ISSN: 2640-1223

Journal of Veterinary Medicine and Animal Sciences

Open Access | Research Article

# Evaluation of "Eddie Mobile Application" as a Tool of Diagnosis and Surviellance of Trypanosomosis and Babesiosis of Cattle at Nekemte, Bako and Shambu Veterinary Clinics, Western Oromia, Ethiopia

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Received: Dec 22, 2022

Accepted: Jan 19, 2023

Published Online: Jan 23, 2023

Journal: Journal of Veterinary Medicine and Animal Sciences

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/



**Keywords:** EDDIE app; Cattle disease; Diagnosis; Smartphone; Surveillance; Ethiopia

## Abstract

Accurate disease reporting, ideally in near real time, is a prerequisite to detecting disease outbreaks and implementing appropriate measures for their control. Hence, a descriptive case study was used in this study by Purposive sampling of cattle coming to veterinary clinics. Accuracy of EDDIE app compared with conventional (paper-based) of cattle disease diagnosis and reporting in terms of demographics and disease information. A total of 811 clinical cases were diagnosed in three veterinary clinics visited using both EDDIE app and paper/manual approach using the same animals. This case explores the use of a Smartphone-based application to increase the accuracy of cattle diseases (trypanosomosis and babesiosis) reporting and surveillance in three veterinary clinics (Nekemte, Bako and Shambu) veterinary clinics. Out of the total animals examined by both EEDDIE app and paper based diagnosis, 778(96%) and 33(4%) were matched and unmatched respectively. The accuracy of EDDIE app was approved by confirmatory diagnosis using laboratory test of 10% from the total matched cases. Accordingly, from 778 matched cases 78(10%) cases were laboratory tested and 21(26.92%) cases were positive for the two heamoprotozoan parasites. This laboratory confirmation indicates EDDIE app was as accurate as paper for diagnosis and surveillance of two cattle disease (trypanosomosis and babesiosis) in the study area. It may therefore provide proportional morbidity in the study area; breed, sex, age and geographic location effects were consistent with current epidemiological understanding. The EDDIE app tool leading to a significantly increase in the number of clinical signs recorded than paper based, suggesting this as a key beneficial consequence of its use. It may also inform approximate proportional morbidity and represent a useful epidemiological tool in poorly resourced areas.

**Cite this article:** Anbese N, Mersha T, Debelo M, Beyene T. Evaluation of "Eddie Mobile Application'' as a Tool of Diagnosis and Surviellance of Trypanosomosis and Babesiosis of Cattle at Nekemte, Bako and Shambu Veterinary Clinics, Western Oromia, Ethiopia. Vet Med Animal Sci. 2023; 6(1): 1123.

## Introduction

Ethiopia is believed to have the largest livestock population in Africa, which is a significant contributor to economic and social development in the country. In Ethiopia, livestock accounts for 15-17% of total GDP and 35-49% of agriculture GDP [1]. In Ethiopia, livestock agriculture contributes around 20% of the total gross domestic product, 45% of the agricultural gross domestic product and directly contributes to the livelihoods of around two-thirds of Ethiopian families [2].

Livestock diseases affect productivity of animals through decreased yield and work output, in addition to direct mortality. On the other hand, the high burden of livestock disease [3] combined with limited infrastructure, pose significant challenges for animal productivity [4].

The occurrence of existing and emerging animal diseases continues to increase, and is combined with the added threat of the relative ease with which biological agents can be agonized and intentionally introduced into human and animal populations. Therefore, there has never been a more critical time at which to leverage information technologies in order to enhance data collection and analysis for the early detection and surveillance of, and response to, natural and intentional disease events.

Protecting animal and human health requires that feasible disease diagnosis and adequate reporting be put in place to allow appropriate actions to be taken to control any potential risks quickly and effectively [5]. Disease monitoring and surveillance systems have thus become a major component of veterinary activity. Such systems are used to assess existing levels of disease, the effectiveness of control programmes, and subsequent to disease eradication, to document the continued absence of disease from a given region or zone [6].

Timely and good quality disease surveillance data at regional and national levels are therefore needed to support and inform continuous improvements in animal health and to detect outbreaks of disease, including emerging and zoonotic diseases [7]. Real-time disease reporting and surveillance as opposed to interval-based ''batch' reporting are essential in minimizing the impact of livestock diseases, as early notice shortens the time between detection and providing measures for control [8].

Application and use of Smartphone technology has been demonstrated to have great potential in public healthcare practice and community-based reporting. Similarly, such tools and services are hypothesized to improve animal health recording and Surveillance sustainably and substantially in developing countries [9].

Surveillance systems and animal disease monitoring more generally are a major component of health-care systems [10]. Such systems are critical to any assessment of disease occurrence, effectiveness of control programs and, in the context of disease eradication programs, population or region, in addition to the detection of emerging diseases [11]. Presence of robust animal disease surveillance systems also benefits human health as around 75% of the emerging infectious diseases that affect humans have their origin in animal populations [12].

The ability to collect data is the key to the success of many organizations operating in the developing world. Given the weaknesses of current tools and the surge in mobile phone growth, there is an opportunity for mobile and cloud technologies to enable timely and efficient data collection and thus change how healthcare is delivered to millions of people [13].

The application and use of Smartphone technology has been more generally explored in the field of public health care [14] and community-based reporting within low resource settings. Such tools and services have been proposed as a means to substantially improve animal health recording, reporting, and surveillance in developing countries [10], but few detailed field-based trials have been reported in the literature [15].

Babesiosis and trypanosomosis are two economically important vector-borne diseases of tropical and subtropical parts of the world including Ethiopia [16]. Bovine trypanosomosis and babesiosis were the most important arthropod borne disease of cattle worldwide they causes significant morbidity and mortality and the first and second most common blood-borne parasitic diseases respectively [17]. Babesiosis is one of the most important diseases in Ethiopia because it occurs sometimes in acute forms with serious recognized clinical manifestations yet lowering the productive performance of the affected animals.

Of Oromia region as well as the country the huge livestock resource is highly challenged by one of economically devastating vector borne disease and its vectors most of the trypanosomosis and tsetse fly. From the year 2000-2019 almost 25 published papers on prevalence of bovine trypanosomosis were identified in Oromia [18]. Hence, the purpose of the present study was to evaluate the accuracy of EDDIE app diagnosis and surveillance of bovine babesiosis and trypanosomiosis infections, for knowing the proportion of these infections in study area.

This paper shares researcher experience which contributed to the design and testing of a Smartphone application-supported "*EDDIE* " system that has potential to improve animal health and productivity, not only in the study area but also in Ethiopia and beyond. In Ethiopia, both the government and civil society not frequently use Smartphone for data gathering.

In Ethiopia, various surveys have been carried out by observational studies on distribution, abundance and prevalence of heamoprotozoan parasites (trypanosomosis and babesiosis) on cattle in different regions of the country by various investigators [19]. However, there was no detailed study on the heamoprotozoan parasites (trypanosomiasis and babesiosis) in cattle "EDDIE app" in our country; particularly Western Oromia Regional State (Nekemte, Bako and Shambu). Therefore, this study is designed with the following objectives:

➢ To evaluate the accuracy of the EDDIE app in diagnosis of Babesiosis and Trypanosomosis affecting cattle compared with the paper/manual based disease reporting system currently used in Ethiopia

➢ To assess the proportion of bovine Babesiosis and Trypanosomosis by EDDIE app versus paper based diagnosis

➢ To evaluate the accuracy of EDDIE app as compared to laboratory confirmatory diagnosis 10% from total cases

## Materials and Methods

### Study areas

This study was conducted from September 2018 to August 2019 at three (3) public veterinary clinics in western parts of Oromia region (Nekemte, Bako and Shambu). Nekemte is found in East Wollega Zone, Oromia regional state. It is located at 331 km west of Addis Ababa at a latitude and longitude of 95°5' N and 360°33'E, respectively with an elevation of 2,088 meters above sea level (m.a.s.l). The minimum and maximum annual rain fall and daily temperature ranges are between 1450 to 2150 mm and 15 to 27C°, respectively [20]. Bako district is located in West Shoa Zone of Oromia Regional state at about 250 km west of Addis Ababa. It is characterized by topography ranging from 1600 to 2870 meters above sea level and its annual rainfall varies between 800-1200 mm per year, of which more than 80% falls in the months of May to September. It has temperature ranging from $11^0$C to $24^0$C. It has a total area about 638 $km^2$and the population density of about 217 per square kilometer [21]. Shambu is found in Horro Guduru Wollega Zone and located at 09º29´N and 37º26´E, at an altitude of approximately 2296 meter above sea level with a uni-modal rainfall ranging between 1200mm-1800mm. The rainy season occurs from April to mid-October where maximum rain is received in months of June, July and August. Maximum temperature of 23-$27^0$C are reached from January to March, and minimum temperature of 7-15 $^0$C is normal from October to November [22].

The study areas were selected due to having high population of cattle, high reports of the cattle disease challenge and having different agro-ecological location. The clinics were selected based on their type of clinic for laboratory access to confirm 10% from the total matched cases and internet access to submit the collected data to higher administrative levels.

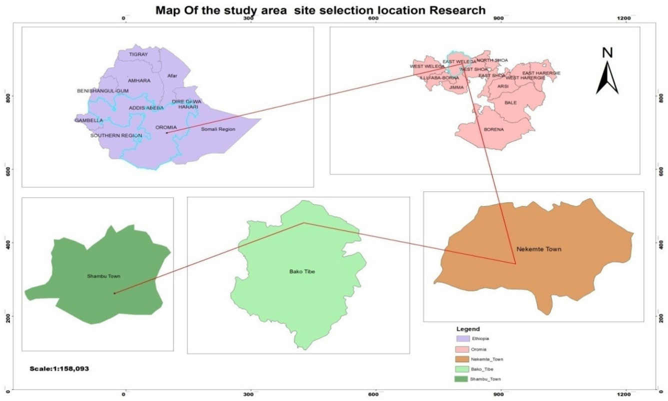


**Figure 1:** Maps of Study Area.

### Study Design and Study Population

A descriptive case study was used in this study. A descriptive study is limited to a description of the occurrence of a disease in a population and is often the first step in an epidemiological investigation. Purposive sampling technique was used on bovines coming to the clinics. Bovine species with different age, breed and sex group were included in this study. This case study was undertaken at animal health facilities center to report important encountered clinical diseases and disorders pertinent to Babesiosis and Trypanosomosis in bovine during the study period.

### Case Handling Protocols

Clinical case handling protocol [23] was used in this case study as indicated in Annex part (Annex 1).

### History Taking/Anamnesis

Disease problems in veterinary medicine are invariably presented to the clinician through the medium of the owner's complaint, which is a request for professional assistance. Owner is the best link between clinician and patient animals, so appropriate anamnesis are very important in disease diagnosis. For completeness and accuracy of history taking, the following check lists were considered (Patient data, Immediate/present history, past history, Management and Environment history) and history of each case was carefully taken which gave a guideline for examination of the animals.

### Physical and General Examination

Physical condition, behavior, posture, gait, roughness of the hair coat, enlargement of peripheral lymph nodes, anaemia, weight loss, pyrexia, abortion, reduced milk yield, loss of appetite, cessation of rumination, labored breathing, emaciation, progressive hemolytic anemia, various degrees of jaundice (Icterus) from paleness in mild case to sever yellow discoloration of conjunctival and vaginal mucous membranes in more progressive cases; haemoglobinuria, accelerated heart and respiratory rates. The temperature, pulse, and respiratory rate from each of sick animals were recorded. Clinical examination of cattle of different ages was conducted on the basis of diseases history, owner complaint, symptoms, to diagnose diseases and disorders.

### Clinical Presentation of cases and Proportional Morbidity by Disease

An assessment of the way in which case presentation was recorded in the traditional paper-based approach was made and compared with the case recording facilitated by EDDIE app. In particular, the number and form of clinical signs recorded under these alternative approaches was summarized and compared. Bovine trypanosomosis, babesiosis and other cases presenting at the veterinary clinics during the study period, as diagnosed by the researcher using EDDIE and the paper-based approach, were reviewed and enumerated. Accordingly the diseases and their estimated proportional morbidity (i.e. the relative frequency of trypanosomosis, and babesiosis diseases from the total cases visiting the clinics during the study period) were reported.

### EDDIE Smartphone Diagnosis and Laboratory Investigation

In addition to EDDIE application as a diagnostic tool; 811 clinical examinations was used in this research and 10% from total matched cases laboratory techniques were also performed to confirm the individual cases. In this research, EDDIE application was developed as a smart phone diagnostic tool. Different data with species of animals, clinical signs, and disease were recorded on EDDIE. At the end clinician's/veterinarian's tentative disease diagnosis was compared with the Smartphone based mobile App result as a diagnostic tool. The appropriate samples was collected from tentatively diagnosed cases (by clinician) from the study sites and transported to laboratory room. From this result the uses of the smart phone-based mobile app in disease diagnosis was evaluated and compared with the laboratory finding. The way in which EDDIE works was mentioned under annex 2.

The cattle diseases selected were: Babesiosis and Trypanosomosis. Cattle disease (Babesiosis and Trypanosomosis) was diagnosed and their relative frequencies from the total number of cases was presented at the veterinary clinics during the study period, as diagnosed by the researcher using *EDDIE* as well as those using 'manual' methods, was computed. The level of completeness of demographic and patient information was compared between the groups.

**Comparison of Features recorded by EDDIE to the Paper/Traditional approach**

The level of completeness associated with demographic and patient information was compared between the group using the EDDIE app and the paper/manual case recording and reporting. In addition, the number of clinical signs observed per case was compared. In the case of EDDIE, the data are available to all authorized users as soon as the details of a case have been uploaded to the Cloud server. Details of the information captured by those using the Smartphone app and those using the paper-based approach are given in **Table 1**.

**Table 1:** Comparison on details of information captured and reported for cattle by EDDIE app users versus paper/ manual system users.

| | EDDIE app | Paper/Manual approach |
|---|---|---|
| Details captured while diagnosing (local level) | For each animal: | For each animal: |
| | Sex | Sex |
| | Age | Age |
| | Breed | Breed |
| | Detailed list of clinical signs | Limited list of clinical |
| | Specific disease | Disease or syndrome |
| Details included while reporting group: (to higher administrative levels) | For each animal | By animal species |
| | All of the above | Number of cases (aggregated over previous month) fordisease/syndrome[b] |
| | noted data were | |
| | available to all administrative Levels in real time[a] | |

[a] Real- time/instant reporting depended on available Internet connection. [b] Reported as batch updates at the end of each month.

### Data Analysis

The collected data were entered into Microsoft Excel database and descriptive statistics were used to explore the proportion of cases diagnosed across demographic and disease specific scenarios. Chi-square tests were used to ascertain differences in profile of sex, age, and breed by study area for both the EDDIE and paper/manually based reported cases. Statistical analysis was performed by Cohen's kappa using SPSS software. Kappa (w) software was used to test the agreement between the categorical variables. P-values of less than 0.05 were used to report the significance of the results. Kappa (k) is one of the most commonly used statistics to test interrater reliability. It is a standardized value and thus is interpreted the same across multiple studies. It can range from -1 to +1, where 0 represents the amount of agreement that can be expected from random chance, and 1 represents perfect agreement between the raters.

**Table 2:** Kappa (w) range and level of agreement.

| Kappa range | Level of agreement |
|---|---|
| 0 | No agreement |
| 0.01-0.20 | Slight agreement |
| 0.21-0.40 | Fair agreement |
| 0.41-0.60 | Moderate agreement |
| 0.61-0.80 | Substantial agreement |
| 0.81-0.99 | Almost perfect agreement |
| 1 | Perfect agreement |

In clinical research, agreement between observers is often analyzed when evaluating various methods. Agreement between observers (inter-rater agreement) can be measured in different ways, and some methods may be regarded as more accurate than other. Depending on which method one uses, one can obtain quite different values (Bland *et al.,* 1986).

## Results

### Characteristics of cases reported by researcher

The total of 811 cattle cases were reported that visited the veterinary clinics from the three study area during the September 2018 to August 2019 studies period and was diagnosed through the EDDIE app and paper/manual based reporting approaches. Relatively higher numbers of animals were examined in Shambu veterinary clinics and lower numbers of animals were examined in the Bako veterinary clinics by EDDIE app and paper based. This difference was due to cattle population that visited the veterinary clinics in the study area during study period **(Table 3)**.

**Table 3:** Kappa (w) range and level of agreement.

| Characteristics | Study Area/Site | | | |
|---|---|---|---|---|
| | Nekemte No (%) | Bako No (%) | Shambu No (%) | Overall No (%) |
| Total cases | 292 | 110 | 409 | 811 |
| Sex | | | | |
| male | 96(32.8) | 43(39) | 162(39.6) | 301(37.1) |
| Female | 196(67.2) | 67(61) | 247(60.4) | 510(62.9) |
| Breed | | | | |
| Local | 255(87.3) | 98(89.1) | 395(96.6) | 748(92.2) |
| Cross and Exotic | 37(12.7) | 12(10.9) | 14(3.4) | 63(7.8) |
| Age | | | | |
| 0-6months | 46(15.7) | 22(20) | 59(14.4) | 127(15.65) |
| 7-12months | 44(15.1) | 20(18.2) | 67(16.4) | 131(16.15) |
| 13-24months | 54(18.5) | 18(16.4) | 31(7.6) | 103(12.7) |
| 2-4years | 62(21.2) | 24(21.8) | 76(18.6) | 162(20) |
| >4years | 86 (29.5) | 26(23.6) | 176(43) | 288(35.5) |

The above table indicates breakdown of all cases reported by EDDIE app and manual/paper based surveillance and reporting approach according to a number of key variables (breed, sex and age). More female animals examined from the shambu veterinary clinic and Nekemte veterinary clinic, and the majority of cattle belonged to the greater than four years age category. In all study area, over 92% of the cattle presenting were local (zebu) breeds, with limited numbers of cross and exotic-bred animals (8%).

### Proportional Morbidity

The proportional morbidity based on the diagnoses reported by the EDDIE and paper is given in Table 3. Causes of morbidity in both diagnoses methods were trypanosomiosis and babesiosis. From the two diseases that trypanosomiosis, was the most commonly reported disease by the *EDDIE* app and paper followed by Babesiosis. The proportional morbidity of each of the two diseases with their variables was explained by the EDDIE app and paper based of reports is illustrated **(Table 4)**.

**Comparison of Babesiosis and Trypanosomosis Diagnoses made by EDDIE app and Paper/Manual**

The relative frequency of both diseases diagnoses suggested by EDDIE app and paper/manual based on clinical signs reported during each of the two reporting approaches of the study. Across the two reporting approaches, the EDDIE app suggested diagnoses in proportions were higher little difference with that of the paper/manual approaches.

**Table 4:** Characteristics of bovine babesiosis and trypanosomosis diagnosis and surveillance data collected using EDDIE app and paper based.

| Characteristics (%) | Total | Total Cases (N=811) | | Matched kappa (w) (N=778) | Unmatched (N=33) |
|---|---|---|---|---|---|
| | | EDDIE (%) | Clinical (%) | | |
| Site | | | | | |
| Nekemte | 292(36) | 292(100) | 292(100) | 286(98) | 6(2) |
| Bako | 110(13.6) | 110(100) | 110(100) | 98(89) | 12(11) |
| 0.72 | | | | | |
| Shambu | 409(50.4) | 409(100) | 409(100) | 394 (96.3) | 15(3.7) |
| Sex | | | | | |
| Male | 301(37.1) | 301(100) | 301(100) | 285(94.7) | 16(5.3) |
| 0.87 | | | | | |
| Female | 510(62.9) | 510(100) | 510(100) | 493(96.7) | 17(3.3) |
| Breed | | | | | |
| Local | 748(92.2) | 748(100) | 748(100) | 723(96.6) | 25(3.4) |
| Cross and Exotic | 63(7.8) | 63(100) | 63(100) | 55(97.7) | 8(34.8) |
| 0.89 | | | | | |
| Age | | | | | |
| 0-6months | 127(15.65) | 127(100) | 127(100) | 121(95.3) | 6(4.7) |
| 7-12months | 131(16.15) | 131(100) | 131(100) | 128(97.7) | 3(2.3) |
| 13-24months | 103(12.7) | 103(100) | 103(100) | 94(91.3) | 9(8.7) |
| 0.25 | | | | | |
| 2-4years | 162 (20) | 162(100) | 162(100) | 158(97.5) | 4(2.5) |
| >4years | 288 (35.5) | 288(100) | 288(100) | 277(96.2) | 11(3.8) |

The two heamoprotozoan parasites out of the total animals examined were (36%), (13.6%) and (50.4%) from Nekemte, Bako and Shambu districts respectively, by both EDDIE app and manual/paper. From these both reports the proportion of both diseases in Nekemte (98%, 2%), Bako (89%, 11%) and Shambu (96.3%, 3.7%) were matched and unmatched respectively. Kappa indicates that substantial level of agreement (w=0.72) between the both reporting approaches of diagnosis and surveillance.

Based on sex groups, the matched and unmatched proportion of both diseases were in male (95.3%, 4.7%) and female (96.7%, 3.3%) respectively and the level of agreement (w=0.87) between the diagnostic methods were almost perfect.

This study revealed that the proportion of both diseases in local breeds (96.5%, 3.5%), cross breeds (90.2%, 9.8%) and in Exotic breeds (75%, 25%) were matched and unmatched in both reporting approaches recorded respectively. Kappa shows that almost perfect agreement between EDDIE and paper based the reporting approaches.

Comparison was also made on the proportion of both disease on the groups of age category that the difference in proportion among the three age groups. In both diseases the EDDIE app and manual/paper surveillance and reporting approaches were relatively highest in >4years (35.5%) old than other age groups. Kappa shows that fair agreement between the two methods of diagnosis and surveillance methods.

Table five (5) indicates that both the EDDIE app and paper/manual based diagnoses and surveillance of trypanosomosis proportions with the variables. In study area, the proportion of matched and unmatched of trypanosomosis which diagnosed through both the EDDIE app and paper/manual were in Nekemte (96.5%, 3.5%), Bako (89%, 11%) and Shambu (96%, 4%) and kappa shows moderate level (w=0.53) of agreement between the two reporting approaches.

The matched and unmatched comparison proportion of trypanosomosis diseases in EDDIE app and paper/manual were in local (95.4%, 4.6%), cross (93.75%, 6.25%) and Exotic breeds (80%, 20%) reporting approaches respectively and kappa indicates that substantial level of agreement (w=0.74) between EDDIE app and paper based diagnosis and surveillance of trypanosomiosis.

Based on sex, bovine trypanosomosis diagnosed by both EDDIE app and manual/paper based and matched and unmatched proportion in male (94%, 6%) and in female (95.8%, 4.2%) were reported respectively and kappa indicates that there is fair level of agreement between the two reporting approaches (w=0.31).

In age groups the proportion of matched and unmatched of EDDIE app and paper-based reporting approaches were in 0-6 months (95.1%, 4.9%), 7-12months (93.4%, 6.6%), 13-24months (94%, 6%), 2-4years (93%, 7%) and >4years (97.6%, 2.4%). Kappa indicates that almost perfect level of agreement between EDDIE and paper reporting approaches.

**Table 5:** Trypanosomosis cases recorded using EDDIE app and those using clinical reporting in terms of proportions across key variables.

| Characteristic | Total (%) | Total Cases (N=578) | | Matched Kappa(w) (N=550)% | Unmatched (N=28)% |
|---|---|---|---|---|---|
| | | EDDIE (%) | Clinical (%) | | |
| Site | | | | | |
| Nekemte | 202(34.95) | 202(100) | 202 (100) | 195(96.5) | 7(3.5) |
| Bako | 82(14.2) | 82(100) | 82(100) | 73(89) | 9(11) |
| 0.53 | | | | | |
| Shambu | 294(50.85) | 294(100) | 294(100) | 282 (96) | 12(4) |
| Sex | | | | | |
| Male | 198(34.25) | 198(100) | 198(100) | 186(94) | 12(6) |

| | | | | | |
|---|---|---|---|---|---|
| 0.31 | | | | | |
| Female | 380(65.75) | 380(100) | 380(100) | 364(95.8) | 16(4.2) |
| Breed | | | | | |
| Local | 541(93.6) | 541(100) | 541(100) | 516(95.4) | 25(4.6) |
| Cross | 32(5.5) | 32(100) | 32(100) | 30(93.75) | 2(6.25) |
| 0.74 | | | | | |
| Exotic | 5(0.9) | 5(100) | 5(100) | 4(80) | 1(20) |
| Age | | | | | |
| 0-6months | 82(14.3) | 82(100) | 82(100) | 78(95.1) | 4(4.9) |
| 7-12months | 91(15.7) | 91(100) | 91(100) | 85(93.4) | 6(6.6) |
| 13-24months | 84(14.5) | 84(100) | 84(100) | 79(94) | 5(6) |
| 0.83 | | | | | |
| 2-4years | 113(19.5) | 113(100) | 113(100) | 105(93) | 8(7) |
| >4years | 208 (36) | 208(100) | 208(100) | 203(97.6) | 5(2.4) |

From both EDDIE app and manual/paper reporting approaches of bovine babesiosis in matched and unmatched were in Nekemte (97.7%, 2.3%), Bako (96.4%, 3.6%) and Shambu (98%, 2%) in study area and the level of agreement between the two reporting approaches were substantial (k=0.64) (table 6).

Comparison of bovine babesiosis proportion in EDDIE app and manual/paper diagnosis and surveillance the matched and unmatched were in local (98.5%, 1.5%), cross (94.7%, 5.3%) and exotic (85.7%, 14.3%) breed respectively. The kappa indicates (w=0.63) substantial level of agreement between the both reporting approaches.

In both reporting approaches, bovine babesiosis was compared based on sex and the matched and unmatched between the EDDIE and paper were in male (98%, 2%) and female (97.7%, 2.3%) respectively. Between the two diagnostic methods of bovine babesiosis based on sex there were (k=0.48) moderate level of agreement.

Based on age groups, bovine babesiosis by two reporting approaches was compared and the proportion of matched and unmatched were in 0-6months (100%, 0%), 7-12months (100%, 0%), 13-24months (89.5%, 10.5%), 2-4years (97.9%, 2.1%) and > 4years (97.5%, 2.5%). The level of agreement between the two diagnostic methods was (k=0.89) almost perfect (table 6).

**Table 6:** Babesiosis cases recorded using EDDIE app and those using paper/manual reporting in terms of proportions across key variables.

| Characteristic | Total (%) | Total Cases (N=578) | | Matched Kappa(w) (N=228) % | Unmatched (N=5) % |
|---|---|---|---|---|---|
| | | EDDIE (%) | Paper (%) | | |
| Site | | | | | |
| Nekemte | 90(38.6) | 90(100) | 90(100) | 88(97.7) | 2(2.3) |
| Bako | 28(12) | 28(100) | 28(100) | 27(96.4) | 1(3.6) |
| 0.64 | | | | | |
| Shambu | 115(49.4) | 115(100) | 115(100) | 113 (98) | 2(2) |
| Sex | | | | | |
| Male | 103(44.2) | 103(100) | 103(100) | 101(98) | 2(2) |
| 0.48 | | | | | |
| Female | 130(55.8) | 130(100) | 130(100) | 127(97.7) | 3(2.3) |
| Breed | | | | | |
| Local | 207(88.8) | 207(100) | 207(100) | 204(98.5) | 3(1.5) |
| Cross and Exotic | 26(11.2) | 26(100) | 26(100) | 24(98.4) | 2(19.6) |
| 0.63 | | | | | |
| Age | | | | | |
| 0-6months | 45(19.2) | 45(100) | 45(100) | 45(100) | 0(0) |
| 7-12months | 40(17.15) | 40(100) | 40(100) | 40(100) | 0(0) |
| 13-24months | 19(8.15) | 19(100) | 19(100) | 17(89.5) | 2(10.5) |
| 0.89 | | | | | |
| 2-4years | 49(21) | 49(100) | 49(100) | 48(97.9) | 1(2.1) |
| >4years | 80 (34.35) | 80(100) | 80(100) | 78(97.5) | 2(2.5) |

**Table 7:** Lab. confirmation of bovine trypanosomosis which diagnosed by EDDIE and paper (matched).

| Characteristic | Trypanosomosis | | | $X^2$(P-Value) | Kappa(w) |
|---|---|---|---|---|---|
| | Matched (EDDIE and Paper) (N=550) | No. of test animals by lab. (N=55) | No. of positive animals (N=15) | | |
| Site | | | | | |
| Nekemte | 195(96.5%) | 19(9.7%) | 7(36.8%) | | |
| Bako | 73(89%) | 8(10.95%) | 3(37.5%) | 9.876(0.04) | 0.63 |
| Shambu | 282(96%) | 28(9.92%) | 5(17.8%) | | |
| Sex | | | | | |
| Male | 186(94%) | 19(10.2%) | 6(31.5%) | 1.58(0.09) | 0.28 |
| Female | 364(95.8%) | 36(9.9%) | 9(25%) | | |
| Breed | | | | | |
| Local | 516(95.4%) | 51(9.88%) | 15(29.4%) | 19.757(0.001) | 0.84 |
| Cross and exotic | 34(98.75%) | 4(12.5%) | 0(0%) | | |
| Age | | | | | |
| 0-6months | 78(95.1%) | 8(10.3%) | 3(37.5%) | | |
| 7-12months | 85(93.4%) | 9(10.6%) | 4(44.4%) | 7.211(0.05) | 0.67 |
| 13-24months | 79(94%) | 8(10.1%) | 3(37.5%) | | |
| 2-4years | 105(93%) | 10(9.5%) | 1(10%) | | |
| >4years | 203(97.6%) | 20(9.8%) | 4(20%) | | |

**Laboratory Confirmation of Bovine Trypanosomosis after Diagnosed by EDDIE app and paper/manual based**

To evaluate the accuracy of EDDIE app, laboratory confirmatory diagnosis was done using 10% from the total of matched cases to identify the causative agents of the diseases. Accordingly, in the three study area the proportion of trypanosomosis which confirmed by laboratory test and the results were in Nekemte (36.8%), Bako (37.5%) and Shambu (17.8%) from matched cases based reporting approaches. The above laboratory confirmation indicates EDDIE app was accurate for diagnosis and surveillance of bovine trypanosomosis.

Based on the breed group, the proportion of trypanosomosis diseases which diagnosed by EDDIE app and paper, the proportion of laboratory confirmed and laboratory result were in local (29.4%), cross and exotic (0%).

However, bovine trypanosomosis was diagnosed by EDDIE app and paper, the proportion of laboratory confirmed and results were in male (31.5%) and female (25%). Laboratory result indicates EDDIE app was accurate than paper based trypanosomosis diagnosis and surveillance.

The proportion of bovine trypanosomosis with the age categories which diagnosed by EDDIE app and paper and the proportion of laboratory results were in 0-6 months (37.5%), 7-12months (44.4%), 13-24months (37.5%), 2-4years (10%) and >4 years (20%). The above laboratory confirmed proportion shows in study area, breed, sex and age groups were almost accurate with EDDIE app for the diagnosis of the trypanosomosis **(Table 7)**.

**Laboratory Confirmation of Bovine Babesiosis after Diagnosed by EDDIE app and paper/manual**

Bovine babesiosis was diagnosed by EDDIE app and paper based reporting approaches. To evaluate the accuracy of EDDIE app in babesiosis diagnosis, 10% from the total matched cases of babesiosis were confirmed by laboratory test. Accordingly, in the three study area the proportion of laboratory result were in Nekemte (33.34%), Bako (0%) and Shambu (27.28%) (Table 8). Based on the above number of laboratory confirmation, EDDIE app was accurate for diagnosis and surveillance of bovine babesiosis.

Based on the breed group, the proportion of babesiosis diseases which diagnosed by EDDIE app and paper and the laboratory results proportion in local (30%), cross and exotic (0%) were examined.

With age categories, the proportion of laboratory results from matched EDDIE app and paper cases were in 0-6 months (20%), 7-12 months (25%), 13-24 months (0%), 2-4 years (20%,) and >4 years (42.85%) reported. The above laboratory confirmed proportion indicates in study area, breed, sex and age groups were accurate with EDDIE app for the diagnosis of the babesiosis diseases **(Table 8)**.

**Clinical Signs Recorded by Two Reporting Approaches**

There were a total of 2957 clinical signs recorded (1864 in EDDIE app and 1093 in Manual/Paper) for the 811 cases investigated by two reporting approaches of the study. The most commonly occurring sign was Staring/Rough coat, seen in over (67.2%, 52.8%), Anemia/pall (63.7%, 46.8%) of cases in EDDIE app and Manual/Paper respectively (table 9). Weight Loss/Emaciation, Lymph node enlargement, and Anorexia/Loss of appetite were observed in almost half of all cases while, Weakness, and Pyrexia/Fever were also present in around 40% of cases. Diarrhea and dyspnoea/difficult breathing was seen in around a 25% of cases, with constipation being seen in just15% of cases. The remaining signs were observed relatively infrequently (i.e. in around 5% or fewer cases).

**Table 8:** Laboratory confirmation of bovine babesiosis which diagnosed by EDDIE and paper (matched).

| Characteristic | Babesiosis | | | $X^2$(P-Value) | Kappa(w) |
|---|---|---|---|---|---|
| | Matched (EDDIE and Clinical) (N=228) (%) | No. of test animals by lab. (N=23) (%) | No. of positive animals (N=6) (%) | | |
| Site | | | | | |
| Nekemte | 88(97.7) | 9(10.2) | 3(33.34) | | |
| Bako | 27(96.4) | 3(11.1) | 0(0) | 2.450(0.07) | 0.42 |
| Shambu | 113(98) | 11(9.7) | 3(27.28) | | |
| Sex | | | | | |
| Male | 101(98) | 10(9.9) | 2(20) | | |
| Female | 127(97.7) | 13(10.23) | 4(30.77) | 6.292(0.04) | 0.51 |
| Breed | | | | | |
| Local | 204(98.5) | 20(9.8) | 6(30) | | |
| Cross and exotic | 24(97) | 3(11.2) | 0(0) | 13.39(0.01) | 0.43 |
| Age | | | | | |
| 0-6months | 45(100) | 5(11.1) | 1(20) | | |
| 7-12months | 40(100) | 4(10) | 1(25) | | |
| 13-24months | 17(89.5) | 2(11.76) | 0(0) | 1.241(0.21) | 0.13 |
| 2-4years | 48(97.9) | 5(10.4) | 1(20) | | |
| >4years | 78(97.5) | 7(8.9) | 3(42.85) | | |

**Table 9:** Proportion of times that a given clinical sign was noted for cattle cases (Trypanosomosis and Babesiosis) captured by each of the disease reporting approaches.

| Clinical signs (%) | EDDIE app (%) | Paper/Clinical based |
|---|---|---|
| Staring/Rough coat | 67.2 | 52.8 |
| Anemia/pallor | 63.7 | 46.8 |
| Weight Loss/Emaciation | 52.2 | 39.1 |
| Lymph node enlargement | 52.1 | 36.4 |
| Anorexia/Loss of appetite | 50.1 | 32.4 |
| Weakness | 41.3 | 27.9 |
| Pyrexia/Fever | 40.5 | 23.2 |
| Diarrhea | 25.1 | 19.4 |
| Dyspnoea/difficult breathing | 23.3 | 11.4 |
| Constipation | 16.8 | 10.1 |
| Icterus /yellowish mucus membrane | 5.2 | 2.1 |
| Ataxia/Incoordination of movement | 3.2 | 1.6 |
| Other | - | 9.4 |
| Total signs recorded | 1864 | 1093 |
| Total number of cases | 811 | 811 |
| Signs per case | 2.3 | 1.3 |

(Table 9) lists signs in order of the proportional change in their observation frequency between EDDIE app and Manual/ Paper reporting approaches. The average number of clinical signs recorded as being present for any given case by the group using the EDDIE app was 2.3 (95% CI: 1.8–2.9); significantly higher than the mean of 1.3 (95% CI: 1.0–1.7) clinical signs recorded in the paper-based system. However, for the sake of making more realistic comparisons with data from the paper-based approach restrict the current analyses to only those signs that were indicated to be present for a given case. The list of clinical signs provided for cases captured using the two recording approaches is shown in Table 9. The signs are ordered according to those which occurred most frequently when signs were recorded by the group using the EDDIE app. Before comparing the proportion of cases for which given signs occurred in it is important to note the "Other" at the foot of the table. This indicates that in 9.4% of the cases records.

Some of the next most common signs were also reported by both approaches, including: Staring/Rough coat, Anemia/pall, Weight Loss/Emaciation, Lymphnode enlargement, Anorexia/ Loss of appetite, Weakness, and Pyrexia/Fever (although their prevalence was higher in the case of EDDIE app due to the much higher number of absolute signs reporting using that approach). Certain signs, such as diarrhea, dyspnoea/difficult breathing, Constipation, Icterus/yellowish mucus membranes and ataxia/ incoordination of movements, occurred an order of magnitude less frequently in the paper-based system; given that each of these signs appeared in at least one in all cases reported in EDDIE app it seems likely that they are being systematically and grossly underreported in the paper-based records.

## Discussion

Data allowing for evaluation and comparison of two surveillance systems employed in different geographical area, and used in reporting similar disease events in the same animal species, and with the data corroborated through response visits conducted by veterinarians. The data show that the EDDIE app mobile phone-based system has a higher probability of reporting valid disease events compared with the paper based disease surveillance visits, paradoxically demonstrating that an EDDIE app mobile phone-aided passive surveillance system can outperform an active surveillance system. Active surveillance systems such as routine visits to study households require more time and resources than a passive surveillance system where animal owners have to decide whether to report disease events occurring at their farm. When it comes to the health of their livestock, people quickly notice unusual signs and tend to report these to health authorities, provided a working system is in operation [24]. Novel approaches are also being developed to combine singles that may exist in multiple data sources associated with syndrome surveillance.

Thus, for example, the researcher can posit that the lower proportion of cross and exotic bred animals reported by both EDDIE app and manual recording system across the three study area; this may be due to few number of cross and exotic bred animals exist in the population. An often reported benefit of reporting using mobile phone is the more accurate geo-referencing of case data [25]. In particular case, this was less relevant as the reports were being made from clinics whose locations were fixed and known; however, if EDDIE app were being used as part of a visit to cattle in their field setting, then the geo-referenced coordinates of each case could add significant value, particularly in the case of a disease outbreak where locational clustering can be a key indicator for early detection.

A major challenge of traditional reporting systems centers on the need to compile reports from various sources and provide these to central offices at regular intervals and to different administrative levels. The compiling process is potentially challenged by unintentional alterations of results due to errors in data submission or transcription [26].

In addition, [10] reported that such mobile phone-based surveillance system reduce the number of data entry errors and facilitate automated data analysis. The increased opportunities offered by "big data" in terms of data integration and semi-automatic analyses have been reported for both human and veterinary health data recording systems [27]. Those cattle diseases that have the highest importance from an economic or trade perspective were included in the EDDIE app, based on the diseases targeted for control by the veterinary services of Ethiopia.

The accuracy of EDDIE app was approved by confirmatory diagnosis using laboratory test 10% from the total matched cases and accordingly, from 778 matched cases 78(10%) cases were laboratory tested and only 21(26.92%) cases were positive for the two heamoprotozoan parasites (bovine trypanosomosis and babesiosis).

Ideally, the accuracy of the data collected by such applications should be supported by field evaluation as to disease outcomes for all cases. In this study, it was not possible to conduct all field evaluation using laboratory confirmation due to logistic constraints including cold chain to keep the samples to destined locations, shortage of laboratory consumables, processing costs, etc. These constraints appear to be shared by many studies of surveillance systems [28].

A recent survey exploring the potential for mobile phone use to deliver animal health information in Uganda found that while almost all livestock keepers owned a feature phone, only around 10% owned a Smartphone [29]. Their use in supporting public health systems in developing countries to address a lack of quality data and instant transmission of health data from lower levels has been documented [30]. Unlike such surveillance systems that depend on healthcare or veterinary workers to report disease events (including those using EDDIE app mobile phones to improve reporting), this study has demonstrated a EDDIE app mobile phone-based surveillance system directly dependent on researchers/veterinary professionals to report disease events. These findings that owning mobile phone is not a determinant of using the EDDIE app phone-based surveillance system are insightful, indicating a good interplay between widespread phone ownership and likelihood of accessing phones to report disease events. This is important as it removes the possible reporting bias that would be associated with mobile phone ownership.

These findings on greater propensity of using the EDDIE app phone-based system for reporting illnesses (especially those presenting with severe clinical signs) and not death events has broader implications for the surveillance for infectious diseases in cattle. The effectiveness of surveillance systems is linked to response actions or incentives for reporting. In this study, all reported cases likely served as an effective incentive for community reporting of disease events observed in their animals. Reporting illness cases provided animal owners with opportunities for receiving immediate help for their sick animals without incurring veterinary treatment expenses. Although reporting death cases may lead to knowledge of what killed the animals and what might be done to prevent similar deaths in the future, this was not seen as sufficient incentive for real-time reporting of death events in this study. The EDDIE app phone-based surveillance system in this study was dependent on internet access and costs associated with data transmission.

The composition of the case data sets remained broadly similar between the two reporting approaches interms of a number of variables, namely animal age group, sex and breeds. This breakdown is broadly reflective of the cattle for which they were receiving requests to carry out diagnosis.

In this study the total number of clinical signs observed in EDDIE app compared with paper based was 2.3 and 1.3 respectively. Clinical signs events were 1.0 times more likely to be reported through the EDDIE app mobile phone-based surveillance system when compared with the paper based visits. The observed significant differences in the reporting methods according to the type of disease sign observed. In paper based the individual signs contributing most to this increase were Staring/Rough coat, anaemia/pallor, Weight Loss/Emaciation, weakness, Anorexia/Loss of appetite, and which all but higher in number in EDDIE app to be seen in over half of all cases. However, while the overall number of signs reported increased in EDDIE app, this increase was limited to signs listed on the EDDIE app; some other signs reported during paper based but not on the EDDIE app, such as haemoglobinuria, lacrymation, dullness etc were no longer reported after its introduction. The interpretation of this may be that while the EDDIE app encourages clinical examination and recording of signs observed, this effect is limited to those signs listed on it.

In the present work, EDDIE app was shown to identify some signs more frequently than paper based. It can be envisaged that the EDDIE app might be helpful to animal health workers in diagnosing endemic disease in their cattle, and the results obtained here support earlier work in confirming they are able to identify at least some clinical signs.

Given that the researcher diagnoses were available for both the EDDIE app and paper based of the study, the initially used these to characterize the disease status of the animals examined as a measure of proportional morbidity in the population under the clinical care of the researcher. The two diseases covered by the EDDIE app and paper based of the putative diagnoses made by the researcher for cases that attended throughout the study period, and hence the EDDIE app diagnoses may also provide an approximate measure of proportional morbidity in the study area (Nekemte, Bako and Shambu) of western Oromia.

The conditions most commonly diagnosed by researcher in both reporting approaches were two vector-borne diseases (trypanosomosis and babesiosis). While trypanosomosis remained the most common diagnosis through both reporting approaches, representing more than half of two diagnosed diseases, but babesiosis was diagnosed significantly less commonly in both reporting approaches.

Specifically, there appeared to be predisposition towards diagnosis of both trypanosomosis and babesiosis in exotic cattle, as compared with cross breed, whereas local (zebu) breed appeared to have greater likelihood of diagnosis of both diseases than other breeds, observations consistent with known breed susceptibilities [31]. Similarly, some district level effects were observed, for example; from laboratory tests (positive animals) lower proportional morbidity of trypanosomosis in Nekemte (3.6%) and Shambu (1.8%) District, consistent with its higher elevation on the slopes of mid highlands, and that highest prevalence of trypanosomosis in was found in Bako district (4.1%) as the area lies at mid lowland compared to other study area. The results reported here are based on data collected over two specific periods in a single year across the areas under consideration.

Age effects on proportional morbidity were possibly of greater interest. In this area of Western Oromia, there appears to be clear evidence that diagnosis of babesiosis is primarily associated with young animals while the opposite appears to be the case with trypanosomosis (significantly fewer cases in the two age classes of animals under one year and significantly more in those cattle of two years or older). However, it is arguably the age distributions for cases diagnosed with tick-borne diseases that are most interesting. For both disease (trypanosomosis and babesiosis) there is evidence that the presence of disease in young animals (less than 6 months old) was significantly lower than would be expected based purely on proportions of cattle in each age group, consistent with the concept of inverse age immunity for these diseases [32].

Previous attempts at evaluating paper based systems for animal disease diagnosis have used selected test cases [33], whereas the present study was based on naturally occurring disease. Hence, one challenge in evaluating the performance of the EDDIE app was having an independent assessment as to which disease or diseases were truly present in each of the cases. Fortunately provisions of definitive diagnostic capability through laboratory confirmation at least 10% from the total matched cases had been done in this study. In the presence of such a laboratory confirmation to evaluate whether the application achieved the 'correct' diagnosis the assumption that the researcher made the correct diagnosis and but simply assessed how often the suggested diagnosis of the EDDIE app.

A further complication is that both paper based and the EDDIE app may suggest multiple diagnoses. Indeed, the concordance values reported here must be interpreted taking into consideration that neither the paper' nor the EDDIE app diagnoses returned perfect scores when compared with each other. In trypanosomosis diagnoses the breakdown of cases from key variables, the kappa statics in breed group shows substantial agreement between EDDIE app (k=0.74) with paper diagnoses, between age groups (k=0.83) almost perfect agreement between sex group (k=0.53) moderate level of agreement (Table 5). For bovine babesiosis diagnosis and surveillance, babesia cases with variables age group showed that kappa statics gave almost perfect level between EDDIE app (k=0.89) with paper diagnoses, and the concordance of other variables showed moderate and substantial level (Table 6**)**. This indicates that EDDIE app was almost as accurate as paper base for diagnosis of bovine trypanosomosis and babesiosis.

Concordance is the proportion of agreement corrected for chance taking into consideration both 'positive' and 'negative' agreements, i.e. where both paper and the EDDIE app agree that the diagnosis either is or is not a particular condition. Hence while concordance is a better measure of whether there was agreement between the two diagnostic tests of the study, it gives only limited indication of where disagreements lie.

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