Research Article

# Nationwide Survey on Knowledge, Attitudes, and Practices regarding Reference Interval Utilization in Clinical Laboratories in Nepal

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**Keywords**

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**Abstract**

**Background**: Reference intervals (RIs) are critical for accurate clinical decision-making, yet many laboratories rely on manufacturer-provided RIs without local validation. This study assessed the knowledge, attitudes, and practices (KAP) of clinical laboratories in Nepal regarding RI utilization, highlighting challenges and opportunities for standardization in alignment with ISO 15189:2022 accreditation.

**Methods**: A nationwide cross-sectional KAP survey was conducted among 56 laboratory professionals. Data were collected via an online questionnaire, covering demographics, RI knowledge, current practices, challenges, and attitudes toward national standardization. Descriptive and inferential statistics (chi-square, Fisher's exact tests) were used for analysis.

**Results**: While 71.4% of respondents correctly defined RIs as the 2.5th–97.5th percentiles, 28.6% held misconceptions. Most laboratories relied on manufacturer-provided RIs (87.5%) or published literature (67.9%). Key challenges to derive one's own RI included method variability and recruiting reference individuals. Accredited labs (ISO 15189) demonstrated better knowledge of RI (93.3% vs. 63.4%, p=0.032) and higher confidence in using current RI (26.7% vs. 7.3%, p=0.047). Strong interest existed in national RI standardization (92.9%) and training (85.7% preferred hands-on workshops).

**Conclusions**: This survey of higher tier clinical laboratories in Nepal reveals that while these laboratories generally understand the importance of reference intervals, significant gaps in practice and standardization remain. The findings highlight an urgent need for inclusive strategies that also address the unique constraints of smaller, widespread laboratories, which perform a large proportion of routine testing in the country. The intense interest in a national program presents an opportunity to improve. Multicenter studies and RI validation integration into accreditation are needed to improve diagnostic accuracy.

**Introduction**

Biological reference intervals (RIs) reported in clinical laboratory test results provide critical information for interpreting a patient's health status and assessing a laboratory's adherence to quality standards. A RI derived from a specific local population using the same analytical platform offers the most accurate interpretation, accounting for biological and analytical variability. Despite this, many laboratories worldwide rely on manufacturer provided RIs for clinical decision making [1].

This reliance is often driven by a lack of knowledge, insufficient resources, or the absence of regulatory requirements mandating the establishment or verification of population specific RIs. In an era of increasing patient engagement and direct-to-consumer testing, discrepancies in RIs may lead to patient confusion and raise concerns among clinicians. Laboratories may respond by quoting published studies, adopting manufacturer RIs, or conducting their studies through direct or indirect methods, to establish or verify RIs [2]. However, each approach carries limitations [3].

Establishing RIs through formal studies is time-consuming, expensive, and methodologically challenging [4]. Factors such as methodological biases, differences in population demographics, and analytical platforms may significantly impact the transferability of RIs across laboratories. Consequently, it becomes essential for laboratories to either establish their RIs or verify adopted ones under local conditions, or for countries to adopt common reference intervals [5].

Improved understanding of RI development and verification processes, better training, and transparent laboratory communication about how RIs are derived are necessary to enhance clinical utility. However, before implementing improvements, it is imperative to assess the current knowledge, attitudes, and practices (KAP) related to RI utilization among clinical laboratories. This study was designed to evaluate KAP regarding reference interval utilization in Nepalese clinical laboratories. Furthermore, as Nepal progresses toward accreditation standards such as ISO 15189:2022, assessing the readiness and attitude of laboratory professionals toward RI utilization can guide stakeholders, including policymakers and professional societies, in developing effective training programs, support mechanisms, and regulatory frameworks to strengthen laboratory quality assurance across the country.

**Methods**

This study employed a cross-sectional KAP survey to assess the understanding and perceptions of Nepalese laboratory professionals regarding RI utilization. Data was collected for:

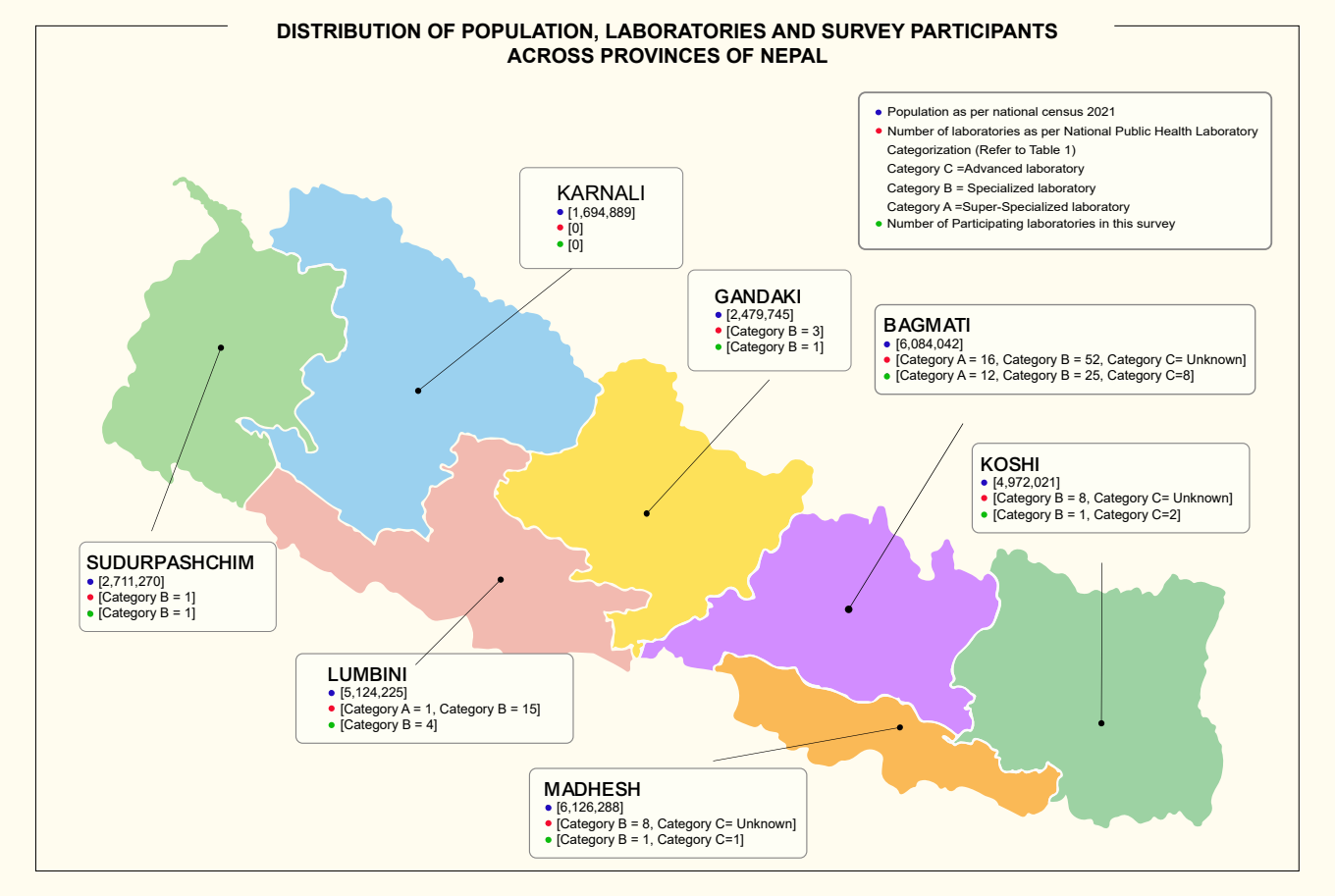
- Laboratory demographics (type, location, years in operation)
- Knowledge about reference intervals
- Current practices in RI utilization
- Challenges faced in establishing RIs
- Attitudes toward national standardization
- Training needs

The study targeted laboratories listed on the National Public Health Laboratory (NPHL)under the Ministry of Health and Population (MoHP) of Nepal, which categorizes clinical laboratories into five levels (A, B, C, D, and E) based on compliance with specific operational standards, including infrastructure, human resources, and test offerings (Table 1). Category A represents the highest standard, while Category E denotes the lowest level of capability and resources.

**Study Population and Sampling**

The study population consisted of laboratory professionals in laboratories classified under Categories A, B and C. The NPHL, operating under the Department of Health Services within the MoHP, maintains an updated list of laboratories in Categories A and B on its official website [6]. As of the latest update, 17 laboratories were categorized as A, and 91 were classified as Category B. A complete list of Category C laboratories is not available, as they are maintained by respective provincial public health laboratories. To ensure broader participation, the Google survey link containing the questionnaire was emailed to the laboratory in charge of each laboratory. Additionally, the survey link was shared on various social media platforms and the official website of national laboratory societies to encourage participation from professionals working in medical college affiliated laboratories and other relevant institutions. Figure 1 illustrates the number of participants from each province, the respective provincial population, and the number of laboratories registered under the NPHL, highlighting regional disparities and resource distribution.

**Figure 1:** Number of participants from each province, the respective provincial population, and the number of laboratories registered under the National public health laboratory as of 10 August 2025 [6].




### Survey Instrument Development

The questionnaire underwent a validation and pilot testing phase prior to its nationwide deployment. The draft instrument was independently reviewed by external experts in clinical biochemistry and laboratory quality assurance to assess content validity, clarity, relevance, and comprehensiveness. Subsequently, a pilot survey was conducted with 10 laboratory professionals from different laboratory categories (A–C). Their feedback on question wording, flow, technical accuracy, and completion time informed minor revisions to enhance clarity and ensure accurate capture of the intended knowledge, attitude, and practice constructs.

### Ethical Considerations

Ethical approval for this study was obtained from the Nepal Health Research Council [Protocol no. 405_ 2024]. Participation in the survey was voluntary, and informed consent was obtained from all respondents before they proceeded with the questionnaire. Data confidentiality and anonymity were maintained throughout the study.

### Data Collection and Analysis

The survey was conducted online using a structured questionnaire in Google Survey. The survey questionnaire used in this study can be provided upon request from the corresponding author. Responses were collected over six months, and the data were analyzed using descriptive and inferential statistical methods to identify key trends and associations in the knowledge, attitudes, and practices of laboratory professionals regarding RI utilization in Nepal. Associations between variables (e.g., accreditation status and RI utilization) were assessed using chi-square tests or Fisher's exact test for small samples. A p-value $<0.05$ was considered significant.

**Table 1:** Clinical laboratory categories in Nepal, outlining the required test scope, infrastructure, equipment, and staffing for each level of operation.

| Category | Test Scope | Space | Equipment & Technology | Staffing |
|---|---|---|---|---|
| **E (Basic)** | Basic hematology, biochemistry, AFB stain, routine urine/stool tests, pregnancy test, simple rapid diagnostic test (RDT). | ≥ 150 sq. ft. | Basic equipment for listed tests. | ≥2 personnel |
| **D (Intermediate)** | Expanded hematology, liver enzymes, lipid profile, creatinine, electrolytes, Gram/KOH stain, serology (RPR, Widal, CRP), all RDTs. | ≥ 250 sq. ft. | Equipment for designated tests. | ≥ 4 personnel (≥ 1 Lab Technologist) |
| **C (Advanced)** | Full hematology, cardiac enzymes, thyroid function, bacterial cultures, ELISA, histopathology, cytopathology, CSF/body fluid, semen analysis. | ≥ 400 sq. ft. | Equipment for expanded diagnostics. | ≥ 6 personnel (≥ 50% with Bachelor's degree, ≥1 with Master's degree) |
| **B (Specialized)** | Special coagulation, hormones, tumor markers, anaerobic & fungal cultures, ELISA/CLIA tests. | ≥ 1,000 sq. ft. | Specialized test equipment. | ≥ 12 personnel (≥ 4 per discipline, ≥ 3 Master's) |
| **A (Super-Specialized)** | All B-category tests + molecular diagnostics, flow cytometry, genetic studies. | ≥ 2,000 sq. ft. | Advanced diagnostic technology. | ≥ 24 personnel (≥ 6 per discipline, ≥ 1 Master's per dept.) |

## Results

### Demographic information

This survey included 56 laboratory professionals, 59% working in Category B laboratories, 21% in Category A, and 19 % in Category C. Each response was collected from a single respondent per laboratory, specifically the quality manager or laboratory in-charge, as they possess the necessary knowledge of RI, their attitude reflects the laboratory's overall stance toward RI, and they are best positioned to describe RI utilization practices within their facility. The majority of participants (82%) were from Bagmati Province, followed by Lumbini Province (7%), Koshi and Madhesh (each 4%), Gandaki and Sudurpaschim, (2%),while no responses were recorded from Karnali Province(Figure 1).Fifty percent of participating laboratories were standalone,12% were from medical college, 18% were private hospital, and the remaining 20% were government laboratories. Most laboratories (69%) had been in operation for more than 10 years, 18% had 1-5 years of experience, and 13% had been operating for 6-10 years. Regarding annual test volume, 69% of laboratories performed more than 50,000 samples, 22% conducted 10,001-50,000 tests, 7% performed 1,001-10,000 tests, and only 2% conducted fewer than 1,000 tests annually. Accreditation under ISO 15189 was reported by 27% of laboratories, while the remaining 73% were not accredited.

### Survey Findings

The KAP survey results are presented in Table 2. Although most respondents demonstrated an understanding of the basic RI concept as the 2.5th to 97.5th percentiles, approximately 29% held misconceptions, interpreting RIs as absolute maximum or minimum values, or as simple averages. Standardization remains a challenge, with 87.5% of laboratories relying on manufacturer provided RIs and 67.9% on published literature, while only 16.1% reported developing in-house RIs.

RI updating practices were inconsistent; about half of the laboratories updated RIs only after significant changes, and only 14.3% did so annually. The most frequently reported challenges in deriving population specific RI included variability in test methods (75%) and difficulty recruiting appropriate reference individuals (62.5%). Encouragingly, there was strong interest (92.9%) in a national RI program, suggesting readiness for coordinated efforts toward standardization. Additionally, there was a high demand for training, with 85.7% of respondents seeking hands-on workshops and 64.3% requesting access to international updated guidelines. Confidence in the current RIs was low, with only 12.5% expressing strong confidence and over half (55.4%) indicating uncertainty or lack of confidence in the intervals they use. However, the ISO 15189:2022 accredited labs were more confident in their RI compared to non-accredited labs (Table 3). Also, the accredited labs demonstrated significantly better knowledge of RI (Table 3).

**Table 2:** Summary of Knowledge, Practices, Challenges, Training Needs, and Attitudes on Reference Intervals.

| Title | Category/Aspect | Details/Responses (%) |
|---|---|---|
| **Knowledge** | Understanding of 2.5th and 97.5th Percentiles | Correct: 71.4%<br>Incorrect: 28.6% |
| | Understanding of Statistical Methods | Correct: 73.2%<br>Incorrect: 26.8% |
| **Practices** | Sources of RI | Manufacturer: 87.5%, Literature: 67.9%<br>RI from other labs: 26.8%, In-house: 16.1% |
| | Frequency of RI Update | When needed: 50%, Instrument change: 23.2%<br>Annual: 14.3%, Every 2–5 years: 19.6%, Never: 7.1% |
| | Use of Age/Sex-Specific RIs | All analytes: 12.5%, Some analytes: 78.6%<br>None: 8.9% |
| | Clinician Engagement | Seek laboratory expertise: 53.6%Do not Seek: 32.1% |
| **Challenges in Establishing RI** | Method Variability | 75.00% |
| | Patient Recruitment | 62.50% |
| | High Reagent Costs | 51.80% |
| **Attitudes** | Confidence in Current RIs | Very: 12.5%, Somewhat: 44.6%, Neutral: 25.0%<br>Low: 10.8% |
| | Interest in National Standardization | Yes: 92.9%<br>No: 3.6% |
| **Training Needs** | Hands on Workshops | 85.70% |
| | Access to guidelines | 64.30% |
| | Online Courses | 55.40% |

**Table 3:** Comparison of study variables among accredited and non-accredited laboratories.

| Variable | Accredited Labs (n=15) | Non-Accredited Labs (n=41) | Statistical Test | p-value |
|---|---|---|---|---|
| **Correct Understanding of RIs (2.5th–97.5th percentiles)** | 14 (93.3%) | 26 (63.4%) | Chi-square Test | 0.032* |
| **Use of Percentile Method** | 12 (80.0%) | 29 (70.7%) | Chi-square ($\chi^2$=0.49) | 0.484 |
| **In-House RI Development** | 4 (26.7%) | 5 (12.2%) | Fisher's Exact Test | 0.234 |
| **Age/Sex-Specific RIs (All Analytes)** | 3 (20.0%) | 4 (9.8%) | Fisher's Exact Test | 0.381 |
| **Annual RI Updates** | 3 (20.0%) | 5 (12.2%) | Fisher's Exact Test | 0.431 |
| **Clinician Engagement** | 10 (66.7%) | 20 (48.8%) | Chi-square ($\chi^2$=1.45) | 0.229 |
| **Very Confident in RIs** | 4 (26.7%) | 3 (7.3%) | Fisher's Exact Test | 0.047* |
| **Top Challenge in RI calculation: Method Variability** | 9 (60.0%) | 33 (80.5%) | Chi-square ($\chi^2$=2.55) | 0.11 |

**Discussion**

The findings from this study underscore several critical issues in the understanding and application of RIs in clinical laboratories in Nepal. A key concern is the evident knowledge gap among laboratory professionals regarding the fundamental concepts of RIs. Misinterpretations of these intervals can lead to inappropriate clinical decisions, emphasizing the need for educational interventions to reinforce foundational statistical and clinical knowledge [7]. A layperson might understand a RI as a way to distinguish between healthy and unhealthy states. However, it should be noted that RI is a guide to clinicians and they are subject to change and depends on the reference population and the methods used. Some healthy individuals may fall outside the reference interval, and some individuals with health issues may have normal results.

Another key challenge identified in this survey is the widespread reliance on externally sourced RIs, particularly those provided by manufacturers or derived from international literature. Although these sources offer convenience, they often lack relevance for local populations due to variations

in ethnicity, diet, altitude, and other demographic and environmental factors. The limited development of locally tailored, in-house RIs raises serious concerns regarding the accuracy and clinical relevance of laboratory interpretations in the local context. A recent study assessing TSH and fT4 RIs from major manufacturers (Roche, Abbott, Beckman, Siemens) found that these manufacturers provided intervals were often inappropriate, being either too narrow or too wide, thus highlighting the importance of establishing population specific RIs and performing regular verification to reduce the risk of misdiagnosis [8]. There is growing support for the development of indigenous RIs in several countries, including India [9], Pakistan [10], various African nations [11], Australia [12], Scandinavia [13] and the Netherlands [14]. These studies consistently conclude that population specific reference intervals are necessary, as the manufacturer provided reference intervals often differ significantly from the values observed in these populations. The standardization of RI between laboratories also reduces patient risk.

Manufacturer recommended RIs may suffer from several limitations, including reliance on outdated studies, lack of essential demographic or pre-analytical information, use of small sample sizes, exclusion of pediatric data, presence of multiple unexplained intervals, and application of inappropriate statistical methods [1]. While regulatory bodies accept these RI, they may not be clinically suitable. Furthermore, verifying RIs by testing 20 healthy individuals may be insufficient, especially if the intervals are overly broad [1]. Establishing RIs is inherently complex, as the choice of method must account for various biological and technical factors tied to both population characteristics and laboratory instrumentation. Understanding the strengths and limitations of RIs is crucial to enhancing diagnostic accuracy and improving clinical decision making. While this study focused on current practices and awareness of traditional direct methods for establishing RI, the potential of indirect methods warrants consideration, especially within resource-limited settings like Nepal. Indirect techniques such as mining existing laboratory information system data or applying statistical models to routine patient results offer a pragmatic, cost-effective alternative for RI estimation [15]. These approaches can circumvent key barriers identified in our survey, including challenges in recruiting reference individuals and high reagent costs. For many stable analytes, indirect methods present a viable pathway toward population specific RI validation without the operational burdens of prospective studies [15]. Future national standardization efforts and training programs in Nepal should therefore explore and integrate validated indirect methodologies as a scalable strategy to improve the appropriateness and applicability of RI across all tiers of laboratories, particularly in widespread Category C, D and E facilities where resources are most constrained.

The absence of standardized and periodic review processes for RIs in nearly half of the participating laboratories raises concerns about these intervals' continued validity and clinical relevance. Without regular updates in response to changes in instrumentation, methodologies, or evolving population health trends, the accuracy of result interpretation may be compromised. This survey also highlights several practical challenges that hinder RI updates, including limited resources, variability in analytical methods, and difficulty in recruiting appropriate reference individuals. According to ISO 15189:2022, accredited clinical laboratories are required to periodically re-evaluate their RIs [16]. Supporting this, a recent study emphasized the importance of seasonally adjusted RIs and proposed an approach that could help minimize over and under diagnosis [17]. Therefore, RIs should be regularly reviewed, revised, and tailored to meet the specific needs of the population served.

Despite these challenges, there is a strong indication of willingness among laboratories to engage in improvement efforts. The high interest in national standardization programs and hands-on training initiatives reflects a collective readiness for capacity building and practice harmonization. The desire for access to updated international guidelines and structured training also suggests that laboratories recognize the importance of aligning with global best practices.

Laboratory accreditation appears to play a crucial role in fostering better RI practices. Institutions that operate within a quality framework in the current survey are more likely to demonstrate higher confidence in their RIs and better conceptual understanding. This reinforces the value of accreditation which a driver of knowledge and performance improvement. While accredited labs report higher confidence, their practical aspect (e.g., update frequency, customization) does not differ significantly from non-accredited labs. This suggests accreditation improves awareness but not necessarily implementation. Nevertheless, increased awareness can be a positive outcome, but translating that awareness into consistent, practical application across all aspects of laboratory operations requires ongoing effort and commitment.

A coordinated national strategy is essential to advance good laboratory practices in Nepal. This should include regular training for laboratory personnel, stronger collaboration between clinical and laboratory professionals, integration of RI review into routine quality management systems and supporting research initiatives to conduct multicentre studies for the development of population specific RIs. Also, the RI validation should be integrated into accreditation processes, with support provided to laboratories pursuing accreditation. Such efforts will support more accurate diagnostic interpretation, promote evidence based clinical care, and improve patient outcomes.

Our study's modest sample size (n = 56) and the concentration of data from Bagmati Province (82%) limit its generalizability. However, it is essential to note that Bagmati is the capital province of Nepal, home to a significant portion of the country's population and a high density of clinical laboratories. Also our study focuses on higher-tier laboratories (categories A and B), which excludes the majority of lower- tier laboratory

facilities in Nepal that perform a substantial volume of basic routine testing, particularly in rural and remote settings. Therefore, while our findings offer a critical first national assessment of RI utilization among higher-tier laboratories and provide a foundation for policy development, they should be interpreted with recognition of these geographic and tier-based limitations, particularly regarding the widespread lower-tier laboratories that serve much of Nepal's rural population.

## Conclusion

This nationwide survey of higher-tier clinical laboratories in Nepal demonstrates that while foundational awareness of reference interval importance is present, substantial implementation gaps persist in practice, standardization, and periodic validation. Despite a strong interest in national RI standardization and targeted training particularly among accredited laboratories, which exhibited more robust knowledge and confidence, widespread reliance on non-validated, manufacturer provided RIs remains a critical concern. These findings emphasize the necessity for structured policy and capacity building initiatives that are inclusive of all laboratory tiers. Moving forward, we recommend integrating RI validation into national accreditation frameworks, supporting multicenter studies to establish population specific reference intervals, and developing scalable training programs to enhance appropriate RI utilization.

## Conflict of Interest

None.

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None.

## Authors Contribution

VP - Conceptualization, Writing original draft
VP, SP, TB - Preparation of survey questionnaire
SP, DT, AK and NK - Conducted online survey and collected results, Manuscript review and editing
TB - Manuscript review and approval of final version

## Ethics approval and consent to participate

This study is in compliance with the ethical principles for medical research involving human subjects, in accordance with the Declaration of Helsinki. Ethical approval for this study was obtained from the Nepal Health Research Council [Protocol no. 405_ 2024].

## References

1. Badrick T, El-Khoury JM, Theodorsson E. Laboratory reference intervals-history and modern approaches for improved utility. Scandinavian Journal of Clinical and Laboratory Investigation. 2025 1-3. doi: https://doi.org/10.1080/00365513.2025.2512995
2. Ozarda Y, Higgins V, Adeli K. Verification of reference intervals in routine clinical laboratories: practical challenges and recommendations. Clinical Chemistry and Laboratory Medicine (CCLM). 2019;57(1):30-37. doi: 10.1515/cclm-2018-0059
3. Katayev A, Balciza C, Seccombe DW. Establishing reference intervals for clinical laboratory test results: is there a better way? American journal of clinical pathology. 2010;133(2):180-186. doi: 10.1309/AJCPN5BMTSF1CDYP
4. CLSI CLSI/IFCC Defining, establishing, and verifying reference intervals in the clinical laboratory;approved guidelibne,3rd ed. CLSI document C28-P3. Wayne,PA; Clinical and and Laboratory Standards Institute;2008,vol 28:1-50 pp. Available from: https://clsi.org/shop/standards/ep28/ (Accessed 10 July 2025).
5. Doyle K, Bunch DR. Reference intervals: past, present, and future. Critical Reviews in Clinical Laboratory Sciences. 2023;60(6):466-482. doi: 10.1080/10408363.2023.2196746
6. National Public Health Laboratory. Deparment of health and services,ministry of health and population, government of Nepal. https://nphl.gov.np/page?id=19&title=registered-laboratory [Accessed 10 August 2025].
7. van SchrojensteinLantman M, van Berkel M, Kuijper P, Langelaan M, Brouwer N, Thelen M. Clinical Decision-Making Suffers from Inequivalent Measurement Results and Inadequate Reference Intervals. Clinical Chemistry. 2024;70(11):1383-1392. doi: 10.1093/clinchem/hvae129
8. Dirks NF, den Elzen WP, Hillebrand JJ, Jansen HI, Boekel ET, Brinkman J et al. Should we depend on reference intervals from manufacturer package inserts? Comparing TSH and FT4 reference intervals from four manufacturers with results from modern indirect methods and the direct method. Clinical Chemistry and Laboratory Medicine (CCLM). 2024;62(7):1352-1361. doi: 10.1515/cclm-2023-1237
9. Malati T. Whether western normative laboratory values used for clinical diagnosis are applicable to Indian population? An overview on reference interval. Indian Journal of Clinical Biochemistry. 2009;24(2):111-122.doi: 10.1007/s12291-009-0022-1
10. Afzal N, Batool H, Raza S, Ayub S, Bashir S, Hayat A et al. A National e-Survey of Adult Reference Intervals of Routine Chemistry Analytes Used by Laboratories across Pakistan: A Step Towards Harmonization. EJIFCC. 2025;36(2):132. https://pubmed.ncbi.nlm.nih.gov/40584990/
11. Price MA, Fast PE, Mshai M, Lambrick M, Machira YW, Gieber L et al. Region-specific laboratory reference intervals are important: A systematic review

of the data from Africa. PLOS Global Public Health. 2022;2(11):e0000783. https://doi.org/10.1371/journal.pgph.0000783
12. Tate JR, Sikaris KA, Jones GR, Yen T, Koerbin G, Ryan J et al. Harmonising adult and paediatric reference intervals in Australia and New Zealand: an evidence-based approach for establishing a first panel of chemistry analytes. The Clinical Biochemist Reviews. 2014;35(4):213. https://pmc.ncbi.nlm.nih.gov/articles/PMC4310061/
13. Rustad P, Felding P, Franzson L, Kairisto V, Lahti A, Mårtensson A, et al. The Nordic Reference Interval Project 2000: recommended reference intervals for 25 common biochemical properties. Scandinavian journal of clinical and laboratory investigation. 2004;64(4):271-284. doi: 10.1080/00365510410006324
14. den Elzen WP, Brouwer N, Thelen MH, Le Cessie S, Haagen IA, Cobbaert CM. NUMBER: standardized reference intervals in the Netherlands using a 'big data'approach. Clinical Chemistry and Laboratory Medicine (CCLM). 2018;57(1):42-56. doi: 10.1515/cclm-2018-0462
15. Jones GR, Haeckel R, Loh TP, Sikaris K, Streichert T, Katayev A, et al. IFCC Committee on Reference Intervals and Decision Limits. Indirect methods for reference interval determination–review and recommendations. Clinical Chemistry and Laboratory Medicine (CCLM). 2018;57(1):20-29. doi: 10.1515/cclm-2018-0073
16. ISO 15189:2022. Medical laboratories-requirements for quality and competence. Geneva:International Organization for Standardization(ISO);2022. Available from: https://www.iso.org/standard/76677.html
17. Muse VP, Aguayo-Orozco A, Balaganeshan SB, Brunak S. Population-wide analysis of hospital laboratory tests to assess seasonal variation and temporal reference interval modification. Patterns. 2023;4(8). doi: 10.1016/j.patter.2023.100778