)			
History of nasal polyp					
Absent	30 (100%)	40 (95%)	-	-	0,507
Present	0 (0%)	2 (5%)			
History of allergic rhinitis					
Absent	7 (23%)	0 (0%)	-	-	**0,001**
Present	23 (77%)	42 (100%)			
History of chronic sinusitis					
Absent	28 (93%)	13 (31%)	**31,23**	**6,45-151,12**	**<0,001***
Present	2 (7%)	29 (69%)			
History of URTI					
Absent	22 (73%)	23 (55%)	2,27	0,83-6,25	0,109*
Present	8 (27%)	19 (45%)			
Smoking history					
Absent	14 (47%)	19 (45%)	1,06	0,41-2,71	0,905*
Present	16 (53%)	23 (55%)			
History of nasal spray use					
Absent	25 (83%)	31 (74%)	1,77	0,54-5,78	0,338*
Present	5 (17%)	11 (26%)			
Duration of residence					
<15 months	6 (20%)	9 (21%)	0,92	0,29-2,92	0,883*
≥15 months	24 (80%)	33 (79%)			

with all highland subjects (100%) having septal deviation, while none of the lowland subjects did. The history of allergic rhinitis also differed significantly (p = 0.001), with all highland subjects (100%) reporting a history of allergic rhinitis compared to 77% in the lowland group.

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The remaining confounding variables showed no significant differences in proportion between the two groups. Age (p = 0.427), sex (p = 0.905), history of nasal polyps (p = 0.507), history of URTI (p = 0.109), smoking history (p = 0.905), intranasal medication use (p = 0.338), and duration of residence (p = 0.883) were all comparably distributed between groups, indicating that these variables did not constitute significant sources of bias in the comparison between the two study groups.

Bivariate analysis of TNSS between study groups was preceded by normality testing, the results of which are presented in Table 4, showing that neither group followed a normal distribution (p <0.05). Log transformation of TNSS data yielded similar results, with normality still not achieved. The Mann-Whitney U test was therefore applied to identify statistically significant differences in median values between the two independent groups.

Table 4. Shapiro-Wilk Normality Test for the TNSS Variable

Research group	p-*value*
Lowland	0,002
Highland	0,001

The Mann-Whitney U test revealed that the median TNSS of the highland group was significantly higher than that of the lowland group, at 7 (range 5–9) versus 3 (range 2–5), with p <0.001, indicating a statistically significant difference in nasal symptom severity between the two populations.

The Mann-Whitney U test revealed that the median nasal patency score of the lowland group was significantly higher than that of the highland group across all measurements, including the left side (5.70 cm^2 vs. 4.10 cm^2), right side (6.45 cm^2 vs. 5.00 cm^2), and bilateral mean (6.10 cm^2 vs. 4.55 cm^2), with all p values <0.001. These findings indicate a statistically significant difference in nasal patency between the lowland and highland populations on both sides individually and overall, with the highland population demonstrating consistently lower nasal patency compared to the lowland population.

Table 5. Bivariate Mann-Whitney Test for the TNSS Variable

Research group	TNSS (median [min-max])	p-*value*
Lowland	3 (2-5)	**<0,001**
Highland	7 (5-9)	

Normality testing of the nasal patency score, calculated as the mean condensation area of the left and right nasal cavities, is presented in Table 5, showing that only one group followed a normal distribution. Log transformation was subsequently performed, but normality was still not achieved in both groups. The Mann-Whitney U test was therefore selected as the bivariate test for this variable.

Table 6. Shapiro-Wilk Normality Test for the Nasal Patency Variable

Variable	Research group	p-*value*
Left nasal patency	Lowland	0,001
	Highland	<0,001
Right nasal patency	Lowland	0,002
	Highland	0,005
Average nasal patency	Lowland	**0,204**
	Highland	0,030

The Mann-Whitney U test revealed that the median nasal patency score of the lowland group was significantly higher than that of the highland group across all measurements, including the left side (5.70 cm^2 vs. 4.10 cm^2), right side (6.45 cm^2 vs. 5.00 cm^2), and bilateral mean (6.10 cm^2 vs. 4.55 cm^2), with all p values <0.001. These findings indicate a statistically significant difference in nasal patency between the lowland and highland populations on both sides individually and overall, with the highland population demonstrating consistently lower nasal patency compared to the lowland population.

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Tabel 7. Bivariate Mann-Whitney Test for the Nasal Patency Variable

Variable	Research group	Nasal patency score (median [min-max])	p-*value*
Left nasal patency	Lowland	5,70 (5,30-6,20)	**<0,001**
	Highland	4,10 (3,50-4,40)	
Right nasal patency	Lowland	6,45 (6,00-7,30)	**<0,001**
	Highland	5,00 (4,40-5,50)	
Average nasal patency	Lowland	6,10 (5,65-6,75)	**<0,001**
	Highland	4,55 (4,10-4,95)	

DISCUSSION

The median age of lowland and highland subjects was 40.5 and 44.5 years, respectively, with older subjects (≥36.5 years) predominating in both groups, consistent with evidence that nasal and sinus symptom prevalence peaks in the 50–59 age group and that aging is associated with progressive nasal mucosal physiological changes.[7,8] Males were predominant in both groups (53% lowland, 55% highland), aligning with prior reports on the male predominance in chronic rhinosinusitis populations, which may be attributed to differences in nasal cavity anatomy, greater exposure to environmental irritants, and sex-related differences in pro-inflammatory cytokine regulation.[9–12] History of allergic rhinitis was more prevalent in the highland group (100%) compared to the lowland group (77%), supported by evidence that highland environmental factors, including lower temperatures and altered aeroallergen distribution, influence allergic sensitization patterns, with dust mite sensitization correlating negatively with altitude and positively with mean annual temperature.[13–15] Chronic rhinosinusitis history was markedly higher in the highland group (69% vs. 7%), likely attributable to chronic mucociliary impairment induced by cold, dry air, causing epithelial desiccation and non-specific mucosal inflammation.[16,17] URTI history was also more prevalent in the highland group (45% vs. 27%), consistent with evidence that cold, dry highland air impairs mucociliary defense and increases susceptibility to upper respiratory infections.[18] Smoking prevalence was nearly identical between groups (53% vs. 55%), making it a naturally controlled confounder, despite its known association with chronic rhinitis and rhinosinusitis.[19–21] The majority of subjects in both groups had resided in their respective areas for ≥15 months (80% lowland, 79% highland), suggesting sufficient chronic environmental exposure to induce adaptive or maladaptive mucosal changes, including epithelial-mesenchymal transition and heterogeneous inflammatory responses as documented in long-term highland residents.[22–24]

Bivariate analysis of confounding variables revealed three significant differences between groups. Septal deviation was present in all highland subjects (100%) and absent in all lowland subjects ($p < 0.001$), consistent with prior reports identifying septal deviation as the most prevalent paranasal sinus anatomical variant in sinonasal disease populations. Mechanistically, septal deviation disrupts nasal airflow and narrows the middle meatus, creating a hypoxic and stagnant sinus environment that predisposes to chronic inflammation and recurrent infection, particularly when compounded by highland environmental conditions.[25,26] History of allergic rhinitis was also significantly more prevalent in the highland group (100% vs. 77%, $p = 0.001$), supporting epidemiological findings that allergic rhinitis prevalence is paradoxically higher in highland populations despite reduced house dust mite concentrations, as cold and dry highland air impairs respiratory epithelial function, reduces ciliary beat frequency, and disrupts mucociliary clearance, thereby increasing chronic mucosal

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exposure to allergens and irritants.[27,28] History of chronic rhinosinusitis was markedly higher in the highland group (69% vs. 7%, p <0.001), consistent with geo-climatic evidence linking low temperature, low humidity, and high elevation to increased chronic rhinosinusitis prevalence through impaired mucociliary clearance. Physiologically, reduced inspiratory air humidity at altitude causes periciliary layer dehydration, diminishes ciliary efficiency, and chronically impairs paranasal sinus drainage, ultimately creating conditions conducive to bacterial proliferation and biofilm formation as the principal pathomechanism of chronic rhinosinusitis.[29–31]

This study demonstrated a statistically significant difference in TNSS between the highland and lowland populations, with the highland group recording a markedly higher median TNSS of 7 (range 5–9) compared to 3 (range 2–5) in the lowland group (p <0.001). While studies specifically comparing TNSS scores between highland and lowland community populations remain scarce, several epidemiological studies support this finding. Gao et al. (2022) reported a significantly higher prevalence of allergic rhinitis in highland compared to lowland populations (36% vs. 19.7%, p <0.001) in adult populations in Shenmu City, China, indirectly reflecting a greater nasal symptom burden at altitude.[13] Roy et al. (2017) further demonstrated that lowland subjects relocated to high altitude reported increased subjective nasal obstruction perception despite unchanged objective nasal resistance, suggesting that highland environmental conditions amplify nasal symptom sensation even without proportional objective changes.[22]

The more pronounced TNSS difference observed in the present study compared to Roy et al. is likely explained by the chronicity of exposure, as the majority of subjects in both groups had resided in their respective areas for ≥15 months, allowing for cumulative adaptive and maladaptive mucosal changes that short-term relocation studies would not capture. Chronic exposure to the highland environment, characterized by low temperature, low humidity, and reduced oxygen partial pressure, is known to directly modulate rhinitis exacerbation through immunological mechanisms and altered aeroallergen exposure patterns. Furthermore, dust mite sensitization, the primary allergic rhinitis aeroallergen in tropical regions, has been shown to correlate negatively with altitude and positively with mean annual temperature, suggesting that long-term residence at higher altitudes with cooler temperatures shapes local allergic sensitization profiles that are ultimately reflected in higher TNSS scores among highland populations.[14,15]

This study demonstrated a statistically significant difference in nasal patency between the two populations, with the lowland group recording a markedly higher median bilateral nasal patency score of 6.10 cm^2 (range 5.65–6.75) compared to 4.55 cm^2 (range 4.10–4.95) in the highland group (p <0.001). These findings indicate that the highland population exhibits consistently lower nasal patency than their lowland counterparts. Direct comparisons of nasal patency between permanently residing lowland and highland populations remain scarce in the literature, as most existing studies have focused on evaluating acute nasal function changes following short-term altitude relocation. Nevertheless, several studies with relevant approaches provide useful comparative context. Cingi et al. (2011) reported significant reductions in PNIF among individuals at high altitude compared to sea level, reflecting the physiological challenges imposed on the upper airway by reduced oxygen partial pressure and altered air physical properties.[32] Barry et al. similarly demonstrated that nasal mucociliary transport time increased markedly at altitude, from a median of 11 minutes at sea level to 60 minutes at high altitude, reflecting serious impairment of upper airway mucosal defense.[30] These findings collectively suggest that highland environments impose a meaningful physiological burden on nasal function, consistent with the lower nasal patency values

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observed in the highland group of the present study.

The findings of this study contrast with those reported by Ottaviano et al. (2020), who observed a significant increase in PNIF at 3,400 m compared to baseline ($p = 0.003$) in healthy volunteers relocated from 2,000 m over the course of one week, attributing this to reduced air density at altitude, lowering airflow resistance.[33] Several factors explain this divergence. First, Ottaviano et al. enrolled relatively healthy subjects with only short-term altitude exposure of one week, whereas the present study involved populations with long-term residence of ≥15 months, predominantly older subjects with high rates of clinical nasal conditions, including chronic rhinosinusitis (69%) and allergic rhinitis (100%) in the highland group. Second, controlled hypobaric chamber studies have shown that while PNIF tends to increase with altitude due to reduced air density, this increase is smaller than predicted, and at altitudes of 5,000–8,000 m, PNIF plateaus or even declines, indicating progressive reduction in functional nasal caliber.[33,34] These observations suggest that the acute physiological effect of reduced air density on nasal airflow is counteracted by structural and mucosal changes that develop with prolonged highland exposure, ultimately resulting in net reductions in nasal patency as observed in the present study.

The mechanistic basis for lower nasal patency in long-term highland residents likely involves a homeostatic phenomenon in which nasal resistance is maintained relatively constant despite major changes in the physical properties of inspired air, possibly through mucosal vasoconstriction or other adaptive changes that reduce functional nasal caliber. Chronic exposure to cold and dry highland air causes mucociliary impairment, epithelial desiccation, and non-specific inflammatory changes in the nasal and sinus mucosa. Luo et al. (2013), studying Tibetan populations with long-term high-altitude residence of more than 4,000 m above sea level, demonstrated that prolonged highland environmental exposure produces a distinct inflammatory pattern dominated by macrophages and neutrophils in response to environmental stress, leading to structural mucosal changes that objectively reduce nasal patency.[24] Taken together, the discrepancy between the present findings and those of short-term altitude exposure studies underscores that the nasal patency response to altitude is strongly modulated by duration of exposure, baseline mucosal health status, and clinical confounders such as age and comorbid nasal conditions, all of which were more pronounced in the highland population of this study.

Several limitations of this study should be considered when interpreting the findings. First, the cross-sectional design precludes the establishment of temporal causal relationships between highland environmental exposure and changes in TNSS or nasal patency. Second, nasal patency was assessed using the Glatzel mirror technique, a simple, non-invasive, and low-cost method that relies on condensation area as an indirect indicator of nasal airflow; however, its correlation with reference methods such as rhinomanometry or acoustic rhinometry has not been fully validated in populations with complex clinical nasal conditions. Third, diagnoses of clinical nasal conditions including septal deviation, allergic rhinitis, chronic rhinosinusitis, and URTI were based primarily on history-taking and physical examination without confirmatory investigations such as nasoendoscopy or radiological imaging, introducing the possibility of misclassification bias. Fourth, environmental parameters including temperature, humidity, barometric pressure, and aeroallergen concentrations were not directly measured at either study site, limiting mechanistic interpretations to theoretical extrapolations from prior literature. Fifth, the unequal sample sizes between groups (lowland $n = 30$, highland $n = 42$) and the high prevalence of certain clinical conditions exclusively in the highland group (100% septal deviation and allergic rhinitis) may represent sources of selection bias that limit the generalizability of findings. Sixth, additional

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confounders known to influence TNSS and nasal patency, including systemic medication use such as oral antihistamines and corticosteroids, family atopy status, and occupational irritant exposure, were not strictly controlled. Nonetheless, these limitations do not diminish the significance of this study as an important preliminary dataset on nasal symptom burden and function across contrasting geographic populations in Bali.

Based on the findings of this study conducted among lowland populations in Klungkung Regency and highland populations in Kintamani, Bangli, it can be concluded that there are significant differences in Total Nasal Symptom Score (TNSS) and nasal patency between lowland and highland populations. The highland population demonstrated higher TNSS scores and lower nasal patency values compared to the lowland population.

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