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Knowledge on Clinical Laboratory Reference Intervals among Healthcare Professionals at the Health District of Bamenda, Cameroon: Associated Factors and Predictors

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Abstract

Background: Clinical laboratory reference intervals (CLRIs) are essential for accurate interpretation of test results, but they differ across populations. Using transferred CLRIs improperly due to limited knowledge among healthcare professionals (HCPs) may lead to misdiagnosis. This study assessed the factors and identified the predictors of the level of knowledge (LOK) regarding CLRIs among HCPs in the Health Districts of Bamenda, Cameroon. **Methods:** A hospital-based cross-sectional study that involved 314 HCPs, aged 18 years and above. Chi-square and multivariable logistic regression analysis were used to assess the factors and identify independent predictors of LOK, respectively. $p \leq 0.05$ was considered significant. **Results:** The proportion of HCPs with adequate LOK on CLRIs was 35%. Our univariable analysis shows that HCPs' LOK regarding CLRIs was significantly associated with interaction with HCCs ($p < 0.001$) and quality of training curriculum ($p = 0.001$). Limited interaction with HCCs was linked to 2.8 times (64%) lower likelihood of having adequate LOK compared to those with extensive interaction (aOR = 0.36, 95% CI 0.21 - 0.63, $p < 0.001$) and those with perceived training curriculum as good rather than better had 1.8 times (44%) lower likelihood of adequate knowledge (aOR = 0.56, 95% CI 0.33 - 0.95, $p = 0.033$) were significant predictors of LOK regarding CLRIs. **Conclusion:** The LOK regarding CLRIs is surprisingly low among HCPs. Frequent provider-patient interactions and training curricula were the associated factors and most significant predictors. Immedi-

ate emphasis on targeted curriculum reform and enhanced clinician-patient interaction is recommended to boost the LOK regarding CLRLs, diagnostic accuracy and patient outcomes.

Keywords

Clinical Laboratory Reference Intervals, Level of Knowledge, Healthcare Professional, Health Districts of Bamenda, Factors, Association, Predictors

1. Introduction

Clinicians and researchers interpret test results based on the RIs provided alongside the laboratory results report. The CLRIs comprise 95% of the values from healthy individuals in a population [1]. These CLRIs vary with sex, age, race, geographical location, diet and genetic make-up [2]-[5]. The use of CLRIs provided by the manufacturer, published literature, and websites is not uncommon but is not good practice, as these values were derived from different populations [6]-[8]. The quality of equipment, capability of personnel, procedure for standardization of the methods, method of verification and quality control on the equipment, has a great role to play in the quality of established CLRIs [5] [9]-[13]. There also exist several guidelines for establishing these values [14]-[17].

Several studies have been done on the establishment of CLRIs [12] [13] [18]-[23]. These can only be effectively established if health care professionals (HCPs), medical doctors, nurses and laboratory professionals possess adequate knowledge of these entire concepts of CLRIs. These can be achieved through adequate training with a standard professional training curriculum that thoroughly elaborates on the concept of CLRIs, a satisfactory training duration, sufficient work experience or exposure, a manageable workload, and frequent interaction with Healthcare consumers (HCCs).

Although all HCPs utilise CLRIs for diagnosis and patient management, most of them are not involved in the establishment process. There is scarce published evidence to demonstrate that they are conversant with the concept. Therefore, our study aimed to identify the factors and predictors of level of knowledge (LOK) regarding CLRIs among HCPs. The outcome from this study shall fill the knowledge gap regarding CLRIs and inform strategies for their effective establishment.

2. Materials and Methods

2.1. Ethical Considerations

Authorisation to carry out this study was obtained from the North-West Regional Delegation for Public Health. Authorisation to access the Health Facilities, Regional Hospital Bamenda was obtained from the Director of the hospital. The Institutional Review Board of the University of Bamenda (Project Identification Number: 2024/0014H/UBa/IRB) and North-West Regional Ethical Committee for

Human and Health Research (CRESH) (No. 2023/09/16/CRESH-NW) provided ethical clearance for this study.

2.2. Study Site

The study site was the Health Districts of Bamenda (HDB) [24] in the North-West Region of Cameroon. The HDB incorporate two health districts (Bamenda and Nkwen Health districts) with 19 health areas, a population of about 337,036 inhabitants, a surface area of about 560 m^2, hilly topography, altitude between 1100 m and 1430 m above sea level [25].

2.3. Study Design

This study employed a hospital-based cross-sectional design conducted between November 2024 and January 2026 at the HDB selected from four hospitals (two public and two private), Regional Hospital Bamenda, St Mary Catholic Hospital Mankon Bamenda, Nkwen District Hospital Bamenda, and The Martins Catholic Hospital, Nkwen, Bamenda. Selection of these hospitals was done by a multi-stage stratified sampling technique (Constantinescu, 1995) [26] [27] based on the populations of HCPs in health facilities (at least two permanent onsite doctors, at least 20 nurses plus laboratory professionals) and workload (at least 50 patients per week). The study participants included Healthcare professionals (HCPs), medical doctors, nurses, and medical laboratory professionals, who were actively involved in patient care, excluding administrators and support staff members. This design is relatively cheap, easy, fast, focused, scientific and relevant.

The study team visited the administration of the different health facilities, explained and distributed the informed consent forms and questionnaires for participants. Participants were given a week to respond to the questionnaires. Those who did not understand any of the questions were free to contact any team, the principal investigator personally or on the phone.

The independent variables constituted the questionnaire including the gender (male and female), age (group groups: <30 years and ≥30 years), HCPs (medical doctor and others (Nurses and medical laboratory professional)), years of training (<3 years and ≥3 years), years of work experience (<3 years and ≥3 years), type of health facility (public and private), workload ("high" indicate ≤ 50 patients and "low" indicate > 50 patients attended to per week), interaction of HCPs with HCCs ("extensive" if CLRIs were discussion with HCCs during interpretation of results and "limited" if it was not discussed) and type of quality of training curriculum ("better" if the concept of RIs was included in the syllabus of training curriculum and "good" if it was not included) [28].

The dependent variable constituted was the LOK regarding CLRIs, which was assessed using the Likert scale (excellent, very good, good, average and poor) using eight questions. Respondents who had ≥50% responses indicating excellent and/or very good were considered to have adequate knowledge. The questions assessed included: population characteristics (age, sex, ethnicity, etc.), biological

variability (pregnancy, menstrual cycle, health status, etc.), lifestyles (diet, physical activity, etc.), technical factors (assay methodology, calibration, quality assurance, method verification, method comparison, multicenter studies, etc.), specimen collection and handling (time of collection, sample type, etc.), geographical environment (climate, altitude, etc.), laboratory standards or guidelines/regulation standards for establishment of CLRIs ((Ethical consideration - confidentiality, Informed consent/Assent, participant selection, transference of CLRIs, etc.) statistical considerations (sample size, data distribution, data analysis, etc.). The questionnaire was pre-tested for validity at St Blaise Catholic Hospital, Bamenda, with 30 healthcare professionals using Cronbach's alpha in SPSS version 25. A Cronbach's alpha of ≥0.7 was considered a good internal consistency.

2.4. Sample Size

The sample size was calculated using the proportion for an infinite population. We assume a maximum sample size with an expected proportion of 50%, with an error margin of 5% at 95% confidence interval. A calculated sample size of 385 HCPs was obtained. The infinite population correction was applied, taking into consideration the sample size of about 946 HCPs obtained from the National Institute of Statistics and a sample size of 228 HCPs [17]. In addition, 30% was added to take care of non-respondents, giving a final sample size of 296 HCPs for administration of the questionnaires.

2.5. Inclusion and Exclusion Criteria

Participants included in the study were HCPs, medical doctors, nurses, and laboratory professionals over 18 years of age, working in any of the selected hospitals, present at the facilities during the period when the questionnaire was administered, and who consented to participate in the study. Excluded from the study were HCPs who consented to participate, completed the questionnaire, but later withdrew.

2.6. Data Collection

Two trained data collectors alongside the principal investigator collected that data. Data were gathered only from participants who met the inclusion criteria. The information on gender, age, health profession, years of training, years of work experience, type of health facility, workload, interaction of HCPs with HCCs, and quality of training curriculum was recorded. The data were coded and entered into Microsoft Office Excel 2012 (Microsoft Corporation, Redmond, Washington, United Kingdom) software and cross-checked by a second data collector for clerical errors.

2.7. Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 25 software (IBM Corporation, Chicago, Illinois, United States). Frequency distribution was employed for descriptive statistics. Univariate analysis with the chi-square test was used to assess the association between HCPs' LOK of CLRIs

and their demographics. Predictors of LOK regrading CLRLs among HCPs were identified by constructing a multivariable logistic regression model. Statistical significance was considered a p-value ≤ 0.05 at 95% confidence interval.

3. Results

Out of 325 questionnaires administered to HCPs, 314 responses were received, giving a response rate of 97% (Table 1). A Cronbach's alpha of 0.8 was obtained, indicating good internal consistency. Out of the 314 HCPs who responded, 160 (51%) were from the Regional Hospital Bamenda, 84 (27%) Nkwen District Hospital, Bamenda, 42 (13%) were from the Martins Catholic Hospital, Nkwen, Bamenda and 28 (9%) St Mary Catholic Hospital Mankon, Bamenda. One hundred and thirty-three (forty-two percent) were males, 180(57%) were less than 30 years old, 43 (14%) were medical doctors, 78 (26%) had less than 3years of professional training, 241 (79%) worked in the public sector, 187 (64%) had less than three years of work experience and 172 (58%) had high workload, 155 (49%) had extensive interaction with HCCs, 143 (49%) had perception of better training curriculum and 110 had adequate knowledge on RIs giving a prevalence of 35%.

Table 1. Frequency distribution of factors associated with levels of knowledge regarding clinical laboratory reference intervals among healthcare professionals.

Variables	Category	Frequency (n)	Percentage (%)
Sex (N = 314)			
	Males	133	42
	Females	181	58
Age Range (N = 314)			
	<30 years	180	57
	≥30 years	134	43
Profession (N = 314)			
	Medical Doctor	43	14
	Others HCPs	271	86
Years of Training (N = 304)			
	<3 years	78	26
	≥3 years	226	74
Type of Practice (N = 306)			
	Public sector	241	79
	Private sector	65	21
Years of Work Experience (N = 292)			
	<3 years	187	64
	≥3 years	105	36
Work Load (N = 298)			
	High	172	57.7
	Low	126	42.3

Continued

Interaction with Healthcare Customers (N = 302)		
extensive	155	51
Limited	147	49
Quality of Training Curriculum (N = 295)		
Better	143	49
Good	152	51
LOK on CLRIs (Outcome) (N = 314)		
Adequate	110	35
Limited	204	65

LOK; Level of knowledge, CLRLs; Clinical Laboratory Reference Interval, HCPs; Health care professionals.

Our univariable analysis (Table 2) indicated that there was a statistically significant association between LOK of HCPs regarding CLRIs and: interaction with HCCs (X^2 = 19.89, $p < 0.001$) and quality of training curriculum (X^2 = 10.162, p = 0.001). There were no statistically significant association with: sex (X^2 = 1.040, p = 0.308), age range (X^2 = 0.535, p = 0.465), profession (X^2 = 0.444, p = 0.505), years of training (X^2 = 2.670, p = 0.102), type of practice (X^2 = 0.257, p = 0.612), years of work experience (X^2 = 1.534, p = 0.216), and workload (X^2 = 1.164, p = 0.28).

Table 2. Univariable analysis of the association of factor and level of knowledge regarding clinical laboratory reference intervals amongst healthcare professionals.

Variable	Category	Level of Knowledge		Total	X^2 Value	p-value
		Limited (n = 204)	Adequate (n = 110)			
Sex (n = 314)						
	Male	82 (62)	51 (38)	133	1.040	0.291
	Female	122 (67)	59 (33)	181		
Age Range (n = 314)						
	<30 years	120 (58.8)	60 (54.5)	180	0.535	0.465
	≥30 years	84 (41.2)	50 (45.5)	134		
Profession (n = 314)						
	Medical Doctor	26 (12.7)	17 (15.5)	43	0.444	0.505
	Others	178 (87.3)	93 (84.5)	271		
Years of Training (n = 304)						
	<3 years	56 (28.7)	22 (20.2)	78	2.670	0.102
	≥3 years	139 (71.3)	87 (79.8)	226		
Type of Practice (n = 306)						
	Public	155 (77.9)	86 (80.4)	241	0.257	0.612
	Private	44 (22.1)	21 (19.6)	65		

Continued

Years of Work Experience (n = 292)					
<3 years	124 (66.7)	63 (59.4)	187	1.534	0.216
≥3 years	62 (33.3)	43 (40.6)	105		
Work Load (n = 298)					
High	107 (55.4)	65 (61.9)	172	1.164	0.281
Low	86 (44.6)	40 (38.1)	126		
Interaction with Healthcare consumer (n = 302)					
Limited	113 (58.2)	34 (31.5)	147	19.895	<0.001*
extensive	81 (41.8)	74 (68.5)	155		
Quality of Training Curriculum (n = 295)					
Good	111 (58.4)	41 (39.0)	152	10.162	**0.001***
Better	79 (41.6)	64 (61.0)	143		

*Statistically Significant.

Table 3. Multivariable logistic regression: factors associated with an adequate level of knowledge regarding clinical laboratory reference interval.

Variables	Category	Unadjusted Odds Ratio (OR)	95 CI	*p*-value	Adjusted Odds Ratio (aOR)	95 CI	*p*-value
Years of professional Training							
	≥3 years	1.00			1.00	–	–
	<3 years	0.63	0.36 - 1.1	**0.104**	0.79	0.43 - 1.47	**0.463**
Interaction with Healthcare Customers							
	Extensive	1.00			1.00	–	–
	Limited	0.33	0.20 - 0.54	**<0.001***	0.36	0.21 - 0.63	**<0.001***
Quality of Training Curriculum							
	Better	1.00			1.00	–	–
	Good	0.456	0.28 - 0.74	**0.002***	0.56	0.33 - 0.95	**0.033***

*statistically significant OR; Odd ratio, aOR; Adjusted Odd Ratio, CI; Confidence Interval.

Following our univariable analysis, years of professional Training, interaction with healthcare customers and quality of training curriculum met the inclusion criteria (p-values < 0.2) and were entered in the final multiple logistic regression model. Cases with missing data on any of the variables were excluded using list-wise deletion, resulting in a final sample of 283 complete cases in the model. The final model showed no evidence of significant lack-of-fit (Hosmer-Lemeshow goodness-of-fit test: $p = 0.26$). The reference categories for the variables were the first (favourable) category (Table 3): ≥3 years of professional training, Extensive interaction with healthcare customers, and perception of better quality of training curriculum. The Variance Inflation Factors (VIF) for all variables were less than 2.0, indicating no significant multicollinearity among the predictors. Our final model reveals that HCPs who had limited interaction with HCCs had 2.8 times

(64%) lower odds of having adequate LOK compared to those with extensive interaction (aOR = 0.36, 95% CI 0.21 - 0.63, $p < 0.001$). Those had perception of training curriculum as good rather than better had 1.8 times (44%) lower odds of adequate LOK (aOR = 0.56, 95% CI 0.33 - 0.95, $p = 0.033$). Years of training were not independently associated with LOK.

4. Discussion

Our study revealed that only 35% of HCPs possessed adequate LOK regarding CLRIs. This low prevalence indicates a significant LOK gap, which is a major concern. It could lead to misinterpretation of test results resulting to miss diagnosis, inappropriate treatment and delay in patient care [29] [30]. Our finding aligns with the regional patterns in low-income and middle-income countries (LMIC), where extensive challenges in clinical laboratory interpretation may cause an increase in false positives in routine work and research [30]. In a study in Kenya, 85% of normal healthy clients for the Blood Urea Nitrogen test were misclassified as abnormal when Western-based CLRIs were used, compared to 10% when locally established CLRIs were used [31]. This was evidence of limited adaptation of locally established CLRIs that may be attributed to a gap in LOK regarding CLRIs. In Ethiopia, western derived CLRIs were adopted because there were no locally established ones available [32]. Similar gaps have also been reported in LMIC, where dependence on Western-derived CLRIs resulted in misclassification of normal individuals as abnormal, aggravating diagnostic challenges [33].

Our univariable analysis identified only two factors significantly associated with adequate LOK of CLRIs extensive interaction of HCPs with HCCs ($p < 0.001$) and perception of better-quality Training curriculum ($p = 0.001$). The former may be because extensive interaction between HCPs and the HCCs forces the HCPs to translate complex laboratory data, including CLRIs, within the HCCs. This process improves practical application and retention of concepts, thereby strengthening the provider's LOK [34] [35]. Likewise, the latter might be because perception of better curriculum enhances better training [36]. There is evidence from several studies that the use of standard curricula enhances the quality of trainees [35] [37]-[42].

Our multivariable logistic regression model shows that HCPs with limited interaction had 2.8 times (64%) lower odds of adequate LOK (adjusted odds ratio (aOR) = 0.36) compared to those with extensive interaction. This supports the "Learning by Doing" theory, which indicates that repeated clinical engagement enhances theoretical LOK through real-world application [43]. The finding that those who had perception of curriculum as "good" rather than "better" resulted in 1.8 times lower odds of LOK (aOR = 0.56) suggests that the perceived excellence of a program directly correlates with its effectiveness. This aligns with the fact that HCPs who are highly satisfied with their quality of training curriculum feel significantly more competent in applying new knowledge. On the contrary, low satisfaction with the quality of training curriculum has been linked to significant

competency gaps [44]. Other studies reveal that curricula that fail to respond directly to "national health needs" or lack the interactive element fail to prepare students effectively [37] [38] [40].

5. Limitations

Since this is a cross-sectional study, the use of a non-probability sampling method in selected sites may limit generalizability.

6. Recommendations

The results recommend that HCPs should:

1) Receive continuing professional training programmes that emphasise clinical laboratory interpretation and locally derived CLRIs.

2) Training curriculum in medical, nursing, and laboratory training professional institutions should be reformed to include knowledge on the concept of CLRIs, including population-specific, analytical variations and the establishment of CLRIs.

3) Physical interventions between HCPs and HCCs and strengthening the laboratory-clinician interface should be encouraged.

7. Conclusion

Our study concludes that the prevalence of LOK regarding CLCLRIs is alarmingly low among HCPs, 35%. Extensive provider-patient interaction and inclusion of better training curricula were the associated factors and most powerful modifiable predictors of LOK. Targeted continuing education, curriculum reform, and improved clinician-client interaction are urgently recommended to boost the LOK regarding CLRLs, diagnostic accuracy and patient outcomes [28].

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Data Availability Statement

The data supporting the findings of this study are available within the article. Data

are also available from the corresponding author, V.N.F. on request.

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Authors' Contributions

VNF conceived and developed the computations, designed the study, trained and supervised (sample collection and analysis), statistical analysis and writing of the manuscript. LLN and MBA conceptualised, reviewed the data collected and supervised the manuscript. All authors discussed the results and contributed to the final manuscript.

Conflicts of Interest

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them to carry out or during the study.

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