Capacities and Functionalities Assessment of Veterinary Laboratories in South-west Nigeria Using the FAO Laboratory Mapping Tool

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Laboratories play significant roles in all the critical processes of detecting rapid infectious disease outbreaks, risk assessments, early warnings, early responses and notifications, and monitoring and surveillance[1,2]. Veterinary Laboratories (VLs) that rapidly identify, respond to and control rapidly spreading and emerging (or re-emerging) infectious and zoonotic diseases is critical to: (1) the financial performance of animal agriculture and international trade; (2) livelihoods of animal related industries; and (3) nutritional status, food security, and the socio-economic well-being of a country[3].

Over the years, the Global Health Security Agenda (GHSA) has supported collective and sustainable capacity-building at the international, regional and local levels in order to promote rapid detection, prevention or mitigation, and to support responses needed to control emerging infectious diseases (EIDs) outbreaks before they become epidemic. Capacity-building is additionally designed to reduce the impact of naturally occurring outbreaks, as well as intentional or accidental releases of dangerous pathogens[4]. The agenda spurs progress toward implementation of the World Health Organization's International Health Regulations (2005) (WHO/IHR) and other global health security frameworks, such as the World Organization for Animal Health. Since the Ebola outbreak in West Africa in 2014, the GHSA has been committed to strengthening capacity in infrastructure, equipment, and skilled personnel across sectors, sustainable national biosafety, biosecurity, and especially laboratory systems in Africa, all to ensure a safer world.

The ability of VLs in developing countries, applicable to Nigeria, is frequently limited by many factors. These factors may be assessed along three dimensions: (1) skilled and competent personnel; (2) adequacy and upgrade of equipment/materials, and (3) the ability to mobilize technical support when needed[5]. To address these limitations in African countries, the Food and Agriculture Organization of the United Nations (FAO) developed a core laboratory mapping tool (LMT-core) to aid in pre-emptive laboratory assessment. Released for public use in May 2014, this instrument can determine and identify gaps in laboratory functions, define strategic pathways, and set targets for capacity building[2]. Currently, to the best of our knowledge, this is the first study in Nigeria to use the FAO LMT tool for veterinary laboratory assessments to determine the capacities and functional status in compliance with the GHSA requirements.

This study was conducted in the south-western states of Oyo and Ogun in Nigeria, selected due to the higher numbers of livestock populations and VLs in these areas. A cross-sectional survey was conducted at eleven laboratories. These included: (i) seven veterinary laboratories that were based at academic institutions (three microbiology, two parasitology and two pathology laboratories); (ii) two government veterinary clinics and laboratories in each state; (iii) one private veterinary laboratory; and (iv) one national veterinary laboratory were purposively selected. The inclusion criteria for laboratories were performance of veterinary diagnostics, location within the study area, and establishment of minimum standards against which assessment might be carried out. Before the commencement of the study consent was obtained from each laboratory. Positive responses indicating a willingness to participate in the study triggered the initiation of the assessment and questionnaire process.

The LMT-Core, is a standardized set of questions embedded in a Microsoft spreadsheet (Microsoft Excel 2007). Using such, we gathered information on five key aspects: (1) general laboratory profile; (2) infrastructure, equipment, and supplies; (3) laboratory performance; (4) quality assurance and bio-safety/bio-security; and (5) laboratory collaboration and networking. Within these areas were 17 categories and 108 subcategories, each of which addressed specific laboratory functions. For instance, the general laboratory profile aspect sought information on geographic location (in terms of strategic placement and accessibility, laboratory budget, basic electricity and potable water supplies, and sustainable personnel organization systems). The aspect of infrastructure, equipment, and supplies gathered information on containment facilities, laboratory biosafety, equipment for bacterial, viral, serological and parasitological diagnosis, and reagent supply. Every laboratory generated an individual profile or 'map' using automatic calculations embedded in the spreadsheet, thus allowing the laboratory to visualize their unique laboratory capability and capacity status for the five aspects assessed.

We scored laboratories based on observations and interviews with heads of respective units of laboratories and by strictly following the guidelines provided by FAO for assessment of laboratories (Supplementary Table S1, available in www.besjournal.com). Briefly, for each question of the assessment set of four options were provided as responses. The single best option describing the existing situation in the laboratory was recorded by the assessor. Where a suitable answer was not available or no answer was provided, the respective scoring area was marked not applicable (N/A). For all questions where 'N/A' was entered, the associated subcategory was omitted from the summary score. Where a laboratory struggled to select between two scoring options, a preferred score best representing the laboratory's situation was selected, and the reason for hesitation was documented as a comment in the assessors' column for comment/observation (column K). Additional information guiding assessors to determine the appropriate score was provided in column L of the spreadsheet (e.g. specific observations or documents needed to select from the 4 possible options), and was used by all assessors to provide consistency in scoring between the different laboratories.

The scoring within the LMT-core sums to 100% that is the ideal and achieved when a laboratory scores the maximum points (n = 4) in all the subcategories. Each laboratory was given a reliability score based on the number of questions answered, excluding N/A as a completed response. Questionnaires with 0%–69% completion rendered a low reliability score and completion of 70%–89% rendered a medium confidence score and, lastly, completion of 90%–100% rendered the questionnaire as confidently reliable.

Following verification for completeness, each LMT-core questionnaire was imported into the LMT automated analytic tool, available through an FAO interface. This process was supervised and eviewed by at least two researchers in every case. Outputs were generated in a ‘Summary sheet’ with scores as sub-values and graphs for the five core areas and seventeen different categories presented in a tabulated format. Graphic depictions of individual laboratory functionalities for each of the five key areas, including the specific strengths and weaknesses, were generated and analyzed. Scores were presented in percentages and compared with the theoretical ideal of 100%. The final laboratory capacity assessment was presented as either ‘advanced’ (67%–100%), ‘moderate’ (34%–66%) or ‘basic’ (0%–33%) (see Figure 1). Inter-laboratory comparisons, regarding performance, was conducted using ordinary one-way ANOVA and Tukey’s multiple comparisons test ($P = 0.05$). For confidentiality purposes, the study excluded any identifiers of individual laboratories, and facilities were further re-grouped into regions A (Oyo state) and B (Ogun state) to assure anonymity.

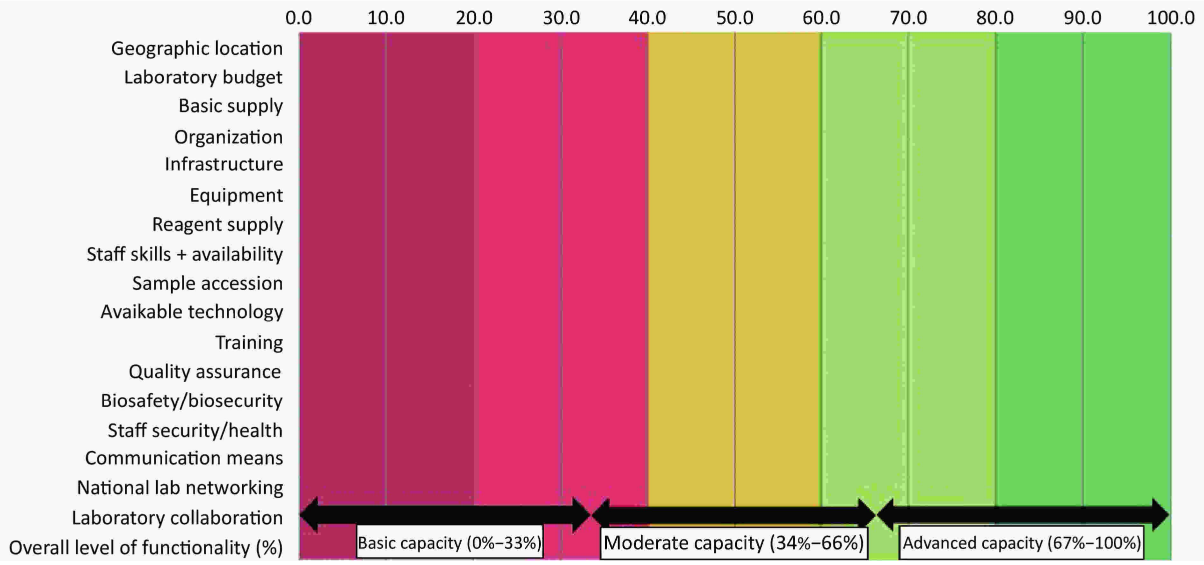

Figure 1. Final output of laboratory capacities and functionalities assessed against a sliding scale with advanced = (67%–100%), moderate = (34%–66%), or basic = (0%–33%).

The preliminary evaluation of eleven veterinary diagnostic laboratories located in selected staes of south-west Nigeria resulted in an average reliability score of 81%, per LMT-core. Teaching and research services were provided by 9 out of the 11 laboratories (81.8%); diagnostic, clinical and hospital services by 81.8%; and a single laboratory additionally offered public health services. Pathogen types handled by laboratories included bacteria (8/11, 72.7%), viruses (4/11, 36.3%), fungi or mucor (3/11, 27.2%), and parasites (6/11, 54.5%). Overall, the capacity and functionality score obtained was 24.3% (ranging from 9.7%–39.7%), with an average score of 24.5% ± 10.0% (ranging from 9.7%–39.0%) for Oyo State and 24.1% ± 9.3% (ranging from 15.7%–39.7%) for Ogun State (Table 1).

The overall laboratory capacity scores were similar in both states ($P = 0.73$). The average scores were low (< 33%) across the different functionalities and capacities assessed (see Table 1). The LMT-core category ‘organization’ was generally strong across-the-board (average: 60.6%; 95% *CI*, 47.1–74.1) with the exception of a single pathology laboratory). Particularly low scores (≤ 25%) were obtained for the aspects of infrastructure, sample accessioning, on-the-job training, quality assurance, biosafety and biosecurity, staff security

Table 1. Outputs from assessment of veterinary laboratories in south-west nigeria using the laboratory mapping tool-core, 2018

	Facility	GL	LB	BS	O	I	E	RS	SS + A	SA	AT	T	QA	BB	SSH	CM	NLN	LC	Grand total
Ogun State	PC	66.7	66.7	66.7	66.7	44.4	50.0	57.1	61.1	52.4	37.0	27.8	15.2	29.2	22.2	55.6	22.2	18.5	39.7
	Uni-Para	44.4	22.2	11.1	66.7	5.6	33.3	16.7	33.3	26.7	29.6	14.3	18.2	25.0	0.0	33.3	22.2	48.1	25.1
	Uni-Path	33.3	22.2	11.1	0.0	14.3	50.0	27.8	26.7	8.3	73.3	9.5	21.2	20.0	0.0	41.7	0.0	3.7	21.0
	Uni-Mic	33.3	22.2	22.2	66.7	20.8	20.0	28.6	16.7	16.7	14.8	22.2	16.7	25.0	0.0	41.7	0.0	3.7	19.1
	Pub Vet C&L	44.4	11.1	0.0	66.7	4.2	0.0	0.0	33.3	N/A	13.3	N/A	5.6	41.7	11.1	33.3	N/A	23.8	15.7
Oyo State	Inst-Mic	55.6	33.3	33.3	66.7	33.3	44.4	44.6	46.7	20.0	16.7	44.4	6.1	11.1	11.1	8.3	0.0	0.0	22.9
	Pub 2 Vet C&L	44.4	0.0	0.0	66.7	8.3	4.8	16.7	0.0	11.1	16.7	11.1	9.1	11.1	0.0	0.0	11.1	0.0	9.7
	Inst L & V	55.6	66.7	33.3	66.7	0.0	8.3	11.1	42.9	16.7	19.4	4.8	3.0	12.5	0.0	33.3	77.8	11.1	18.6
	Uni2- Mic	44.4	16.7	22.2	66.7	45.8	66.7	57.1	83.3	38.9	25.9	33.3	12.1	28.6	0.0	41.7	11.1	59.3	39.0
	Uni2- Para	44.4	44.4	44.4	66.7	33.3	50.0	53.3	44.4	26.7	23.8	19.0	23.3	25.0	0.0	41.7	0.0	3.7	28.0
	Uni2- Path	44.4	33.3	44.4	66.7	28.6	66.7	38.9	61.1	33.3	36.4	28.6	18.2	33.3	0.0	8.3	0.0	3.7	28.6
	Mean value	46.4	30.8	26.2	60.6	21.7	35.8	32.0	40.9	25.1	27.9	21.5	13.5	23.9	4.0	30.8	14.4	16.0	24.3
	Median	44.4	22.2	22.2	66.7	33.3	44.4	27.8	33.3	23.3	19.4	25.0	18.2	25.0	0.0	41.7	0.0	23.8	22.9
	SEM	2.9	6.4	6.2	6.1	4.9	7.3	5.9	6.9	4.3	5.2	3.9	2.0	2.9	2.3	5.3	7.6	6.1	2.8
	95% Confidence Interval	37.1–55.8	16.5–45.1	12.4–40.1	47.1–74.1	10.7–32.7	19.6–52.1	18.8–45.2	25.5–56.2	15.4–34.8	16.4–39.4	12.8–30.2	9.0–18.1	17.4–30.3	0.0–9.1	19.0–42.6	−2.8–31.6	2.3–29.6	18.1–30.5

Note. Functionality categories assessed: GL = Geographic location; LB = Laboratory Budget; BS = Basic supply; O = Organization of the laboratory; I = Infrastructure; E = Equipment; RS = Reagent supply; SS + A = Staff skills + availability; SA = Sample accession; AT = Available technology; T = Training; QA = Quality Assurance; BB = Biosafety/Biosecurity; SSH = Staff Security/Health; CM = Communication means; NLN = National laboratory networking; LC = Laboratory collaboration. Categories of laboratories/facilities: PC = private clinic; Uni-Para = University parasitology; Uni-Path = University pathology; Uni-Mic = University microbiology; Pub Vet C&L = State Veterinary clinic and laboratory; Inst-Mic = Training institution microbiology; Pub 2 Vet C&L = 2nd State Veterinary clinic and laboratory; Inst L & V = Institution with laboratory and vaccine supply chain; Uni2-Para = 2nd University parasitology; Uni2-Path = 2nd University pathology; Uni2-Mic = 2nd University microbiology. SEM = Standard error of the mean. All values are expressed in percentages (%).

and health, and national laboratory networking and collaboration. The weakest scores were observed for staff security and health (e.g. regular health checks, protection against zoonoses through prophylactic immunizations, and medical health surveillance) (average 4.0%; 95% *CI*, 0.0–9.1). Other scores obtained were for the laboratory budgets in relation to finance, research autonomy and upgrading (30.8%; 95% *CI*, 16.5–45.1); basic electricity, water and deionized water supplies (26.2%; 95% *CI*, 12.4–40.1); reagent supplies (validity and affordability) (32.0%; 95% *CI*, 18.8–45.2); case sample throughputs (25.1%; 95% *CI*, 15.4–34.8); advanced technology for molecular and serological assays (27.9%; 95% *CI*, 16.4–39.4); communication including the availability of landlines, internet facilities, access to scientific publications and dissemination of data (30.8%; 95% *CI*, 19.0–42.6).

Only two of the laboratories, a private laboratory with an overall average score of 39.7% and a university microbiology laboratory with 39.0%, were rated by the LMT-core as having moderate diagnostic capability. The remaining nine laboratories received scores placing them within the basic range for diagnostic laboratory services (< 30.0%). None of the laboratories had comprehensively advanced facilities for disease diagnosis, active surveillance or early warning systems. Inter-laboratory comparison of capacities and functionalities showed significant variations in laboratory capacities with the private laboratory performing best (ranging from 9.7%–39.7%; $P = 0.04$).

In this study the performance, reported as functionality and capacity of veterinary laboratories, were systematically evaluated and documented using a standardized assessment tool, the FAO Core Laboratory Mapping Tool (LMT-core). The results provided for 11 veterinary laboratories in south-west Nigeria were quantitatively assessed and analyzed. The LMT-core has been tested and validated in at least fourteen African countries to date and resulting outputs have been used to recommend priority actions for laboratory improvements across Africa. Where such has been implemented, tremendous progress has been noticed in service delivery and laboratory outputs[2]. The use of the LMT-core to assess laboratories and assist them in identifying weaknesses and prioritize improvements is consistent with the Joint External Evaluation (JEE) protocol of the WHO/IHR[4].

Although low-performance scores were reported across many functionalities accessed in this study, the outputs should be viewed not as negative findings, but as a valuable guide towards individual laboratory level improvements. The ongoing use of the LMT-core would ultimately provide a means for tracking positive changes and new enhancements in the overall functionality and capacity of VLs. Almost all of the VLs reported good organizational structure that is the basic requirement and template on which improvements can be made. Our findings will aid the various laboratory managements to begin the process of correcting the identified weak areas and moving towards the implementation of quality laboratory systems.

Poor levels of laboratory infrastructure, sample accessioning, on-the-job training, quality assurance, biosafety and biosecurity, staff security and health, and national laboratory networking and collaboration hamper the functionalities and efficiencies of these laboratories. Poor infrastructure in particular, is a major drawback in animal disease detection, investigation, and control in many developing countries[6,7]. The lack of robust infrastructure, consistent with the findings documented for the small sub-set of laboratories reported here, is most often associated with insufficient funding for the purchase and maintenance of equipment, supplies, reagents and staff training; the designing and specification of proper sample collection, traceable accession methods, planned disease surveillance strategy, and regular appraisal of the performance of novel diagnostic techniques are all important.

A consistent weakness identified in the current study was in training programs implemented to ensure that each staff member is suitably trained to meet the skills required for undertaking their job responsibilities. Such training (e.g. skills and competencies) is critical for efficiency in the day-to-day performance of routine duties, the handling of hazardous biological agents, the acquirement of knowledge and the interpretation of results, epidemiology, pathogenicity, and human susceptibility to various biological materials[8]. Without sound quality assurance and quality control, as observed in this study, performing procedures to standard is limited and may result in non-comparable data for other international laboratories with established capacity[9,10].

In any laboratory, biosafety and biosecurity are key to ensure occupational health and safety of staff. However, the health and safety of staff in this study may be compromised routinely by the poor biosafety practices, the non-existence of medical health policies and surveillance, lack of adequate immunizations or emergency plans for control of laboratory-acquired diseases, and the absence of health and safety protocols. Only 1 of the 11 laboratories in the current study had networks and collaborations with other facilities at national, regional and international levels. We expect other VLs desire to enhanced their functions as per the WHO/IHR; the objective of the laboratory twinning and collaborations is to contribute to the sustainable improvement of public health services in developing countries through the establishment of partnerships between laboratories and institutions. Results of the LMT-core assessment indicated that more efforts to build collaborations and networking may be made a priority in order to facilitate future effective functioning of VLs in developing countries.

Our study was limited by the inadequate record keeping in many of the laboratories visited. Where records were unavailable, the authors' judgement was strictly based on the assessment guidelines provided by the FAO. Record keeping in many developing countries is an issue and continuous training, monitoring and evaluation, and the supply of recorded materials for laboratory staff is critical.

The status of VLs in south-west, Nigeria is currently poor and falls below required standards. This is a major concern, especially when VLs are to ensure rapid responses to infectious diseases outbreaks and control. It is required that each VL should develop implementable actions plans aimed at progressively addressing the identified gaps. The weaknesses identified need timely interventions and political will to continuously invest in infrastructures that enhance research and disease surveillance in the country. VLs also need to contribute to the global health security agenda (GHSA) in combatting infections through the development of initiatives, projects, and partnerships with established international laboratories, that should promote capacitation for early detection and emergency response to infectious pathogens which threaten the public.

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