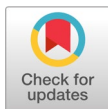


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Morphological Variation of the Human Tongue in an Ethnic Population of Swat: Implications for Forensic Personal Identification

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ABSTRACT

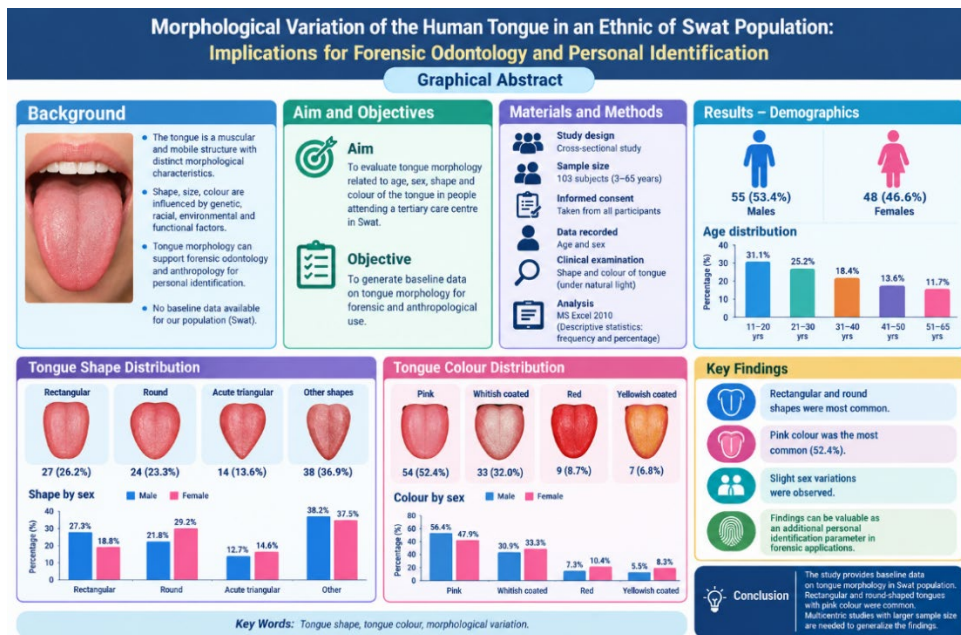
Tongue is a muscular and mobile organ with considerable morphological variation. Tongue shape and color may be influenced by genetic, environmental, and functional factors and have been investigated as potential supplementary characteristics in forensic odontology. The current study was undertaken to determine the variation of tongue morphology, with special reference to the shape and color of the tongue, among the individuals of Swat population. Furthermore, the study also focused to generate baseline population-specific data for forensic purposes. The descriptive cross-sectional study was conducted on 103 participants of Swat District, Khyber Pakhtunkhwa (KPK), Pakistan. The participants were recruited by convenience sampling according to the pre-established eligibility criteria. Written informed consent was obtained prior to examination. Tongue morphology was assessed by direct physical examination and the observations were recorded as per the classification criteria of the study. The data was summarized as frequencies and percentages. There were 55 males (53.4%) and 48 females (46.6%) in the study. Eight categories of tongue shape were recorded. The most frequent categories included rectangular (25, 24.3%), round (24, 23.3%), and acute triangular (14, 13.6%). The most common color of the tongue was pink (54, 52.4%), followed by whitish coated (33, 32.0%), red (11, 10.7%), and yellowish coated (5, 4.9%). Males most commonly fell in the rectangular shape category, whereas females most commonly fell in the round shape category. The results showed a considerable variation in the shape and color of tongue among the studied Swat population. These features may have potential value as supplementary forensic characteristics, in conjunction

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with established methods of identification. Larger, multicentric studies with standardized classification systems and reliability assessment are needed to establish their reproducibility and forensic discriminatory value.

GRAPHICAL ABSTRACT



Keywords: forensic odontology, personal identification, tongue color, tongue morphology, tongue shape

Highlights

- There was a considerable variation in morphology of tongue in Swat population.
- The tongue shapes most frequently seen were rectangular and round.
- Tongue morphology could serve as an additional forensic characteristic.

1.INTRODUCTION

The tongue is a special and highly individualized muscular organ. The morphological features of which, for instance, shape, color, and surface characters, vary greatly from person to person. Since long, tongue assessment has been used for diagnostic purposes in traditional medical

systems, such as Chinese and Ayurvedic medicine. Recently, some studies have attempted to use it as a biometric tool for forensic identification as a supplement [1-3]. Forensic odontology is a specialized branch of forensic science that has been recognized by the American Academy of Forensic Sciences (AAFS) and the International Association of Identification (IAI). The main method of human identification used by forensic odontology is through dental records, notably in mass disasters and in cases of decomposed or otherwise unidentifiable remains [4]. While dental identification remains a gold standard, situations arise where dental records are unavailable, incomplete, or inconclusive. This necessitates the exploration of supplementary identification characteristics.

Biometric identification methods, such as fingerprints, facial recognition, and iris scanning have well-established limitations. Fingerprints can be degraded, altered, or intentionally removed, facial features change with age and expression, and voice recognition is affected by health status and emotional states [5]. These limitations have prompted investigation into secondary biometric traits, including tongue morphology. The tongue offers several theoretical advantages for identification: it is internally located and relatively protected from external trauma and environmental damage. It can only be voluntarily protruded by living individuals, thus demonstrating vitality of a characteristic important for both medical and forensic contexts. Additionally, its complex network of muscles, blood vessels, nerves, papillae, and taste buds contribute to substantial inter-individual variation [6-7].

Recent studies have documented variation in adult tongue shape [8-11] and reported shape classification in children, with tongue forms described as U-shaped, V-shaped, or bifid, the latter occurring in 11.6% of a Nepalese population [12]. Automated Tongue-Diagnosis Systems (ATDS) have been developed to extract features including tongue shape (small, median, large), color (pink, red, blue, pallid), coating thickness and color, fistulation, and moisture level, based on traditional Chinese medicine classification experience [13]. However, despite growing interest in tongue morphology as a biometric tool, there remains a notable lack of population-specific reference data, particularly for South Asian populations other than Indian.

People of Swat Khyber Pakhtunkhwa (KPK), Pakistan belong to an ethnic group and are mostly Pashtuns (in particular Yousafzai tribe). Being under the effect of different genetic, dietary, and environmental factors,

their tongue might show a different morphology. So far, there has not been any research done on tongue morphometric variation that would be a limitation to using morphology of the tongue as a supplementary factor in forensic identification.

So, the primary goal of this study was to examine the differences in the shape and color of the tongue among members of Swat community. The novelty of this research lies in its consideration of the Swat population as an ethnic group that has had little information recorded about its tongue morphology. This is also likely to be one of the few reports on the systematic study of tongue shape and color in this population with a view to presenting reference materials that would be relevant to forensic dentistry, anthropological investigations, and also to the designing of population-biometric standards which might be specific to South Asian communities.

2. MATERIALS AND METHODS

2.1. Research Design and Study Area

The study was conducted in the Swat District, Khyber Pakhtunkhwa (KPK), Pakistan, an area predominantly known for its Pashtun population. More precisely, the Yousafzai tribe dominates the area demographically and culturally. The term, 'Swat Population' describes people who have been living permanently in the Swat District, mainly from the Pashtun group, sharing linguistic (Pashto), cultural, and genetic backgrounds. Due to the geopolitical arrangement, the terms 'Swat Population' and 'Malakand Population' sometimes refer to the same people as Swat falls within Malakand, a region encompassing several mountain valleys. To make their selection of participants, the researchers considered both university students and members of the local community in Swat District who also fit the study criteria. "The study was approved by the Institutional Review Board/Ethics Committee of the University of Swat (Approval No. UoS/Oric,024). All procedures were conducted in accordance with the ethical standards of the institutional research".

2.2. Sample Size and Sampling Technique

In all, 103 participants were studied, of whom 55 were men and 48 were women. The sample was a convenience one: individuals who were available, generally in good health, and prepared to take part were included, as long as the eligibility criteria had been met.

2.2.1. Inclusion Criteria. The study included permanent residents of Swat District who were willing to provide written informed consent. Participants were required to be in good general health (self-reported) and aged 3 years and above.

2.2.2. Exclusion Criteria. Individuals with current oral or systemic disease affecting the tongue, a history of oral or lingual surgery, or congenital abnormalities of the oral cavity were excluded from the study. Additionally, inability to protrude the tongue voluntarily served as an exclusion criterion.

2.3. Data Collection Procedures

Data collection involved a physical examination and photography that conformed to the standards of the physical examination itself and the methods of picture taking. An expert examiner was responsible for the physical evaluation by directly looking at the tongue in the standardized sunlit room. The examiner used the prescribed evaluation form to write the results of the examination related to the shape, color, surface characteristics, and mobility of the tongue. Documentation through photographs was based on the technique of taking the same series of photos by having the participant sit upright and showing the tongue naturally and comfortably. To ensure similarities between photographs of the participants, the research only used one camera and one light setup.

2.4. Photography Procedure

Photography was performed using a Canon camera equipped with a 100 mm macro lens. The camera settings were set to an aperture of f/8, a shutter speed of 1/125, and ISO 100, with a fixed distance of 40 cm from the camera to the participant's face. A color calibration card was included in each image to ensure accurate color recording. During the procedure, participants were required to stick out their tongue with the tip placed on the lower lip. For each participant, a sequence of three images was taken to verify quality; if the images turned out not very well, they were re-photographed after checking the quality.

2.5. Parameters of the Study

The characteristics of the tongue that were noted for each of the subjects included tongue shape, tongue length, base tone/color, coating characteristics (thickness and color), presence of surface fissures, lateral

tooth indentations, and the pattern of sublingual veins.

Table 1. Tongue Shape Classification Criteria

Shape Category	Definition
Rectangular	Sides are approximately parallel with a squared anterior margin
Round	Anterior margin is curved or rounded without distinct angles
Acute Triangular	Sides converge to form a sharp, pointed anterior tip (angle $< 90^\circ$)
Obtuse Triangular	Sides converge to form a rounded/blunt tip (angle $> 90^\circ$)
Square	Equal length and width with sharp corners
Elliptical	Oval-shaped, longer than wide with regular curves
Bifid	Presence of a distinct cleft or fork at the anterior tip
Triangular	Sides converge to form a triangular shape (general category)

Table 2. Tongue Color Classification Criteria

Color Category	Definition
Pink	Normal healthy pink coloration without visible coating
Whitish Coated	Presence of a white or grayish coating on the dorsal surface
Red	Increased redness beyond normal pink (erythematous)
Yellowish Coated	Presence of a yellow or yellowish coating on the dorsal surface

2.6. Ethical Guidelines

The research followed the accepted human research ethics. Before enrolment, all participants were made aware of the study's aim and procedures and after signing, their informed consent was recorded on a proforma. Being part of the study was wholly optional, and all study records and photos were kept confidential by the staff of the study. "The study was approved by the Institutional Review Board/Ethics Committee of the University of Swat (Approval No. UoS/Oric,024). All procedures were conducted in accordance with the ethical standards of the institutional research".

2.7. Statistical Analysis

The chi-square test was used to compare the tongue shape and tongue color distributions in males and females. The statistical analysis was done via SPSS 26.0 software. Statistical significance was considered at $p < 0.05$.

3. RESULTS

3.1. Shape of the Tongue in the Study Population

In this research, there were 103 samples involved with 55 males and 48 females who participated. The sex ratio was below: 53.4% of participants were males and 46.6% were females. Six varieties of tongue contours based on morphology were discovered as part of this investigation. Some of the various tongue shapes seen are shown in detail through the diagrams 3.1 to 3.6 of this chapter. This depicts all sorts of tongue shapes, such as elliptical, acute triangular, obtuse triangular, rectangular round, and two forked tongues called 'bifid'.

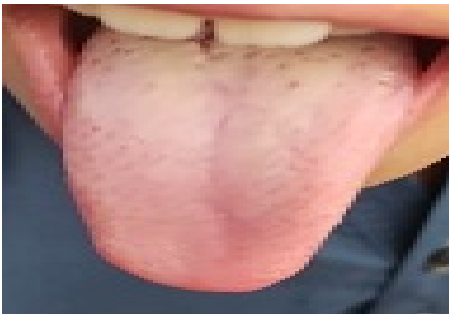


Figure 1. Elliptical Tongue Observed in a 9-year-old Male



Figure 2. Acute Triangular Tongue Observed in a 10-year-old male



Figure 3. Obtuse Triangular Tongue Observed in a 12-year-Old



Figure 4. Rectangular Tongue Observed in a 21-year-old Male

Male

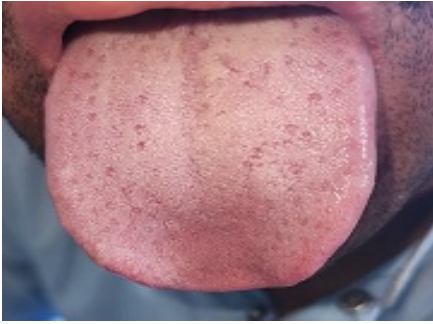


Figure 5. Round Tongue Observed in a 28-year-old Male



Figure 6. Bifid Tongue Observed in a 40-year-old Female

Table 3. Distribution of Participants by Gender ($N = 103$)

Gender	Frequency	Percentage (%)
Male	55	53.4
Female	48	46.6
Total	103	100

Triangular tongues could be divided into three groups: triangles, obtuse angles, and acute angles. Rectangular tongue shapes were reported most often (24.3%), followed by round tongues (23.3%). Among the least found tongue shapes were bifid (5.8%) and simple triangular (2.9%) ones. This variety is in line with previous studies recognizing the shape of the tongue as a possible biometric feature helpful in the identification of corpses.

Table 4. Frequency Distribution of Tongue Shape ($N = 103$)

Tongue Shape	Frequency	Percentage (%)
Rectangular	25	24.3
Round	24	23.3
Acute triangular	14	13.6
Square	13	12.6
Elliptical	10	9.7
Obtuse triangular	8	7.8
Bifid	6	5.8
Triangular	3	2.9
Total	103	100

Table 5. Frequency Distribution of Tongue Color ($N = 103$)

Tongue Color	Frequency	Percentage (%)
Pink	54	52.4
Whitish coated	33	32
Red	11	10.7
Yellowish coated	5	4.9
Total	103	100

Pink was the most commonly reported tongue color, accounting for 52.4% of cases, followed by white-like coating for 32.0%; in contrast, red and yellowish coatings comprised a minority. This finding coincides with the idea that pink is the standard color of the tongue among healthy individuals. Furthermore, coating variation adds another level of distinctive morphological features that might be of importance in the field of forensic identification.

Table 6. Distribution of Tongue Color According to Gender

Tongue Color	Male <i>n</i> (%)	Female <i>n</i> (%)	Total <i>n</i> (%)
Pink	31 (56.4)	23 (47.9)	54 (52.4)
Whitish coated	18 (32.7)	15 (31.3)	33 (32.0)
Red	6 (10.9)	5 (10.4)	11 (10.7)
Yellowish coated	2 (3.6)	3 (6.3)	5 (4.9)
Total	55 (100)	48 (100)	103 (100)

Pink color was predominantly dominant in both genders, and then the whitish coating of tongue appeared. Males and females, in general, showed very similar patterns. This indicated that color variation of the tongue cannot be considered a reliable sex identifier. However, it might be a helpful factor in an overall biometric model that contains the shape of the tongue and other morphology of the oral cavity. This is in agreement with the previous suggestion that combining various tongue traits would be beneficial for use in forensics.

Table 7 shows that the rectangle and circle shapes were found to be the most popular in both sexes. Rectangular pattern was the main choice among men with 27.3%, whereas circle pattern was the most common one in women (16.7% of women vs. 29.1% of men for the leading shape). Interestingly, all six bifid-tongue individuals belonged to female gender.

Moreover, no such cases were found in male participants. Although the size of the sample was a little limited, one can be quite careful when interpreting the result of this finding. However, at the same time, it opens up a discussion as to whether or not the difference in tongue shape can be related to gender, and if so, this topic needs to be explored further.

Table 7. Distribution of Tongue Shape According to Gender

Tongue Shape	Male n (%)	Female n (%)	Total
Rectangular	15 (27.3)	10 (20.8)	25
Round	16 (29.1)	8 (16.7)	24
Acute triangular	9 (16.4)	5 (10.4)	14
Square	8 (14.5)	5 (10.4)	13
Elliptical	7 (12.7)	3 (6.3)	10
Obtuse triangular	3 (5.5)	5 (10.4)	8
Triangular	1 (1.8)	2 (4.2)	3
Bifid	0 (0.0)	6 (12.5)	6
Total	55 (100)	48 (100)	103

Table 7 shows that an overwhelming number of the participants were in the 3-30 years age group, and only a few were above age 30. Besides, as the tongue shape does not generally change after the period of development, it is still a good choice to have several age groups in order to have baseline information for comparative works on tongue in the future forensic context.

Table 8. Age-wise Distribution of Participants

Age Group (Years)	Frequency	Percentage (%)
3–10	33	32
11–20	29	28.2
21–30	28	27.2
31–40	8	7.8
41–50	3	2.9
51–65	2	1.9
Total	103	100

The inferential statistical method was used to compare gender-related differences. Tongue shapes across genders: = 10.62, $df = 7$, $p = 0.156$ (not quite a bit different).

Tongue color across genders: = 1.14, $df = 3$, $p = 0.767$ (not significant).

The findings suggested that even there was some variation in tongue shapes (and color) distributed across genders, these variations were not statistically significant at the conventional threshold of $p < 0.05$.

It means that it could be wrong to think that gender influences tongues' features in such a big way. More studies with more cases must be carried out to see if this is correct.

4. DISCUSSION

The current study analyzed the morphological and color variation of tongues among 103 members of the Swat population. Furthermore, the study also provided a description of baseline reference data for this ethnic group with which one can compare tongue shapes and color at forensic examinations. The study revealed a high degree of morphological variability, with rectangular (24.3%) and round-shaped (23.3%) tongues dominating and pink color (52.4%) being the most abundant one. These results add new knowledge about tongue morphology as one of the traits that can be of importance in forensic identification.

The predominance of rectangular and round-shaped tongues observed in this study population is broadly consistent with findings from other populations, though some variation exists. Jeddy et al. [14] reported U-shaped tongues as the predominant morphology in an Indian population, with V-shaped tongues observed in a subset of females. In contrast, Malik et al. [12] found U-shaped tongues to be the most prevalent in a Nepalese population, while Astekar [8] reported significant variation across different age groups. These differences may reflect population-specific genetic, dietary, and environmental influences, as well as variations in classification systems used across studies [15].

The finding of rectangular shape predominance among males (27.3%) and round shape predominance among females (16.7% vs. 29.1% in males) aligns with some previous observations of gender-related differences in tongue morphology [6, 16]. However, the chi-square analysis in the current study revealed that the differences between gender and tongue shape or tongue color as a gender marker are not statistically significant ($\chi^2=10.62$, $p=0.156$ and $\chi^2=1.14$, $p=0.767$, respectively). This means, despite the presence of some differences for frequency related to gender, these features would probably not act as dependable gender characteristics. This is because the same pattern of results was confirmed by a number of studies

that critically evaluated the usefulness of tongue traits in gender determination [13]

The pattern of tongue color observed, that is, pink tongue in 52.4% of cases, whitish coating 32.0% of people, red tongue - 10.7%, and yellow coating - 4.9% - matched those in previous studies where pink was usually considered as the healthiest color so far [17]. The presence of a whitish coating (32.0%) is most likely due to differences in oral hygiene, hydration status, diet, and normal desquamation of filiform papillae and not disease [9]. The modestly elevated percentage of yellowish coating in female population (6.3% vs. 3.6% of males) could be a result of dietary or hormonal differences between the two groups. This research revealed that only women with bifid tongue were recorded in females (5.8%). Bifid tongue, also called as ‘cleft tongue’, is a condition that is present in many individuals around the world but its frequency varies from person to person. From the lowest of 0.25% to as high as 11.6%. [12, 18] the fact that it only happened to females in this study is something that definitely needs to be looked into more studies. This result should be treated with a considerable caution due to the relatively smaller sample size (n=103), and also very few people who suffered from bifid tongue (n=6). Some earlier studies show the connection between having bifid tongue with certain syndromes but still, most of the cases are the ones without the syndrome [11]. Further studies need to be conducted to determine whether this is a real gender-related pattern in the Swat population or an incidental finding due to sampling variation.

In the first place, the use of convenient sampling from one geographical area restricts the capacity to generalize the results to the entire Pakistani population or other ethnic groups. Since the local residents of Swat belong to a particular Pashtun subgroup with exclusive genetic, cultural, and environmental features, what has been discovered so far might not hold up for the rest of the groups. Secondly, the younger age group (3-30 years of age) made the majority (87.4%) of the group and because of these, the older age groups were underrepresented. As reported, tongue morphology undergoes age-related changes, including papilla loss and changes in mucosal thickness, [19] Additionally, as the sample included in this study was drawn mainly from younger age groups, and a relatively small number of older age groups was included (i.e. elderly group), it is unlikely that the effects of age can be identified at this level. The third issue concerns the

descriptive characteristics of this study.

The present findings suggest that tongue morphology may have potential value as a supplementary forensic characteristic. However, it is essential to moderate claims regarding its forensic applicability. Tongue morphology should not be considered as a validated standalone identification method [3]. Instead, it may provide additional discriminatory information when used in conjunction with established forensic methods, such as fingerprint analysis, DNA profiling, and dental record comparison [4].

For tongue morphology to be considered for forensic applications, several requirements must be met: (1) standardized classification systems that can be reliably applied across examiners and settings; (2) population-specific reference data accounting for genetic, environmental, and demographic influences; (3) demonstration of sufficient inter-individual variation and intra-individual stability over time; and (4) validation through large-scale, multicentric studies with rigorous statistical analysis [20]. The current study contributed to the first two requirements by providing a standardized approach and baseline data for the Swat population.

The exclusive observation of bifid tongue in females, while statistically underpowered, highlights the potential to identify population-specific patterns that may be useful as supplementary characteristics. However, such patterns require confirmation in larger studies before they can be considered for forensic applications.

4.1. Strengths

This study attempted to make the first systematic documentation of tongue morphology in the population of Swat. The employment of standardized examination and photography procedures, the use of systematic classification criteria, and the evaluation of intra - observer reliability all contributed to methodological rigor. Participants from a wide range and both genders were included. This resulted in an overall picture which can be used as a reference for future work.

4.2. Limitations

The main limitations of this study are: (1) convenience sampling, with potential for selection bias; (2) the sample size is 103 individuals, which while being able to provide information is quite limited to make

comparisons; (3) age distribution is extremely skewed with very limited coverage of older age groups; (4) single examiner with no interobserver reliability done; (5) no comprehensive statistical analysis other than that of descriptive statistics and gender comparison; (6) one geographic location is represented, which limits the possibility of the study findings to apply to a larger population; (7) the study being descriptive in nature and not establishing the stability or uniqueness of tongue morphology for identification purposes.

4.3. Conclusion

This study provided morphological data baseline on tongue for Swat population of Pakistan. The results depicted rectangular and round-shaped tongue as predominant among the tongue shapes. On the other hand, pink color of the tongue was the most common finding. Among females, some distributional differences, such as exclusively bifid tongue were observed. Whereas, the differences between males' and females' tongues were not statistically significant, and the small sample size prevented concluding with certainty. The tongue shapes revealed considerable differences among the members of the family population. So, the tongue shape can be considered as an additional means of identification for people in combination with other means of identification. At the same time, the findings did not support the use of tongue morphology alone as an identification tool. It rather furnished some information which might be useful to guide further research projects. Tongue morphology can be considered among many possible supplementary characteristics, that if jointly taken into account as other oral and facial traits, may help compose the biometric profile for personal identification. The current study provided a reference set of morphological characteristics for the understudied Swat population and, at the same time, evidence that tongue analysis is both effective and reliable. Large sample studies with interobserver reliability assessment, balanced age distribution, more comprehensive statistical analysis, and integration of results from tongue morphology with other forensic methods are very much needed to establish the validity and discriminatory power of tongues in the forensics domain.

4.4. Future Research Directions

This study should also take into account its major limitations. Firstly, participants were recruited using convenience sampling technique. This

might mean selection bias and hinder the generalizability of the results to the wider Swat population. Secondly, the age range predominantly comprised younger people with limited older people involved. So, the assessment of age-related variation in tongue shape could be compromised. Thirdly, the small sample size (n=103) was not enough for statistical tests that can detect even subtle differences. Additionally, it was not possible to perform subgroup analyses. Fourthly, since the study was descriptive and used little inferential statistical analysis of the main parameters, it was difficult to make strong statements about population characteristics. Lastly, since the study was restricted to a single location, the authors stated that without additional validation the results might not be applicable to other ethnic populations.

Author Contribution

Abbas Bostan: conceptualization, methodology, data curation. **Sabir Khan:** conceptualization, methodology, data curation. **Asad Ullah:** formal analysis, writing- original draft. **Fazal Akbar:** writing- original draft, data curation, writing- review & editing. **Muhammad Israr:** formal analysis, writing- original draft. **Ishaq Khan:** writing- original draft, data curation, writing- review & editing. **Wajid Khan:** formal analysis, writing- original draft. **Muhammad Ilyas:** data curation, writing- review & editing. **Mukhtar Alam:** data curation, writing- review & editing. **Murad Ali Rahat:** supervision

Conflict of Interest

The authors declare that they have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

Data Availability Statement

Data supporting the findings of this study will be made available by the corresponding author upon request.

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Generative AI Disclosure Statement

The authors did not use any type of generative artificial intelligence software for this research except for the graphical abstract.

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