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Knowledge, Attitude, and Practices Regarding One Health and Zoonotic Diseases Among Undergraduate Medical Students at a Tertiary Care Hospital in Assam, India: A Cross-Sectional Study

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Abstract

Background

Zoonotic diseases are a major public health concern in Northeast India, and future physicians need One Health competencies to control them. We assessed One Health and zoonosis-related knowledge, attitudes, and practices (KAP) among MBBS students.

Methodology

This cross-sectional study (September 11 to October 11, 2026) used an attempted census of MBBS students across all three phases (Phase I, Phase II, and Phase III, the last comprising Part I and Part II) at Gauhati Medical College and Hospital, Assam. A pilot-tested online questionnaire assessed knowledge (20 items), attitude, and practice (15 items each); scores ⩾80% (modified Bloom's cut-offs) indicated good knowledge, positive attitude, or good practice. Kruskal-Wallis, chi-square, and multivariable logistic regression were used for data analysis.

Results

Of the 881 eligible students, 512 (58.1%) responded (median age = 20 years; interquartile range = 19-21 years; 333 (65.0%) male); only 37 (7.2%) had previous One Health training. Good knowledge, positive attitude, and good practice were found in 352 (68.8%), 269 (52.5%), and 323 (63.1%) students, respectively. Knowledge was lowest for brucellosis (286, 55.9%), Nipah virus (331, 64.6%), and avian influenza (333, 65.0%). Protective practices were common, but fewer than half often or always attended seminars (243, 47.5%) or awareness activities (253, 49.4%). All domains differed significantly by phase: good knowledge and practice were highest in Phase III Part II (103, 86.6% and 89, 74.8%), and lowest in Phase II (68, 50.7% and 74, 55.2%), whereas positive attitude was highest in Phase I (134, 66.3%). Compared to Phase I, Phase III Part II students had higher odds of good knowledge (adjusted odds ratio (aOR) = 2.63, 95% confidence interval (CI): 1.39-4.99) and good practice (aOR = 1.81, 1.06-3.08; practice model p = 0.057), while all later phases had lower odds of positive attitude (aOR = 0.28-0.51). After excluding 51 (10.0%) students with uniform "strongly disagree" attitude responses, 269 (58.4%) of 461 had a positive attitude, and lower odds persisted for Phase II and Phase III Part I but not Phase III Part II. About two-thirds (326, 63.7%) supported including One Health in the MBBS curriculum.

Conclusions

Knowledge and practice were reasonably good, but attitude was the weakest domain, particularly in Phase II and Phase III Part I. Knowledge of priority zoonoses was limited. Structured One Health teaching across all phases, emphasizing priority zoonoses, joint learning with veterinary students, and field-based training, is recommended.

Categories: Public Health, Preventive Medicine, Epidemiology/Public Health
Keywords: assam, attitude, barriers, india, knowledge, medical education, medical students, one health, practice, zoonotic diseases

Introduction

One Health is an integrated approach that aims to optimize the health of people, animals, and ecosystems by recognizing their interconnectedness [1]. It brings together multiple sectors, disciplines, and communities at different levels of society to work jointly to promote well-being and tackle threats to the health of people, animals, and ecosystems [2].

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The term "One Health" came into use in 2003-2004 and was associated with the emergence of severe acute respiratory syndrome (SARS) in early 2003 and the subsequent spread of highly pathogenic avian influenza H5N1 [3]. In 2004, a meeting convened by the Wildlife Conservation Society produced the "Manhattan Principles," a set of strategic recommendations that explicitly linked human and animal health and acknowledged the threat that diseases pose to food supplies and economies [3,4]. These principles called for collaborative, cross-disciplinary responses to emerging and resurging diseases and for wildlife health to be included as an essential component of global disease prevention, surveillance, control, and mitigation [4].

The World Health Organization (WHO) describes zoonoses as diseases and infections that pass naturally between vertebrate animals and humans, including infections shared by both [5,6]. Based on their etiology, zoonoses are grouped as bacterial (e.g., anthrax, brucellosis, plague, salmonellosis, and tuberculosis), viral (e.g., rabies, Ebola, and avian influenza), parasitic (e.g., toxoplasmosis, trichinosis, giardiasis, and echinococcosis), fungal (e.g., ringworm), rickettsial (e.g., Q fever), and chlamydial (e.g., psittacosis) zoonoses, together with diseases caused by acellular non-viral agents such as the transmissible spongiform encephalopathies [7]. In South East Asia, environmental and socioeconomic conditions favor both the persistence of well-known endemic zoonoses and the emergence of new pathogens at the human-wildlife interface [8].

Emerging infections pose a serious threat: epidemics caused by emerging and re-emerging pathogens can cause heavy loss of life and spread quickly across national borders, and beyond their health impact, they present a grave economic, developmental, and security challenge [9]. Zoonotic pathogens are about twice as likely as non-zoonotic ones to be associated with emerging diseases, and roughly three-quarters of emerging pathogens are zoonotic [10]. Human activities, together with environmental change, bring people and animals into closer contact and thereby raise the risk of zoonotic transmission [11]. Although zoonoses are a global problem, low- and middle-income countries (LMICs) are particularly vulnerable to spillover: the risk of emerging zoonoses is elevated in forested tropical regions undergoing land-use change, and deforestation and the construction of settlements in forested areas have increased human contact with animals [12,13].

India is passing through an epidemiological transition marked by a double burden of communicable and non-communicable diseases [14], while new and re-emerging pathogens add a further threat [9]. Climate change adds to this risk: as mammal species shift their geographic ranges in response to warming, they will meet in new combinations, and by 2070, these first encounters are projected to produce at least 15,000 new cross-species viral transmission events, concentrated in biodiversity hotspots and densely populated areas of Asia and Africa [15]. Developing countries such as India bear a disproportionate burden of infectious diseases, and India has recently experienced outbreaks caused by eight emerging or re-emerging pathogens, six of them of zoonotic origin [9]. A national multisectoral prioritization exercise ranked zoonotic influenza, anthrax, Japanese encephalitis (JE), leptospirosis, brucellosis, dengue, rabies, scrub typhus, plague, and Crimean-Congo hemorrhagic fever as the 10 zoonoses of greatest national concern for India [16]. An analysis of national Integrated Disease Surveillance Programme (IDSP) data found that 583 (8.3%) of the 6,948 outbreaks reported between 2018 and 2023 were zoonotic; JE accounted for 29.5% of these, followed by leptospirosis (18.7%) and scrub typhus (13.9%) [17].

Zoonoses are rising worldwide and in India [5]. Of 1,407 recognized human pathogen species, 58% are zoonotic, meaning they can be transmitted naturally between animals and humans; the 1,407 species comprise 538 bacteria and rickettsia, 317 fungi, 208 viruses and prions, 287 helminths, and 57 protozoa [18]. A report by the International Livestock Research Institute estimated that 13 zoonoses cause 2.4 billion cases of human illness and 2.2 million deaths each year, mainly in LMICs, with Ethiopia, Nigeria, Tanzania, and India among the highest-burden hotspots [19].

Northeast India is particularly vulnerable to zoonoses: the region contributed 35.8% of all zoonotic outbreaks reported under the IDSP between 2018 and 2023, the largest share of any region of the country [17]. JE remains a major problem in Assam: at a tertiary care hospital in upper Assam, 36.7-46.8% of patients with acute encephalitis syndrome tested positive for JE each year during 2012-2014, and the cases came mainly from rural areas, clustered in the rainy season (June-August), and occurred more often in adults than in children [20]. A scoping review of the Indian subcontinent further identified various human behaviors that may drive zoonotic disease risk and found that people's behavior often does not correspond to their disease knowledge, so that raising awareness alone is unlikely to be sufficient [21].

Medical students constitute the future healthcare workforce and may play an important role in the prevention, early recognition, reporting, and control of zoonotic diseases. Their understanding of zoonotic disease transmission, prevention, and the importance of interdisciplinary collaboration is essential for effective participation in clinical and public health activities. Assessing their knowledge, attitude, and practices (KAP) can help identify gaps in preparedness and areas requiring greater emphasis in undergraduate medical education.

In India, undergraduate medical training follows the competency-based medical education (CBME) curriculum of the National Medical Commission (NMC), introduced for students admitted from 2019 and most recently revised in 2024 [22,23]. The four-and-a-half-year MBBS course is divided into three

professional phases, Phase I, Phase II, and Phase III, with Phase III subdivided into Part I and Part II, followed by a one-year compulsory rotating internship, with each phase covering a different set of subjects [22]. Content relevant to One Health is therefore spread across the course: zoonotic infections are taught in microbiology in Phase II, whereas the epidemiology and control of communicable diseases, including zoonoses, is taught in community medicine and examined at the end of Phase III Part I [22,23]. However, the curriculum does not identify One Health as a distinct theme, and none of the integrated teaching modules it specifies deals with zoonoses [22]. Because students in different phases have had different exposure to this content, comparing KAP across phases can indicate where One Health teaching could best be strengthened. Medical educators have argued that One Health competencies should be built into undergraduate medical training [24,25].

Although previous research has explored medical students' knowledge of zoonotic diseases and awareness of the One Health approach, the extent to which undergraduate medical students understand these concepts, hold appropriate attitudes, and report relevant practices remains an important area for further investigation. In particular, evidence on the combined assessment of KAP regarding the One Health approach and zoonotic diseases among undergraduate MBBS students in Northeast India appears limited. Understanding these domains together may help identify misconceptions, gaps in preparedness, and educational needs that could be addressed through undergraduate medical training.

Gauhati Medical College and Hospital (GMCH), Guwahati, Assam, provides an appropriate setting to investigate these issues in Northeast India, a region characterized by rich biodiversity and diverse human-animal interactions. Assessing One Health-related KAP among undergraduate medical students at this institution can provide insight into their understanding of zoonotic disease prevention and the importance of interdisciplinary collaboration. In this context, the present study aimed to assess the KAP regarding the One Health approach and zoonotic diseases among MBBS students in all three phases (Phase I, Phase II, and Phase III Parts I and II) of GMCH, Guwahati, Assam. It also examined the associations between KAP and selected sociodemographic and academic characteristics of the participants and compared KAP across the three phases of undergraduate medical training, with the two parts of Phase III considered separately.

The findings are expected to provide baseline evidence for educators and policymakers, identify existing knowledge gaps and educational needs, support the integration of One Health competencies into undergraduate medical education, and strengthen interdisciplinary collaboration and preparedness for zoonotic disease threats in alignment with national and global One Health initiatives.

Materials And Methods

A cross-sectional study was conducted among undergraduate MBBS students of all three phases (Phase I, Phase II, and Phase III, comprising Part I and Part II) at GMCH, Guwahati, Assam, to assess their KAP regarding the One Health approach and zoonotic diseases. Data were collected over a period of one month, from September 11, 2026, to October 11, 2026.

The study population comprised all MBBS students enrolled in the respective phases at GMCH during the study period. All students enrolled in the specified phases who were willing to participate and provided informed consent before completing the questionnaire were eligible for inclusion. Students who did not provide informed consent were excluded from the study.

An attempted census approach was adopted. The eligible study population comprised 881 undergraduate MBBS students, including 250 students from Phase I, 250 from Phase II, and 381 from Phase III (187 in Part I and 194 in Part II). Because Phase III Part I and Part II are separate academic years with different subjects, they were analyzed as separate groups, resulting in four comparison groups. All eligible students were invited to participate in the study. Participation was voluntary. The questionnaire was administered electronically using Google Forms, and the link was circulated through the respective batch WhatsApp groups by the class representatives of each phase. Each batch was sent a total of four reminders at weekly intervals, in addition to the initial circulation of the Google Form on September 11, 2026. Thus, a total of five communications (one initial invitation and four subsequent reminders) were made to encourage participation until the survey closed on October 11, 2026. The form was set to accept only one response per Google account, and responses were checked for duplicate submissions (identical time stamps and response patterns); none were found. Students who had not responded by October 11, 2026, were considered non-respondents. Of the 881 eligible undergraduate MBBS students invited to participate, 512 completed the questionnaire, yielding an overall response rate of 512 (58.1%). As participation was anonymous and voluntary, non-respondents could not be followed up individually, and their reasons for not participating were not recorded.

The questionnaire was developed following a review of previously published literature on the One Health approach and zoonotic diseases. It comprised three domains: knowledge, attitude, and practice. Although certain topics were represented in both the knowledge and attitude domains, they assessed different constructs. The knowledge domain assessed students' awareness of key One Health concepts, whereas the attitude domain explored their perceptions and opinions regarding these concepts. A separate section, which did not contribute to the KAP scores, assessed perceived barriers to implementing the One Health

approach, educational needs (including support for formal One Health training in the MBBS curriculum and for joint training with veterinary students), and the preferred mode of learning about One Health; these items were analyzed descriptively. Pilot testing was conducted among 50 undergraduate MBBS students from another medical college before the main data collection to assess the clarity and comprehensibility of the questions, the feasibility of electronic administration, and the time required to complete the questionnaire. Feedback obtained during pilot testing was used to refine the questionnaire, where necessary, before its final administration. These students were not part of the 881 students in the main study population and were not included in the analysis.

Content validity was assessed by a panel of four faculty members from the Department of Community Medicine, comprising one Professor, one Associate Professor, and two Assistant Professors. The experts reviewed the questionnaire items for relevance, clarity, and comprehensiveness in relation to the study objectives. Each expert rated the relevance of every item on a four-point scale (1, not relevant, to 4, highly relevant). The item-level content validity index (I-CVI) was calculated as the proportion of experts rating an item 3 or 4, and the scale-level index (S-CVI/Ave) as the mean of the I-CVIs [26]; items with an I-CVI below 0.78 were revised or removed. The S-CVI/Ave was 0.92 for the knowledge domain, 0.94 for the attitude domain, 0.93 for the practice domain, and 0.93 for the questionnaire overall. Internal consistency reliability was assessed using Cronbach's alpha for the attitude and practice domains and the Kuder-Richardson Formula 20 (KR-20) for the knowledge domain, which comprised dichotomously scored items.

Knowledge was assessed using 20 items, with each correct response assigned 1 point and each incorrect or "Don't know" response assigned 0 points, yielding a total score ranging from 0 to 20. Attitude and practice were assessed using 15 items each on five-point Likert scales, scored from 1 to 5, with total scores ranging from 15 to 75 for each domain. Knowledge scores were converted into percentages by dividing the total score by 20 and multiplying by 100, whereas attitude and practice scores were converted into percentages by dividing the respective total scores by 75 and multiplying by 100. Domain scores were categorized using modified Bloom's cut-off criteria [26,27]: scores ⩾80% were classified as good knowledge, positive attitude, or good practice, as applicable; scores 60-79% as moderate knowledge, neutral attitude, or moderate practice; and scores <60% as poor knowledge, negative attitude, or poor practice. For association analyses, each domain was dichotomized at the 80% cut-off.

Electronic informed consent was obtained through Google Forms before participants accessed the questionnaire. The introductory section provided information regarding the study objectives, the voluntary nature of participation, confidentiality of responses, and the approximate time required to complete the questionnaire. Participants were required to select the "I agree to participate" option before proceeding to the study questions. Only those who provided consent could access the questionnaire. Confidentiality was maintained during data handling and analysis, and the collected information was used only for research purposes.

Ethical approval was obtained from the Institutional Ethics Committee of GMCH, Guwahati, before data collection (approval number: 190/2007/Pt-II/Sept, 2026/4; date of approval: September 9, 2026).

Data collected through Google Forms were exported to Microsoft Excel for cleaning, coding, and consistency checks. As all questions in the Google Form were mandatory, all 512 submitted responses were complete; this was confirmed during data cleaning, and no missing data were identified in any variable analyzed. Consistency checks identified 51 (10.0%) respondents who selected "strongly disagree" for every statement in attitude items 1-10, items 11-15, or both; 33 of them did so for all 15 statements. Because this pattern could reflect genuine disagreement and no exclusion rule had been prespecified, these responses were retained, and no responses were excluded from the primary analysis.

Statistical analysis was performed using Python 3.15.0. Categorical variables were summarized as frequencies and percentages, and continuous variables as mean ± standard deviation (SD) or median with interquartile range (IQR), as appropriate, after testing normality with the Shapiro-Wilk test. KAP scores were not normally distributed (Shapiro-Wilk $p < 0.05$) and were therefore summarized as median (IQR) and compared using non-parametric tests. Associations between categorical variables were assessed using Pearson's chi-square or Fisher's exact test, as appropriate. KAP scores were compared across the four MBBS phases using the Kruskal-Wallis test, and KAP levels using the chi-square test or, when more than 20% of expected cell counts were below 5, the Fisher-Freeman-Halton exact test (Monte Carlo estimate, 200,000 samples).

Factors independently associated with good knowledge, positive attitude, and good practice were identified using separate multivariable binary logistic regression models (Statsmodels 0.15.0). Gender, MBBS phase, residence, family type, pet ownership, farm animal exposure, family involvement in animal handling or farming, previous One Health training, and main source of information were entered simultaneously; age was not entered because of its collinearity with MBBS phase. Overall model significance was assessed using the likelihood-ratio chi-square test, model fit using Nagelkerke's R^2 and the Hosmer-Lemeshow test (deciles of predicted probabilities), and multicollinearity using variance inflation factors (VIFs). Events per variable (EPV) were calculated as the number of events in the smaller outcome category divided by the 13 estimated

parameters. Results are presented as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). In a sensitivity analysis, the attitude analyses were repeated after excluding the 51 uniform responders (n = 461). All tests were two-sided, with p-values <0.05 considered statistically significant.

Results

Of the 881 eligible undergraduate MBBS students, 512 (58.1%) completed the questionnaire (Figure *1*). Response was highest in Phase I (80.8%) and lowest in Phase III Part I (30.5%), with Phase II (53.6%) and Phase III Part II (61.3%) in between. All three domains showed high internal consistency (knowledge KR-20 = 0.93; attitude α = 0.98; practice α = 0.91).

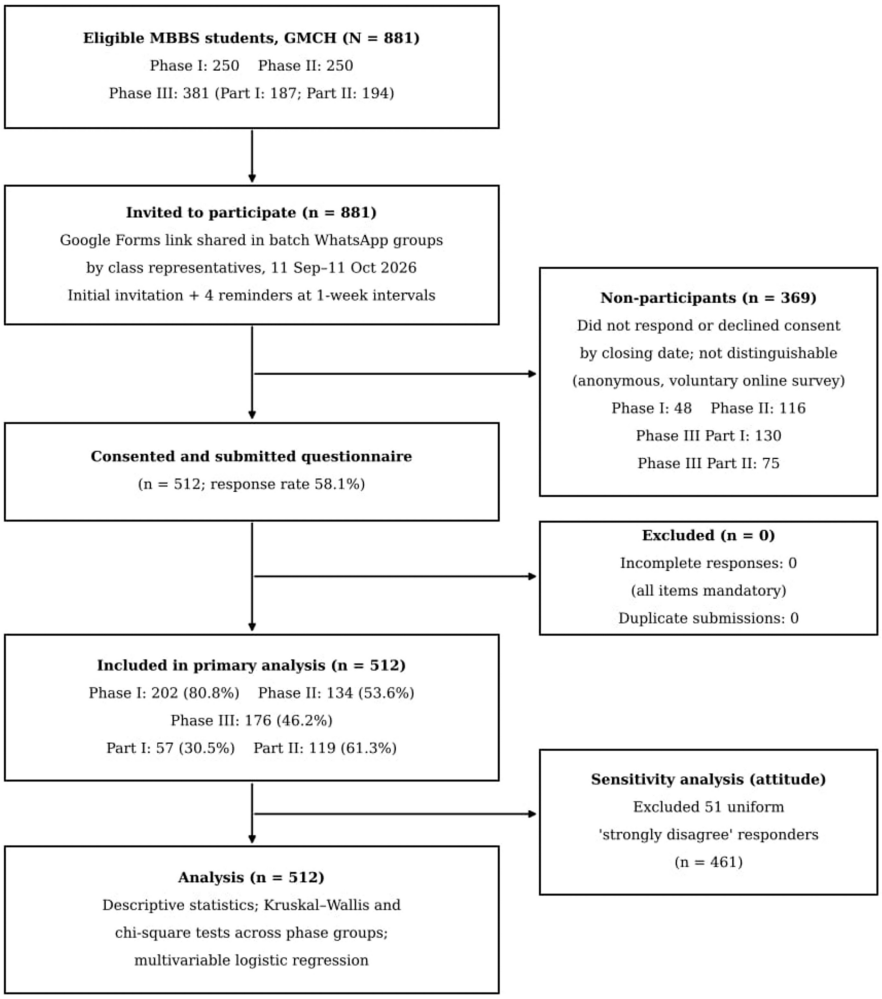


FIGURE 1: STROBE flow diagram of participant recruitment, non-participation, and analysis.

Response rates are shown in parentheses for each phase.

GMCH: Gauhati Medical College and Hospital

The respondents were mostly young adults, and nearly two-thirds were male. Phase I students formed the largest group, while Phase III Part I, the phase with the lowest response rate, formed the smallest. Urban and rural backgrounds were almost equally represented, and most students came from nuclear families. Only a minority had direct contact with animals: about one in four owned a pet, had been exposed to farm animals, or had a family member involved in animal handling or farming. Formal exposure to One Health was rare, with fewer than one in ten having received any previous training. Most students learned about the topic in the classroom, and very few through continuing medical education (Table *1*).

Characteristic	Frequency (n)	Percentage (%)

Age (years), median (IQR)	20 (19–21)	
Age (years)		
17–20	297	58.0
21–26	215	42.0
Gender		
Male	333	65.0
Female	179	35.0
MBBS phase		
Phase I	202	39.5
Phase II	134	26.2
Phase III Part I	57	11.1
Phase III Part II	119	23.2
Residence		
Urban	261	51.0
Rural	251	49.0
Type of family		
Nuclear	426	83.2
Joint	78	15.2
Three generation family	8	1.6
Pet ownership		
No	397	77.5
Yes	115	22.5
Exposure to farm animals		
No	396	77.3
Yes	116	22.7
Family member involved in animal handling/farming		
No	378	73.8
Yes	134	26.2
Previous training on One Health		
No	475	92.8
Yes	37	7.2
Main source of information on One Health		
Classroom	301	58.8
Internet	144	28.1
Social media	55	10.7
CME	12	2.3

TABLE 1: Distribution of MBBS students according to their sociodemographic and exposure characteristics (N = 512).

Age was not normally distributed (Shapiro–Wilk test, $p < 0.001$) and is therefore summarized as median (IQR).

IQR: interquartile range; CME: continuing medical education

Students were most familiar with general One Health principles and practical preventive measures. About nine in ten correctly recognized the value of hand hygiene after animal contact, surveillance of animal diseases, early reporting of animal illness, and collaboration between veterinarians and physicians. Knowledge was weakest for specific zoonoses. Brucellosis was the least recognized item, and a large share of students answered “Don’t know” to it. Avian influenza and Nipah virus disease were each recognized as zoonotic by only about two-thirds. The link between antibiotic use in animals or livestock and antimicrobial resistance was also less well recognized than most general concepts. Incorrect “No” responses were uncommon for every item, which suggests that the gaps reflected a lack of awareness rather than misconceptions (Table *2*).

Serial number	Knowledge statement	Yes, n (%)	No, n (%)	Don't know, n (%)
1	One Health is an approach integrating human, animal and environmental health	434 (84.8)	6 (1.2)	72 (14.1)
2	Rabies is a zoonotic disease	428 (83.6)	8 (1.6)	76 (14.8)
3	Antimicrobial resistance is related to irrational antibiotic use in animals and humans	380 (74.2)	45 (8.8)	87 (17.0)
4	Climate change can influence zoonotic diseases transmission	397 (77.5)	27 (5.3)	88 (17.2)
5	Brucellosis can spread from animals to humans	286 (55.9)	17 (3.3)	209 (40.8)
6	Avian influenza is a zoonotic disease	333 (65.0)	25 (4.9)	154 (30.1)
7	Collaboration between veterinarians and physicians is important for outbreak control	455 (88.9)	13 (2.5)	44 (8.6)
8	Safe food handling helps prevent zoonotic diseases	421 (82.2)	31 (6.1)	60 (11.7)
9	Environmental degradation may increase emerging infectious diseases	435 (85.0)	14 (2.7)	63 (12.3)
10	COVID-19 highlighted the importance of One Health	421 (82.2)	25 (4.9)	66 (12.9)
11	Hand hygiene after animal contact reduces disease transmission	472 (92.2)	11 (2.1)	29 (5.7)
12	Vector borne diseases are linked with environmental factors	450 (87.9)	22 (4.3)	40 (7.8)
13	Surveillance of animal diseases is important for human health protection	465 (90.8)	11 (2.1)	36 (7.0)
14	Antibiotic use in livestock can contribute to antimicrobial resistance	384 (75.0)	21 (4.1)	107 (20.9)
15	Vaccination of animals can reduce human disease burden	452 (88.3)	12 (2.3)	48 (9.4)
16	Nipah virus disease is zoonotic in origin	331 (64.6)	15 (2.9)	166 (32.4)
17	Veterinary professionals are important stakeholders in outbreak prevention	434 (84.8)	14 (2.7)	64 (12.5)
18	Improper biomedical waste disposal may contribute to disease spread	458 (89.5)	11 (2.1)	43 (8.4)
19	Wildlife trade may increase zoonotic disease transmission	406 (79.3)	22 (4.3)	84 (16.4)
20	Early reporting of animal illness is important in outbreak prevention	460 (89.8)	13 (2.5)	39 (7.6)

TABLE 2: Item-wise responses to knowledge statements on One Health and zoonoses (N = 512).

"Yes" was considered the correct response for all statements.

Attitude was moderately favorable and followed a strikingly similar pattern across all 15 statements. For every item, a majority agreed, about one in five were neutral, and a consistent minority of roughly one in

eight strongly disagreed. Agreement was strongest for the health consequences of climate change, community participation in zoonosis control, animal vaccination programs, and the need for more One Health research. It was weakest for the inadequacy of public awareness and for the value of intersectoral collaboration in outbreak response; the latter also drew the largest neutral response. Only about two-thirds of students supported including One Health in the MBBS curriculum or giving medical students formal training in it. The steady strongly disagree minority across items largely reflected the 51 uniform responders. When they were excluded, strong disagreement became uncommon, and agreement rose for every statement (Table *3*; see Sensitivity analysis).

Serial number	Statement	Strongly disagree (1), n (%)	Disagree (2), n (%)	Neutral (3), n (%)	Agree (4), n (%)	Strongly agree (5), n (%)	Mean ± SD
1	One Health should be included in the MBBS curriculum	66 (12.9)	9 (1.8)	111 (21.7)	193 (37.7)	133 (26.0)	3.62 ± 1.25
2	Medical students should receive formal training on One Health	64 (12.5)	11 (2.1)	107 (20.9)	192 (37.5)	138 (27.0)	3.64 ± 1.25
3	Collaboration between doctors and veterinarians is important	60 (11.7)	15 (2.9)	98 (19.1)	212 (41.4)	127 (24.8)	3.65 ± 1.22
4	Climate change has important health consequences	61 (11.9)	14 (2.7)	75 (14.6)	201 (39.3)	161 (31.4)	3.76 ± 1.26
5	Public awareness regarding zoonotic diseases is inadequate	71 (13.9)	28 (5.5)	109 (21.3)	192 (37.5)	112 (21.9)	3.48 ± 1.28
6	Zoonotic diseases are an important public health issue	65 (12.7)	7 (1.4)	81 (15.8)	211 (41.2)	148 (28.9)	3.72 ± 1.25
7	Environmental conservation helps prevent disease outbreaks	64 (12.5)	13 (2.5)	89 (17.4)	203 (39.6)	143 (27.9)	3.68 ± 1.26
8	Intersectoral collaboration improves outbreak response	56 (10.9)	12 (2.3)	128 (25.0)	193 (37.7)	123 (24.0)	3.62 ± 1.19
9	Antibiotic misuse in animals affects human health	64 (12.5)	22 (4.3)	104 (20.3)	194 (37.9)	128 (25.0)	3.59 ± 1.26
10	Physicians should actively participate in One Health initiatives	64 (12.5)	8 (1.6)	110 (21.5)	196 (38.3)	134 (26.2)	3.64 ± 1.24
11	One Health approaches are necessary for pandemic prevention	64 (12.5)	11 (2.1)	98 (19.1)	183 (35.7)	156 (30.5)	3.70 ± 1.27
12	Community participation is important in controlling zoonotic diseases	62 (12.1)	6 (1.2)	87 (17.0)	192 (37.5)	165 (32.2)	3.77 ± 1.26
13	Animal vaccination programs are important for human health	60 (11.7)	10 (2.0)	86 (16.8)	197 (38.5)	159 (31.1)	3.75 ± 1.25
14	More research is needed in One Health and zoonoses	59 (11.5)	11 (2.1)	88 (17.2)	193 (37.7)	161 (31.4)	3.75 ± 1.25
15	Early outbreak reporting should involve multiple sectors	61 (11.9)	14 (2.7)	92 (18.0)	207 (40.4)	138 (27.0)	3.68 ± 1.24

TABLE 3: Item-wise responses to attitude statements regarding One Health (N = 512).

SD: standard deviation

Practices showed a clear divide between personal and community-oriented behavior. Nearly nine in ten students often or always followed personal protective practices: washing hands after animal contact, maintaining food hygiene, avoiding unnecessary antibiotics, avoiding sick animals, and reporting animal bites promptly. Almost none reported never doing these. Community and academic engagement was much weaker. Only about half often or always attended One Health seminars or workshops, took part in public awareness activities, or educated others about zoonoses. Seminar and workshop attendance had both the

lowest mean score and the largest share of students who never or rarely took part (Table 4).

Serial number	Statement	Never (1), n (%)	Rarely (2), n (%)	Sometimes (3), n (%)	Often (4), n (%)	Always (5), n (%)	Mean ± SD
1	I wash hands after animal contact	0 (0.0)	1 (0.2)	33 (6.4)	120 (23.4)	358 (69.9)	4.63 ± 0.61
2	I follow proper food hygiene practices	0 (0.0)	2 (0.4)	39 (7.6)	163 (31.8)	308 (60.2)	4.52 ± 0.65
3	I avoid unnecessary antibiotic use	0 (0.0)	4 (0.8)	42 (8.2)	128 (25.0)	338 (66.0)	4.56 ± 0.68
4	I educate others regarding zoonotic diseases	22 (4.3)	79 (15.4)	151 (29.5)	124 (24.2)	136 (26.6)	3.53 ± 1.16
5	I seek information regarding emerging infectious diseases	4 (0.8)	24 (4.7)	143 (27.9)	163 (31.8)	178 (34.8)	3.95 ± 0.94
6	I use protective measures during exposure to animals	8 (1.6)	27 (5.3)	78 (15.2)	172 (33.6)	227 (44.3)	4.14 ± 0.96
7	I participate in public awareness activities	32 (6.2)	77 (15.0)	150 (29.3)	111 (21.7)	142 (27.7)	3.50 ± 1.22
8	I dispose biomedical waste appropriately during postings	6 (1.2)	8 (1.6)	59 (11.5)	136 (26.6)	303 (59.2)	4.41 ± 0.84
9	I keep myself updated on public health issues related to One Health	6 (1.2)	39 (7.6)	109 (21.3)	183 (35.7)	175 (34.2)	3.94 ± 0.98
10	I follow infection prevention practices regularly	3 (0.6)	8 (1.6)	81 (15.8)	175 (34.2)	245 (47.9)	4.27 ± 0.82
11	I encourage vaccination awareness in the community	4 (0.8)	17 (3.3)	81 (15.8)	157 (30.7)	253 (49.4)	4.25 ± 0.89
12	I avoid close contact with sick animals	0 (0.0)	8 (1.6)	45 (8.8)	110 (21.5)	349 (68.2)	4.56 ± 0.72
13	I report animal bite incidents promptly	6 (1.2)	8 (1.6)	47 (9.2)	124 (24.2)	327 (63.9)	4.48 ± 0.82
14	I participate in seminars/workshops related to One Health	83 (16.2)	73 (14.3)	113 (22.1)	108 (21.1)	135 (26.4)	3.27 ± 1.41
15	I practice environmental sanitation measures regularly	11 (2.1)	24 (4.7)	94 (18.4)	158 (30.9)	225 (43.9)	4.10 ± 1.00

TABLE 4: Item-wise responses to practice statements related to One Health (N = 512).

SD: standard deviation

Knowledge was the strongest of the three domains, with more than two-thirds of students classified as having good knowledge, followed closely by practice. Attitude was the weakest domain: only about half of the students had a positive attitude, and attitude had the largest proportion in the lowest category. The domains also differed at the lower end. Poor practice was rare, whereas poor knowledge and, in particular, negative attitude affected a notable minority. Attitude scores were also the most widely spread of the three domains (Table 5).

Domain	Possible range	Observed range	Median (IQR)	Good/Positive (≥80%), n (%)	Moderate/Neutral (60–79%), n (%)	Poor/Negative (<60%), n (%)
Knowledge	0–20	0–20	18 (15–20)	352 (68.8)	98 (19.1)	62 (12.1)
Attitude	15–75	15–75	60 (46–66)	269 (52.5)	161 (31.4)	82 (16.0)
Practice	15–75	39–75	62 (56–70)	323 (63.1)	174 (34.0)	15 (2.9)

TABLE 5: Overall knowledge, attitude, and practice scores and their levels (N = 512).

Scores categorized using modified Bloom's cut-offs. Scores were not normally distributed (Shapiro–Wilk test, $p < 0.05$ for all three domains) and are therefore summarized as median (IQR).

IQR: interquartile range

All three domains differed significantly across MBBS phases, but not in the same direction. Knowledge and practice followed a similar pattern. Both were lowest in Phase II and highest in Phase III Part II, the final-year group, in which nearly nine in ten students had good knowledge; no Phase III student had poor practice. Attitude followed a different pattern. It was most positive in Phase I and lower in every later phase, with the lowest levels in Phase II and Phase III Part I. Phase III Part II, despite having the best knowledge and practice, had the largest share of students with a negative attitude. The pattern was not linear, as Phase II students scored below Phase I students in all three domains (Table *6*).

Variable	Phase I (n = 202)	Phase II (n = 134)	Phase III Part I (n = 57)	Phase III Part II (n = 119)	Test statistic	P-value
Knowledge score, median (IQR)	18 (15–20)	16 (12–19)	18 (14–20)	19 (18–20)	H = 42.65	<0.001*[a]
Good knowledge, n (%)	143 (70.8)	68 (50.7)	38 (66.7)	103 (86.6)		
Moderate knowledge, n (%)	41 (20.3)	37 (27.6)	9 (15.8)	11 (9.2)	$\chi^2 = 42.85$	<0.001*[b]
Poor knowledge, n (%)	18 (8.9)	29 (21.6)	10 (17.5)	5 (4.2)		
Attitude score, median (IQR)	63 (57–70)	58 (45–62)	56 (45–62)	60 (42–64)	H = 37.34	<0.001*[a]
Positive attitude, n (%)	134 (66.3)	52 (38.8)	21 (36.8)	62 (52.1)		
Neutral attitude, n (%)	50 (24.8)	61 (45.5)	25 (43.9)	25 (21.0)	$\chi^2 = 48.59$	<0.001*[b]
Negative attitude, n (%)	18 (8.9)	21 (15.7)	11 (19.3)	32 (26.9)		
Practice score, median (IQR)	63 (56–71)	60 (54–66)	61 (56–75)	64 (60–71)	H = 14.14	0.003*[a]
Good practice, n (%)	122 (60.4)	74 (55.2)	38 (66.7)	89 (74.8)		
Moderate practice, n (%)	71 (35.1)	54 (40.3)	19 (33.3)	30 (25.2)	$\chi^2 = 16.46$[d]	0.007*[c]
Poor practice, n (%)	9 (4.5)	6 (4.5)	0 (0.0)	0 (0.0)		

TABLE 6: Comparison of knowledge, attitude, and practice scores and levels among Phase I, Phase II, Phase III Part I, and Phase III Part II MBBS students regarding One Health and zoonotic diseases (N = 512).

Levels are n (%) within each phase. Test statistic: H, Kruskal–Wallis H statistic (df = 3) for comparison of scores; χ^2, Pearson chi-square statistic (df = 6) for comparison of the three levels (good/moderate/poor) across the four phases. Statistical tests used to calculate p-values: [a]Kruskal–Wallis test; [b]Pearson's chi-square test; [c]Fisher–Freeman–Halton exact test (Monte Carlo estimate, 200,000 samples), used because 3 (25.0%) of 12 expected cell counts were <5; [d]the Pearson χ^2 value is shown for reference (asymptotic p=0.011). Table 7 compares good versus not good. *$p < 0.05$.

IQR: interquartile range; df: degrees of freedom

In the bivariate analysis, academic characteristics were more closely associated with KAP than background characteristics were. MBBS phase and age were associated with all three domains. Older students more often had good knowledge and good practice but less often a positive attitude, which mirrors the phase-wise pattern. Previous One Health training was associated with better practice but, unexpectedly, with a less positive attitude. Attitude was also associated with farm animal exposure, which was linked to a less positive attitude, and with the main source of information; a positive attitude was least frequent among the few students who relied on continuing medical education. Gender, residence, family type, and pet ownership were not associated with any domain (Table 7).

Variable	Total	Good knowledge, n (%)	χ^2 value (df)	P-value	Positive attitude, n (%)	χ^2 value (df)	P-value	Good practice, n (%)	χ^2 value (df)	P-value
Age (years)										
17–20	297	189 (63.6)	8.61 (1)	0.003*	169 (56.9)	5.40 (1)	0.020*	176 (59.3)	4.45 (1)	0.035*
21–26	215	163 (75.8)			100 (46.5)			147 (68.4)		
Gender										
Male	333	224 (67.3)	0.97 (1)	0.324	174 (52.3)	0.03 (1)	0.859	210 (63.1)	0.00 (1)	0.988
Female	179	128 (71.5)			95 (53.1)			113 (63.1)		
MBBS phase										
Phase I	202	143 (70.8)	38.28 (3)	<0.001*	134 (66.3)	31.20 (3)	<0.001*	122 (60.4)	11.50 (3)	0.009*
Phase II	134	68 (50.7)			52 (38.8)			74 (55.2)		
Phase III Part I	57	38 (66.7)			21 (36.8)			38 (66.7)		
Phase III Part II	119	103 (86.6)			62 (52.1)			89 (74.8)		
Residence										
Urban	261	183 (70.1)	0.46 (1)	0.497	141 (54.0)	0.47 (1)	0.493	168 (64.4)	0.38 (1)	0.540
Rural	251	169 (67.3)			128 (51.0)			155 (61.8)		
Type of family										
Nuclear	426	292 (68.5)	0.05 (1)	0.823	224 (52.6)	0.00 (1)	0.965	272 (63.8)	0.64 (1)	0.425
Joint/Extended	86	60 (69.8)			45 (52.3)			51 (59.3)		
Pet ownership										
No	397	275 (69.3)	0.22 (1)	0.637	208 (52.4)	0.02 (1)	0.902	255 (64.2)	1.00 (1)	0.318
Yes	115	77 (67.0)			61 (53.0)			68 (59.1)		
Exposure to farm animals										
No	396	275 (69.4)	0.39 (1)	0.531	218 (55.1)	4.42 (1)	0.035*	253 (63.9)	0.48 (1)	0.487
Yes	116	77 (66.4)			51 (44.0)			70 (60.3)		
Family member involved in animal handling/farming										
No	378	262 (69.3)	0.21 (1)	0.645	204 (54.0)	1.18 (1)	0.277	246 (65.1)	2.46 (1)	0.116
Yes	134	90 (67.2)			65 (48.5)			77 (57.5)		
Previous training on One Health										
No	475	323 (68.0)	1.72 (1)	0.190	258 (54.3)	8.32 (1)	0.004*	294 (61.9)	4.01 (1)	0.045*
Yes	37	29 (78.4)			11 (29.7)			29 (78.4)		
Main source of information on One Health										
Classroom	301	210 (69.8)			158 (52.5)			198 (65.8)		
Internet	144	104 (72.2)			83 (57.6)			83 (57.6)		

Social media	55	32 (58.2)	5.78 (3)	0.123	27 (49.1)	11.17 (3)	0.011*	36 (65.5)	3.79 (3)	0.285
CME	12	6 (50.0)			1 (8.3)			6 (50.0)		

TABLE 7: Association of sociodemographic and exposure factors with good knowledge, positive attitude, and good practice regarding One Health among MBBS students (N = 512).

Row percentages. Test statistic: Pearson chi-square (χ^2) value with degrees of freedom (df) in parentheses. Statistical test used to calculate p-values: Pearson's chi-square test without continuity correction for all comparisons; all expected cell counts in the 2×2 tables were ≥5, so Fisher's exact test was not required. For main source of information, 1 (12.5%) of 8 expected cell counts was <5 for good knowledge and good practice. *p < 0.05.

CME: continuing medical education

After the 51 uniform responders were excluded, the associations of attitude with age and farm animal exposure were no longer significant, whereas those with previous training and source of information persisted (see Sensitivity analysis).

The knowledge and attitude models were statistically significant and fitted the data adequately. The practice model was not significant overall and explained little of the variation in practice, so its estimates should be interpreted with caution. EPVs were adequate, and there was no important multicollinearity in any model. After adjustment, MBBS phase remained the main independent factor. Compared with Phase I, final-year (Phase III Part II) students had about two and a half times the odds of good knowledge and higher odds of good practice, whereas Phase II students had lower odds of good knowledge. For attitude, the direction was reversed: every later phase had lower odds of a positive attitude than Phase I. Previously trained students also had lower odds of a positive attitude, although this was of borderline significance. No sociodemographic or exposure factor was independently associated with any domain (Table *8*).

Variable	Good knowledge, aOR (95% CI)	Wald χ^2	P-value	Positive attitude, aOR (95% CI)	Wald χ^2	P-value	Good practice, aOR (95% CI)	Wald χ^2	P-value
Gender									
Male (ref)	1	–	–	1	–	–	1	–	–
Female	1.27 (0.83–1.96)	1.21	0.272	1.00 (0.67–1.48)	0.00	0.994	1.04 (0.70–1.54)	0.04	0.845
MBBS phase									
Phase I (ref)	1	–	–	1	–	–	1	–	–
Phase II	0.39 (0.25–0.64)	14.64	<0.001*	0.32 (0.20–0.52)	21.83	<0.001*	0.78 (0.49–1.23)	1.13	0.288
Phase III Part I	0.77 (0.40–1.48)	0.62	0.433	0.28 (0.15–0.52)	15.61	<0.001*	1.30 (0.68–2.45)	0.63	0.426
Phase III Part II	2.63 (1.39–4.99)	8.79	0.003*	0.51 (0.31–0.84)	6.93	0.008*	1.81 (1.06–3.08)	4.76	0.029*
Residence									
Urban (ref)	1	–	–	1	–	–	1	–	–
Rural	1.11 (0.71–1.74)	0.21	0.644	0.83 (0.54–1.26)	0.77	0.379	1.14 (0.75–1.74)	0.38	0.540
Type of family									
Nuclear (ref)	1	–	–	1	–	–	1	–	–
Joint/Extended	1.30 (0.76–2.22)	0.94	0.331	1.19 (0.72–1.98)	0.48	0.489	0.89 (0.55–1.45)	0.21	0.643
Pet ownership									
No (ref)	1	–	–	1	–	–	1	–	–

Yes	0.97 (0.59–1.59)	0.02	0.893	1.28 (0.80–2.05)	1.08	0.298	0.87 (0.55–1.38)	0.36	0.549
Exposure to farm animals									
No (ref)	1	–	–	1	–	–	1	–	–
Yes	0.95 (0.51–1.76)	0.02	0.875	0.61 (0.34–1.09)	2.81	0.094	1.21 (0.68–2.16)	0.42	0.517
Family member involved in animal handling/farming									
No (ref)	1	–	–	1	–	–	1	–	–
Yes	0.95 (0.52–1.72)	0.03	0.868	1.07 (0.61–1.87)	0.06	0.814	0.62 (0.36–1.08)	2.86	0.091
Previous training on One Health									
No (ref)	1	–	–	1	–	–	1	–	–
Yes	1.83 (0.76–4.39)	1.82	0.177	0.46 (0.21–0.998)	3.87	0.049*	2.21 (0.95–5.11)	3.42	0.064
Main source of information on One Health									
Classroom (ref)	1	–	–	1	–	–	1	–	–
Internet	1.16 (0.73–1.84)	0.38	0.538	1.13 (0.74–1.72)	0.31	0.575	0.74 (0.48–1.12)	2.03	0.154
Social media	0.54 (0.29–1.01)	3.73	0.053	0.75 (0.41–1.38)	0.84	0.360	1.05 (0.57–1.95)	0.02	0.875
CME	0.67 (0.20–2.26)	0.41	0.520	0.12 (0.02–1.02)	3.75	0.053	0.63 (0.19–2.10)	0.57	0.449
Model statistics									
Omnibus likelihood-ratio χ^2 (df=13)	–	49.13	<0.001*	–	52.70	<0.001*	–	21.88	0.057
Hosmer–Lemeshow χ^2 (df = 8)	–	8.39	0.396	–	5.09	0.748	–	1.86	0.985
Nagelkerke R^2	0.13	–	–	0.13	–	–	0.06	–	–
Events per variable	12.3	–	–	18.7	–	–	14.5	–	–
Maximum VIF	1.79	–	–	1.79	–	–	1.79	–	–

TABLE 8: Multivariable logistic regression of factors independently associated with good knowledge, positive attitude, and good practice regarding One Health among MBBS students (N = 512).

Multivariable binary logistic regression (n = 512 in each model; no missing data). Test statistic: Wald χ^2 (df = 1) for each adjusted odds ratio; likelihood-ratio χ^2 (df = 13) for the overall model; Hosmer–Lemeshow χ^2 (df = 8) for goodness of fit. Statistical tests used to calculate p-values: Wald chi-square test for individual aORs; likelihood-ratio chi-square test for overall model significance; Hosmer–Lemeshow test (deciles of predicted risk) for calibration, where a non-significant p-value indicates adequate fit. All listed variables were entered simultaneously (13 estimated parameters per model); age was not entered because of collinearity with MBBS phase, although it was significantly associated with all three domains in the bivariate analysis (Table 7). Estimates are rounded to two decimal places; three decimal places are shown where a confidence limit would otherwise round to 1.00. Events per variable = number of outcomes in the smaller outcome category divided by 13. VIFs ranged from 1.03 to 1.79, indicating no important multicollinearity. The good-practice model was not statistically significant overall (p = 0.057), so its individual estimates should be interpreted with caution. Wide confidence intervals for CME (n = 12) and previous One Health training (n = 37) reflect small category sizes. A sensitivity analysis excluding the 51 uniform responders is shown in Supplementary Table S2. *p < 0.05.

aOR: adjusted odds ratio; CI: confidence interval; ref: reference category; df: degrees of freedom; VIF: variance inflation factor; CME: continuing medical education

Sensitivity analysis

All 51 uniform responders had a negative attitude and accounted for most students in that category, 51

(62.2%) of 82. They were most concentrated in Phase III Part II (17.6%) and least in Phase I (4.0%). Their responses were internally inconsistent: most had good knowledge (44, 86.3%) and good practice (41, 80.4%), and nearly all (49, 96.1%) supported formal One Health training in the separate educational needs section. Excluding them made the attitude distribution more favorable, with a higher proportion having a positive attitude and a sharp fall in negative attitude, but the main pattern did not change. Attitude still differed across phases and remained most positive in Phase I, and the lower adjusted odds of a positive attitude in Phase II and Phase III Part I persisted. In contrast, the adjusted associations of attitude with Phase III Part II and previous One Health training, and its bivariate associations with age and farm animal exposure, were no longer significant, whereas the bivariate associations with previous training and source of information persisted. These findings were therefore sensitive to the uniform responders (Table S2 in Appendices).

Educational needs and perceived barriers

Perceived barriers to implementing the One Health approach were widely reported. Lack of awareness, interdisciplinary training, workshops, and practical exposure, together with poor intersectoral coordination, were each cited by nearly nine in ten students, whereas inadequate curriculum content and lack of institutional support were cited somewhat less often, by about four in five. Support for One Health education was even stronger. Nearly all students favored formal One Health training in the MBBS curriculum, and about nine in ten supported joint training with veterinary students and the inclusion of One Health in competency-based teaching, and were willing to attend workshops if available. This direct support was considerably higher than agreement with the comparable attitude statement in Table 3, which only about two-thirds endorsed. Students preferred experiential learning: field visits were chosen most often, followed by workshops, while lectures and online modules were less favored (Table S3 in Appendices).

Discussion

This study assessed the KAP regarding One Health and zoonotic diseases among undergraduate MBBS students of GMCH. Good knowledge, positive attitude, and good practice were found in 352 (68.8%), 269 (52.5%), and 323 (63.1%) students, respectively, making attitude the weakest domain. MBBS phase was the main factor independently associated with knowledge and attitude, with a weaker association with practice, and only 37 (7.2%) students had received previous One Health training.

Knowledge of One Health and zoonotic diseases

The proportion with good knowledge is comparable to that among professionals from the key One Health sectors in Bhutan, of whom 63% had above-average knowledge of One Health and 51% of zoonotic diseases [28]. It is considerably higher than among livestock-keeping communities in India: only 31.7% of livestock farmers in Thiruvarur, Tamil Nadu, had good knowledge [29], while in South-West Delhi, 75% of women handling livestock had low knowledge of specific zoonoses [30], and in Assam and Bihar, only 3.4% of 534 dairy farmers knew about brucellosis [31]. These comparisons are limited by differences in study populations, scoring methods and cut-offs, and by the narrower measure used in the Assam and Bihar study, which assessed awareness of brucellosis alone rather than knowledge of zoonoses in general [28-31].

Students were familiar with general concepts and practical measures such as hand hygiene after animal contact (472, 92.2%), but knowledge of specific zoonoses was weaker: only 286 (55.9%) knew that brucellosis spreads from animals to humans, while 209 (40.8%) did not know, and 333 (65.0%) and 331 (64.6%) recognized avian influenza and Nipah virus disease as zoonotic. Veterinary undergraduates in Kerala showed a similar pattern of good overall awareness but gaps in identifying specific pathogens, although 88.1% recognized Nipah as zoonotic, possibly reflecting the state's experience of the 2018 Nipah outbreak [32]. The brucellosis gap is important because brucellosis and zoonotic influenza are among the 10 zoonoses of greatest national concern for India [16], and only 0.8% of dairy farmers in Assam and Bihar were aware that brucellosis could be transmitted to humans [31]. About one-quarter of our students also did not link antibiotic use in humans, animals, or livestock with antimicrobial resistance.

Good knowledge was most frequent in Phase III Part II (103, 86.6%) (aOR = 2.63, 95% CI: 1.39-4.99 vs Phase I), and least frequent in Phase II (68, 50.7%) (aOR = 0.39, 95% CI: 0.25-0.64). Veterinary students in later years of study in Kerala and Nepal likewise had higher knowledge [32,33]. These differences may reflect variations in academic exposure, curriculum-related learning, and clinical experiences across phases. As the pattern across phases was not linear and the study was cross-sectional, the lower knowledge in Phase II may reflect batch-specific factors rather than change over time.

Attitude toward One Health

Attitude was the weakest domain, with agreement on individual statements ranging from 304 (59.4%) to 362 (70.7%), similar to the 50% of Bhutanese professionals with above-average attitude toward One Health [28]. Intersectoral collaboration had one of the lowest levels of agreement (316, 61.7%) and the most neutral responses (128, 25.0%), and only about two-thirds supported including One Health in the MBBS curriculum (326, 63.7%), or formal training for medical students (330, 64.5%), whereas 85.9% of Kerala veterinary students were very or moderately interested in learning more about One Health [32]. However, 488 (95.3%) supported formal One Health training when asked directly in the separate educational needs section, and

nearly all uniform "strongly disagree" responders (49, 96.1%) did so as well, despite most having good knowledge and practice. Part of the negative attitude may therefore reflect inattentive responding or misreading of the scale rather than genuine opposition; after excluding these responders, agreement with curricular inclusion rose to 326 (70.7%) of 461.

Attitude was most positive in Phase I (134, 66.3%) and lower in every later phase; compared with Phase I, the adjusted odds of a positive attitude were 0.32 (95% CI: 0.20-0.52) in Phase II, 0.28 (95% CI: 0.15-0.52) in Phase III Part I, and 0.51 (95% CI: 0.31-0.84) in Phase III Part II. In the sensitivity analysis, the lower odds persisted for Phase II and Phase III Part I but not for Phase III Part II, where uniform responders were concentrated, so the finding for this phase is not robust. Older students also less often had a positive attitude (100 (46.5%) vs 169 (56.9%); p = 0.020), although this difference disappeared after excluding uniform responders. In Kerala, attitude did not differ between years of study [32], whereas in Bhutan, professionals with less than one year of experience had better attitude, which the authors tentatively attributed to recent initiatives such as the inclusion of a One Health module at the College of Natural Resources [28]. The lower attitude scores among students in later phases may relate to a discipline-based curriculum in which One Health is not taught as an integrated theme [22], although, as the phases represent different batches, differences between cohorts cannot be excluded. The lower odds of a positive attitude among previously trained students (aOR = 0.46, 95% CI: 0.21-0.998, p=0.049) contrast with evidence that, after a joint medical-veterinary One Health exercise, students reported increased confidence in their communication skills and an improved ability to contribute to One Health collaborative teams [34] and probably reflect the small trained group (n = 37), the unknown nature of the training, and borderline significance; the association was also no longer significant in the sensitivity analysis (p = 0.073). Farm animal exposure (51 (44.0%) vs 218 (55.1%); p = 0.035), and source of information (p = 0.011) were associated with attitude only in the bivariate analysis, and the association with farm animal exposure was no longer significant after excluding uniform responders (p = 0.053). Familiarity with animals may lower perceived risk, and in a Delhi study of women handling livestock, the authors suggested that the gap between knowledge and practice may reflect beliefs such as "nothing happened over generations in the family" [30]. These findings should be interpreted with caution.

Practices related to One Health and zoonotic diseases

Personal protective practices were high: most students often or always washed their hands after animal contact (478, 93.4%), followed food hygiene (471, 92.0%), avoided unnecessary antibiotic use (466, 91.0%), avoided close contact with sick animals (459, 89.6%), and promptly reported animal bites (451, 88.1%). Community and academic engagement was weaker, with only 243 (47.5%) often or always attending One Health seminars or workshops, 253 (49.4%) taking part in public awareness activities, and 260 (50.8%) educating others about zoonoses. The proportion with good practice resembled the 66% of Bhutanese professionals with above-average One Health practices [28], and in a community study in Delhi, most women washed their hands before milking, but 90% did not wear gloves while assisting cattle during reproduction [30].

Good practice was least frequent in Phase II (74, 55.2%) and most frequent in Phase III Part II (89, 74.8%); Phase III Part II was the only factor independently associated with good practice (aOR = 1.81, 95% CI: 1.06-3.08 vs Phase I), possibly reflecting clinical postings in which infection prevention, biomedical waste disposal, and animal bite management are practiced routinely. Previous training was associated with good practice in the bivariate analysis (29 (78.4%) vs 294 (61.9%); p = 0.045), but showed only a non-significant trend after adjustment (aOR = 2.21, 95% CI: 0.95-5.11, p = 0.064), and the practice model was not statistically significant overall (p = 0.057) and explained little of the variation (Nagelkerke R^2 = 0.06), so the association with Phase III Part II should be interpreted with caution; this suggests that factors not measured in this study shape practice. Unlike in Kerala, where practice did not differ across years despite increasing knowledge [32], practice in our study was highest in the phase with the highest knowledge. Nevertheless, the gap between personal protective practices and community engagement is consistent with evidence from the Indian subcontinent that behavior often does not correspond to disease knowledge, so raising awareness alone is unlikely to be sufficient [21]. Gender was not associated with any domain, unlike in Kerala, where female students had significantly better practice scores, and in Bhutan, where gender was associated with One Health KAP [28, 32].

One Health in the existing MBBS curriculum

Table S1 in the Appendices maps the phases of the current CBME curriculum, their duration, and main subjects against the content most relevant to One Health. The curriculum promotes alignment of related topics within a phase and horizontal and vertical integration across subjects, with about 20% of the teaching time of each phase allotted to integrated teaching [22]. It also includes components that run across phases, such as the Attitude, Ethics and Communication (AETCOM) module, the Family Adoption Programme (FAP) from Phase I to Phase III Part I, and a pandemic module [22]. However, One Health-related content remains largely confined to individual subjects. Zoonoses appear as a two-week block on zoonotic and miscellaneous infections in Phase II microbiology, where students are expected to enumerate the agents and vectors of zoonotic diseases and describe their transmission, laboratory diagnosis, and prevention (competency MI8.1), and within the epidemiology and control of communicable diseases in community medicine

(competencies CM7.2, CM7.7 and CM8.1) [22,23]. The six integrated modules named in the 2024 curriculum (anemia, ischemic heart disease, diabetes mellitus, tuberculosis, hypertension, and thyroid disorders) do not include zoonoses or One Health, and the curriculum makes no provision for joint learning with veterinary students [22].

This structure is consistent with the phase-wise pattern in our study. Final-year (Phase III Part II) students, who had completed microbiology, community medicine, and most clinical postings, had the highest knowledge and practice, whereas Phase II students, who had not yet completed microbiology or the main community medicine course, had the lowest. In contrast, attitude did not improve with progression through the course and was lowest in Phase II and Phase III Part I, even though community medicine is taught most intensively in Phase III Part I, with 150 teaching hours and a four-week clinical posting [22]. This suggests that subject-based teaching of zoonoses builds knowledge but may not, by itself, build an interdisciplinary outlook or a sense of the physician's role in intersectoral work. As the phases represent different batches, some of which were trained under earlier versions of the curriculum, and as the exact timing of zoonosis teaching relative to data collection was not recorded, this interpretation remains tentative.

Educational needs and curriculum integration

Only 37 (7.2%) students had received any previous One Health training; the classroom was the main source of information for 301 (58.8%) and CME for only 12 (2.3%). Similarly, 84% of Bhutanese professionals reported a lack of One Health training and capacity-building programs [28], and very few such programs exist in South Asia [35]. Because the gaps in our study were concentrated in knowledge of priority zoonoses and in attitude, which was lower in Phase II and Phase III Part I than in Phase I in both the primary and sensitivity analyses, One Health content should be reinforced throughout the course rather than confined to one phase; a multidisciplinary One Health course improved undergraduates' confidence in defining and applying One Health concepts [36]. This is especially relevant in Assam: Northeast India contributed 35.8% of zoonotic outbreaks notified under the IDSP during 2018-2023, and in 2022-2023, several Assam districts, including Kamrup Metro, were identified as high-cluster districts for zoonotic outbreaks [17]. Assam also accounts for more than one-third of India's JE cases [37]. In keeping with this, most students in our study supported joint training with veterinary students (469, 91.6%), and field visits were the most preferred mode of learning about One Health for 209 (40.8%). As close collaboration between veterinarians and health personnel is a priority for zoonosis control in India [5], joint sessions with veterinary colleges, field visits, and outbreak-based case discussions could be incorporated into competency-based teaching.

In Phase I, a One Health session could be added to the Foundation Course, and FAP household visits could record animal contact, livestock keeping, and zoonosis risk in the adopted families. In Phase II, the microbiology block on zoonoses could be aligned with pharmacology teaching on antimicrobial use and with community medicine, so that priority zoonoses and antimicrobial resistance are taught across the human-animal interface. In Phase III Part I, community medicine postings could include visits to the district surveillance unit and joint sessions with a veterinary college, while Phase III Part II could use case-based integrated sessions on acute encephalitis syndrome, leptospirosis, scrub typhus, and animal-bite management, together with One Health electives. Adding a One Health module to the integrated modules specified in the curriculum would make this content explicit and assessable across all phases, in line with proposals for core One Health competencies in medical education [24,25].

Strengths and limitations

The strengths of this study include the attempted census of students in all three phases of MBBS training, including both parts of Phase III, the combined assessment of KAP, and the use of multivariable analysis. The study also has limitations. The overall response rate was 512 (58.1%) of 881 and was particularly low in Phase III Part I (57 (30.5%) of 187) compared with 134 (53.6%) and 202 (80.8%) in the other phases, so the findings for this phase may be less representative. Reasons for non-participation were not recorded, so respondents and non-respondents could not be compared. Online recruitment through batch WhatsApp groups may also have favored students more interested in the topic. Self-reported data are subject to social desirability and recall bias and may overestimate actual practice. One in ten respondents (51, 10.0%) strongly disagreed uniformly with attitude statements, while most reported good knowledge and practice and supported formal training elsewhere in the questionnaire, which suggests inattentive responding; retaining these responses may have inflated the internal consistency of the attitude scale ($\alpha = 0.98$) and underestimated positive attitude. A sensitivity analysis excluding them did not alter the main finding of lower attitude in Phase II and Phase III Part I, but the associations of attitude with Phase III Part II, age, farm animal exposure, and previous training were not robust. The single-institution, cross-sectional design precludes causal inference and limits generalizability, and differences between phases reflect different batches rather than change over time. Some items in the knowledge domain had conceptual overlap with the attitude domain, particularly those concerning veterinary-medical collaboration, animal vaccination, and antibiotic use. This may have resulted in partial overlap between the constructs. Finally, differences in scoring methods and cut-offs limit direct comparison with other KAP studies.

Recommendations

One Health should be built into competency-based undergraduate medical education as a theme that runs

across all phases rather than being confined to a single subject. Teaching should focus on priority zoonoses, joint learning with veterinary students, and field-based, experiential training. Such an approach could better prepare future physicians in Assam and Northeast India to prevent, recognize, report, and control zoonoses in collaboration with other sectors. Longitudinal and multi-institutional studies are needed to evaluate the effect of such curricular changes on students' attitudes and practices.

Conclusions

Undergraduate medical students understood general One Health principles well and consistently followed personal protective practices, but their recognition of specific priority zoonoses and their engagement in community and academic One Health activities were limited. Attitude was the weakest domain and was not more favorable in the later phases of training, which suggests that the current discipline-based teaching of zoonoses may not be enough to build an interdisciplinary outlook.

Appendices

Appendix 1

Phase	Duration	Main subjects (university examination)	Cross-phase components	One Health-related content in the current curriculum	Opportunities for One Health integration (suggested)
Phase I	12 months, including a two-week Foundation Course	Anatomy, Physiology, Biochemistry; introduction to Community Medicine	Foundation Course, early clinical exposure, AETCOM, FAP, pandemic module	No explicit One Health or zoonosis content	One Health session in the Foundation Course; FAP visits recording animal contact, livestock keeping and zoonosis risk; zoonotic origin of pandemics in the pandemic module
Phase II	12 months	Pathology, Microbiology, Pharmacology; Community Medicine (with FAP) and Forensic Medicine and Toxicology also taught; clinical postings begin	AETCOM, FAP, pandemic module	Microbiology block on zoonotic and miscellaneous infections (two weeks; MI8.1); antimicrobial pharmacology	Aligned microbiology–pharmacology–community medicine sessions on priority zoonoses and AMR in humans and animals
Phase III Part I	12 months	Community Medicine, Forensic Medicine and Toxicology, Ophthalmology, Otorhinolaryngology; clinical postings, including a four-week community medicine posting	AETCOM, FAP, pandemic module	Epidemiology and control of communicable diseases, including zoonoses; epidemic investigation; surveillance and national programmes (CM7.2, CM7.7, CM8.1)	Visit to the district IDSP surveillance unit; joint sessions with a veterinary college; outbreak-based case studies (e.g., JE, leptospirosis, scrub typhus)
Phase III Part II	18 months, including one month of electives (two 15-day blocks)	General Medicine, General Surgery, Obstetrics and Gynaecology, Paediatrics and allied subjects (Psychiatry, DVL, Orthopaedics, Anaesthesiology, Radiodiagnosis)	AETCOM, pandemic module, electives	Clinical management of infections encountered in postings; no dedicated One Health content	Case-based integrated sessions on AES/JE, leptospirosis, scrub typhus, animal-bite management and disease notification; One Health elective
Internship	12 months, compulsory rotating	Rotations through clinical and community postings	–	–	Disease notification and outbreak response during community posting

TABLE 9: S1: Curriculum map of the MBBS course showing the duration, main subjects, and One Health-related content of each phase.

Based on the NMC Competency Based Medical Education Curriculum 2024 [22] and the competency-based undergraduate curriculum for the Indian Medical Graduate [23]. Durations and subjects are those of the 2024 curriculum, which applies to batches admitted from 2024–25; earlier batches followed earlier versions of the CBME curriculum with a broadly similar distribution of subjects. Competency codes are from the 2018 curriculum. The last column lists the authors' suggestions.

AETCOM: Attitude, Ethics and Communication; FAP: Family Adoption Programme; AMR: antimicrobial resistance; IDSP: Integrated Disease Surveillance Programme; JE: Japanese encephalitis; AES: acute encephalitis syndrome; DVL: Dermatology, Venereology and Leprosy

Appendix 2

Measure	Primary analysis (N = 512)	Test statistic	P-value	Excluding uniform responders (n = 461)	Test statistic	P-value
Attitude domain						
Cronbach's alpha	0.98	–	–	0.97	–	–
Attitude score, median (IQR)	60 (46–66)	–	–	60 (55–67)	–	–
Positive attitude, n (%)	269 (52.5)	–	–	269 (58.4)	–	–
Neutral attitude, n (%)	161 (31.4)	–	–	161 (34.9)	–	–

Negative attitude, n (%)	82 (16.0)	–	–	31 (6.7)	–	–
Positive attitude by MBBS phase, n/N (%)						
Phase I	134/202 (66.3)	–	–	134/194 (69.1)	–	–
Phase II	52/134 (38.8)	–	–	52/121 (43.0)	–	–
Phase III Part I	21/57 (36.8)	–	–	21/48 (43.8)	–	–
Phase III Part II	62/119 (52.1)	–	–	62/98 (63.3)	–	–
Attitude score across phases[a]	–	H = 37.34 (3)	<0.001*	–	H = 27.06 (3)	<0.001*
Attitude level across phases[b]	–	χ^2 = 48.59 (6)	<0.001*	–	χ^2 = 34.51 (6)	<0.001*
Bivariate association with positive attitude[b]						
Age (17–20 vs 21–26 years)	–	χ^2 = 5.40 (1)	0.020*	–	χ^2 = 0.95 (1)	0.330
Exposure to farm animals	–	χ^2 = 4.42 (1)	0.035*	–	χ^2 = 3.76 (1)	0.053
Previous training on One Health	–	χ^2 = 8.32 (1)	0.004*	–	χ^2 = 6.21 (1)	0.013*
Main source of information	–	χ^2 = 11.17 (3)	0.011*	–	χ^2 = 9.40 (3)	0.024*
Multivariable model, aOR (95% CI)[c]						
Phase II (ref: Phase I)	0.32 (0.20–0.52)	Wald χ^2 = 21.83 (1)	<0.001*	0.33 (0.20–0.54)	Wald χ^2 = 19.50 (1)	<0.001*
Phase III Part I (ref: Phase I)	0.28 (0.15–0.52)	Wald χ^2 = 15.61 (1)	<0.001*	0.31 (0.16–0.61)	Wald χ^2 = 11.49 (1)	<0.001*
Phase III Part II (ref: Phase I)	0.51 (0.31–0.84)	Wald χ^2 = 6.93 (1)	0.008*	0.69 (0.40–1.19)	Wald χ^2 = 1.77 (1)	0.184
Previous training on One Health (ref: No)	0.46 (0.21–0.998)	Wald χ^2 = 3.87 (1)	0.049*	0.47 (0.21–1.07)	Wald χ^2 = 3.22 (1)	0.073
CME as source (ref: Classroom)	0.12 (0.02–1.02)	Wald χ^2 = 3.75 (1)	0.053	0.15 (0.02–1.30)	Wald χ^2 = 2.97 (1)	0.085
Overall model[d]	–	LR χ^2 = 52.70 (13)	<0.001*	–	LR χ^2 = 44.21 (13)	<0.001*
Hosmer–Lemeshow test[e]	–	χ^2 = 5.09 (8)	0.748	–	χ^2 = 3.50 (8)	0.899
Nagelkerke R^2	0.13	–	–	0.12	–	–
Events per variable	18.7	–	–	14.8	–	–

TABLE 10: S2: Sensitivity analysis of attitude toward One Health among MBBS students, with and without the 51 uniform "strongly disagree" responders.

Uniform responders: students who selected "strongly disagree" for every statement in attitude items 1–10, items 11–15, or both; 33 of the 51 did so for all 15 statements. Test statistic columns give the statistic with degrees of freedom (df) in parentheses; p-values are shown in the adjacent column. Statistical tests used to calculate p-values: [a]Kruskal–Wallis test (H, df = 3); [b]Pearson's chi-square test (1 (8.3%) of 12 expected cell counts <5 for phase-wise attitude levels in the sensitivity analysis); [c]Wald chi-square test (df = 1); [d]likelihood-ratio chi-square test; [e]Hosmer–Lemeshow goodness-of-fit test. Both models included the same 13 parameters as in Table 8; other covariates were non-significant in both analyses. *p < 0.05.

aOR: adjusted odds ratio; χ^2: chi-square statistic; CI: confidence interval; CME: continuing medical education; IQR: interquartile range; LR: likelihood-ratio

Appendix 3

Item	n (%)
Perceived barriers to implementing the One Health approach (Yes)	
Lack of awareness	477 (93.2)
Lack of interdisciplinary training	462 (90.2)
Limited workshops/training	456 (89.1)
Lack of practical exposure	455 (88.9)
Poor intersectoral coordination	451 (88.1)
Inadequate curriculum content	414 (80.9)
Lack of institutional support	405 (79.1)
Educational needs (Yes)	
Formal One Health training should be incorporated into the MBBS curriculum	488 (95.3)
Interdisciplinary training with veterinary students should be conducted	469 (91.6)
Would participate in One Health workshops if available	462 (90.2)
One Health topics should be included in competency-based MBBS teaching	457 (89.3)
Preferred mode of learning	
Field visits	209 (40.8)
Workshops	123 (24.0)
Lectures	112 (21.9)
Online modules	68 (13.3)

TABLE 11: S3: Perceived barriers to implementing the One Health approach and educational needs reported by MBBS students (N = 512).

Values are n (%) of all respondents (N = 512). Barriers are ordered by frequency. Each item was answered separately (Yes/No); the preferred mode of learning was a single choice (total = 512). Descriptive statistics only; no statistical tests were applied, so no test statistic or p-value is reported.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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